TC 3-09.81

Field Artillery Manual Cannon Gunnery

APRIL 2016

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*This publication supersedes TC 3-09.81/MCWP 3-16.4, dated 1 March 2016.

Headquarters, Department of the Army

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Training Circular
No. 3-09.81

Headquarters
Department of the Army
Washington, DC, 13 April 2016

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Contents

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Figures

Tables

Preface

Training Circular (TC) 3-09.81 sets forth the doctrine pertaining to the employment of artillery fires. It explains all aspects of the manual cannon gunnery problem and presents a practical application of the science of ballistics. It includes step-by-step instructions for manually solving the gunnery problem which can be applied within the framework of decisive action or unified land operations. It is applicable to any Army personnel at the battalion or battery responsible to delivered field artillery fires.

The principal audience for ATP 3-09.42 is all members of the Profession of Arms. This includes field artillery Soldiers and combined arms chain of command field and company grade officers, middle-grade and senior noncommissioned officers (NCO), and battalion and squadron command groups and staffs. This manual also provides guidance for division and corps leaders and staffs in training for and employment of the BCT in decisive action. This publication may also be used by other Army organizations to assist in their planning for support of battalions. This manual builds on the collective knowledge and experience gained through recent operations, numerous exercises, and the deliberate process of informed reasoning. It is rooted in time-tested principles and fundamentals, while accommodating new technologies and diverse threats to national security.

Commanders, staffs, and subordinates ensure their decisions and actions comply with applicable United States, international, and, in some cases, host-nation laws and regulations. Commanders at all levels ensure that their Soldiers operate in accordance with the law of war and the rules of engagement. (See FM 27-10.)

TC 3-09.81 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text. Terms for which publication TC 3-09.81 is the proponent publication (the authority) are marked with an asterisk (*) in the glossary. Definitions for which Publication TC 3-09.81 is the proponent publication are boldfaced in the text with the term being italicized. For other definitions shown in the text, the term is italicized and the number of the proponent publication follows the definition.

TC 3-09.81 applies to the Active Army, Army National Guard/Army National Guard of the United States, and United States Army Reserve unless otherwise stated.

The proponent for TC 3-09.81 is the United States Army Fires Center of Excellence. The preparing agency is the U.S. Army Fires Center of Excellence, Directorate of Training and Doctrine. Send comments and recommendations on Department of the Army (DA) Form 2028, *Recommended Changes to Publications and Blank Forms*, to Directorate of Training and Doctrine, 700 McNair Avenue, Suite 128, ATTN: ATSF-DD (TC 3-09.81), Fort Sill, OK 73503-4436; by email to: usarmy.sill.fcoe.mbx.dotd-doctrine-inbox@mail.mil.

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Introduction

Army and Marine Corps forces are employed to deliver fires in support of the maneuver commander. Consequently, this TC is grounded in Army and Marine Corps doctrine publications such as Army Doctrine Publication (ADP), Army Doctrine Reference Publication (ADRP) 3-09 to field artillery operations techniques in support of the maneuver commander, Marine Corps Warfighting Publication (MCWP) 3-16.1. Artillery Operations and Marine Corps Interim Publication (MCIP) 3-16.01. Tactics, Techniques, and Procedures for Lightweight 155mm.

Techniques are non-prescriptive ways or methods used to perform missions, functions, or tasks. The techniques herein build on the collective knowledge and experience gained through recent operations, numerous exercises, and the deliberate process of informed reasoning. These techniques are rooted in the deliver manual gunnery principles identified in TC 3-09.81, and accommodate force design changes, new technologies and diverse threats.

TC 3-09.81 is organized into 15 chapters and supporting appendixes A through H.

Chapter 1 is an introduction to the gunnery problem and the relationship between the gunnery team for the effective accomplishment of tasks during operations.

Chapter 2 describes the responsibilities of members of the fire direction center (FDC), and the battery organization in the brigade combat team (BCT).

Chapter 3 describes a practical application of the science of ballistics.

Chapter 4 describes the requirements muzzle velocity management and guidance in establishing an order of preference when managing muzzle velocity.

Chapter 5 details the procedures for determine fire order, message to observer, and fire commands.

Chapter 6 describes one of the elements to the solution of the gunnery problem by determination of chart data.

Chapter 7 described the use of tabular firing tables (TFT) and graphical firing tables (GFT) in the solution of the gunnery problem.

Chapter 8 discuses the procedures that are follow to account for the difference in altitude between the firing unit and the target.

Chapter 9 details the use of the record of fire as well as the basic mission processing for high explosive and illumination munitions.

Chapter 10 describes the means of determining cumulative errors and the correction for those errors. It explains registrations and their application to the gunnery problem.

Chapter 11 describes the met techniques that allow a unit to account for the effects of non standard conditions and achieve first round fire for effect.

Chapter 12 explains the techniques that can be use on the battlefield to enhance survivability.

Chapter 13 discusses the characteristics and procedures or techniques required to fire special munitions.

Chapter 14 provides guidance on delivering of fire under emergency situations.

Chapter 15 provides guidance on the determination of safety and executive officer minimum quadrant elevation.

Appendix A provides a standard operation procedure that can be use a guideline for setting the fire direction center.

Appendix B describes the procedures that can be follow when a unit does not achieve accurate first round and is in needs of troubleshoot.

Appendix C provides planning ranges for artillery weapons systems.

Appendix D described the procedures to determine the refinements data transmitted by the observer.

Appendix E describes the basic operation of an automated fire direction center.

Appendix F assists in the determination of firing data with a graphical firing table.

Appendix G is a supplement of chapter 13 which details more common special situations.

Appendix H contains the tables for firing smoke missions.

Based on current doctrinal changes, certain terms have been added, modified, or rescinded for purposes of this manual. The glossary contains acronyms and defined terms.

Table I-1. New or revised army terms

Term	*Remarks*
vertical angle	Modified the definition and changed the proponent manual from ATP 3-09.30 to TC 3-09.81.

Chapter 1

The Gunnery Problem and the Gunnery Team

The mission of the Field Artillery is to destroy, defeat or disrupt the enemy with integrated fires to enable maneuver commanders to dominate in unified land operations (ADRP 3-09).

The mission of the Firing Battery is to destroy, neutralize, or suppress the enemy by indirect cannon, mortars, rocket, and missile fires and to help integrate all fire support assets into combined arms operations. Field artillery weapons are normally employed in masked or defilade positions to conceal them from the enemy. Placing the firing platoon in defilade precludes direct fire on most targets. Consequently, indirect fire must be used when Field Artillery (FA) weapons fire on targets that are not visible from the weapons. ***Indirect fire*** **is 1. Fire delivered at a target not visible to the firing unit. 2. Fire delivered to a target that is not itself used as a point of aim for the weapons or the director.** The gunnery problem is an indirect fire problem. Solving the problem requires weapon and ammunition settings that, when applied to the weapon and ammunition, will cause the projectile to achieve the desired effects on the target.

GUNNERY PROBLEM SOLUTION

1-1. The steps in solving the gunnery problem are as follows:

- Determine the location of the target and know the location of the firing unit.
- Determine chart (map) data (deflection, range from the weapons to the target).
- Determine altitude of the target, vertical interval (VI) and site (SI).
- Compensate for nonstandard conditions (meteorological corrections using concurrent and subsequent met technique applications).
- Convert chart data to firing data (shell, charge, fuze, fuze setting, deflection, and quadrant elevation).
- Apply the firing data to the weapon and ammunition.

1-2. The solution to the problem provides weapon and ammunition settings that will cause the projectile to function on or at the predetermined height above the target. This is necessary so the desired effects will be achieved.

FIELD ARTILLERY GUNNERY TEAM

1-3. The coordinated efforts of the field artillery gunnery team are required to accomplish the solution of the gunnery problem outlined in paragraph 1-1. The elements for the team must be linked by an adequate communications system.

Note: The terms battery and platoon used throughout this manual are synonymous, unless otherwise stated.

1-4. **Observer**. The observer and/or the target acquisition assets serve as the "eyes and ears" of all indirect fire systems. The role of the forward observer is to detect and locate suitable indirect fire targets within his zone of observation and bring fires on them. When a target is to be attacked, the observer transmits a call for fire and adjusts the fires onto the target as necessary. **A *call for fire* is a request for fire containing data necessary for obtaining the required fire on a target.** An observer provides surveillance data of his own fires and any other fires in his zone of observation. Trained and untrained observers include:

- Forward Observers (FOs).
- Fire support teams (FISTs).
- Air and naval gunfire liaison company (ANGLICO).
- Firepower control teams (FCTs).
- Any other friendly battlefield personnel.

1-5. Target Acquisition. Target acquisition (TA) assets also function as observers. They provide accurate and timely detection, identification, and location of ground targets, collect combat and/or target information, orient and/or cue intelligence sources, and permit immediate attack of specific targets. Field artillery TA assets include the following:

- Weapons-locating radar sections.
- Aircraft radar systems.

Note. See Army Techniques Publication (ATP) 3-09.12 for a discussion of TA assets.

1-6. **Fire Direction and the Fire Direction Center.** ***Fire direction*** **is 1. The tactical employment of firepower exercising the tactical command of one or more units in the selection of targets, the concentration and distribution of fire, and the allocation of ammunition for each mission. 2. The methods and techniques used to convert target information into the appropriate fire commands.** The fire direction center serves as the "brains" of the gunnery team. It is the control center for the gunnery team and is part of the firing battery headquarters. The FDC personnel receive calls for fire directly from an observer or they may be relayed through the battalion FDC. The FDC will then process that information by using tactical and technical fire direction procedures.

- <u>Tactical Fire Direction</u> includes processing calls for fire and determining the appropriate method of fire, ammunition expenditure, unit(s) to fire, and time of attack. The fire direction officer's (FDO) decision on how to engage the target is concisely stated as a **FIRE ORDER**.
- <u>Technical Fire Direction</u> is the process of converting weapon and ammunition characteristics (muzzle velocity, propellant temperature, and projectile weight), weapon and target locations, and met information into firing data. Firing data consist of shell charge, fuze, fuze setting, deflection, and quadrant elevation. The FDC transmits firing data to the guns as **FIRE COMMANDS**.

1-7. **Firing Battery**. The firing battery serves as the "muscle" of the gunnery team. The firing battery includes the battery headquarters (HQ), the howitzer sections, the ammunition section and the FDC. The howitzer sections apply the technical firing data to the weapon and the ammunition.

Note: See ATP 3-09.50 for organization and employment considerations of the firing sections.

FIVE REQUIREMENTS FOR ACCURATE FIRE

1-8. The goal of the firing battery is to achieve accurate first-round fire for effect (FFE) on a target. ***Fire for effect*** **is 1. A command to indicate that fire for effect is desired. 2. Fire that is intended to achieve the desired result on target.** In order to accomplish this goal an artillery unit must compensate for nonstandard conditions as completely as time and the tactical situation permit. There are five requirements for achieving accurate first-round fire for effect. These requirements are accurate target location and size, accurate firing unit location, accurate weapon and ammunition information, accurate meteorological information, and accurate computational procedures. If these requirements are met, the firing unit will be able to deliver accurate and timely fires in support of the ground-gaining arms. If the requirements for accurate fire cannot be met completely, the firing unit may be required to use adjust-fire (AF) missions to engage targets. Adjust-fire missions can result in reduced effect on the target, increased ammunition expenditure, and greater possibility that the firing unit will be detected by hostile TA assets.

- **Accurate Target Location and Size**. Establishing the range (RG) from the weapons to the target requires accurate and timely detection, identification, and location of ground targets. Determining their size and disposition on the ground is also necessary so that accurate firing data can be computed. Determining the appropriate time and type of attack requires that the target size (radius or other dimensions) and the direction and speed of movement are considered. Target location is determined by using the TA assets mentioned in paragraph 1-4 and 1-5.
- **Accurate Firing Unit Location**. Accurate range and deflection from the firing unit to the target requires accurate weapon locations and that the FDC knows this location. The battalion survey section uses different equipments to provide accurate survey information for the battery location. Survey techniques available to the firing battery may also help in determining the location of each weapon.

Note: These techniques are explained in ATP 3-09.50 and FM 6-2.

- **Accurate Weapon and Ammunition Information**. The actual performance of the weapon is measured by the weapon muzzle velocity (velocity with which the projectile leaves the muzzle of the tube) for a projectile-propellant combination. The firing battery can measure the achieved muzzle velocity of a weapon and correct it for nonstandard projectile weight and propellant temperature; this is done through use of the Muzzle Velocity Systems (MVS). The corrections that the MVS makes are similar to those found in the Muzzle Velocity Correction Table (MVCT). Calibration should be conducted continuously by using the MVS. Firing tables and technical gunnery procedures allow the unit to consider specific ammunition information (projectile square weight, fuze type, and propellant temperature); thus, accurate firing data are possible.
- **Accurate Meteorological Information**. The effects of weather on the projectile in flight must be considered, and firing data must compensate for those effects. Firing tables and technical gunnery procedures allow the unit to consider specific weather information (air temperature, air density/pressure, wind direction, and wind speed) in determining accurate firing data.
- **Accurate Computational Procedures**. The computation of firing data must be accurate. Manual and automated techniques are designed to achieve accurate and timely delivery of fire. The balance between accuracy, speed, and the other requirements discussed in this chapter should be included in the computational procedures.

Note: **Nonstandard Conditions**. If the five requirements for accurate fire cannot be met, the FDC needs to take steps to improve firing data (See Chapter 11).

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Chapter 2

Firing Battery and Battery Organization

The FA cannon battery is firing unit within the cannon battalion and is organized in one of two ways: a battery-based unit (3 x 6 organization) or a platoon-based unit (3 x 2 organization). In either case, they have the personnel and equipment needed to shoot, move, and communicate. This chapter describes the organization of the firing battery and the battery FDC.

BATTERY ORGANIZATION IN THE BCT

2-1. The organization of all cannon batteries is basically the same. Differences in organization stem from differences in weapon caliber, whether the weapon is towed or self-propelled (SP), and whether the battery is in a Brigade Combat Team (BCT) or a Fires Brigade. The cannon battery is organized as follows:

2-2. Battery-based unit--consists of a battery headquarters and a firing battery.

- The battery HQ has the personnel and equipment to perform mission command; supply; communications; and chemical, biological, radioactive, nuclear (CBRN) functions.
- The firing battery has the personnel and equipment to determine firing data, fire the howitzers, and resupply ammunition. (In some units, ammunition assets may be consolidated at battalion level.)

2-3. Platoon-based unit--consists of a battery HQ and two firing platoons.

- The battery HQ has the personnel and equipment to perform mission command, supply, communications, and chemical, biological, radioactive, nuclear (CBRN) functions.
- Each firing platoon has the personnel and equipment to determine firing data, fire the howitzers, and resupply ammunition. (In some units, ammunition assets may be consolidated at battalion level.)

BATTERY OR PLATOON FDC

2-4. The battery FDC performs the tactical and/or technical fire direction, while the battalion FDC performs tactical fire direction. If the FDC is operating without a battalion FDC, the battery FDC conducts both tactical and technical fire direction. The battery FDC receives the call for fire and converts the request into firing data. The firing data are then transmitted to the howitzer sections as fire commands. In addition to an FDC, United States Marine Corps (USMC) batteries have a battery operations center (BOC), which is organized and equipped to perform technical fire direction. BOCs enhance unit survivability, simplify displacements, and enable split-battery operations. In battery positions, BOC personnel may augment the FDC to facilitate 24-hour operations.

2-5. The FDC is organized to facilitate 24-hour operations Duties of manual FDC personnel follow.

2-6. **Fire Direction Officer (FDO).** The FDO is responsible for all FDC operations. He is responsible for the training of all FDC personnel, supervises the operation of the FDC, establishes standard operating procedure (SOP), checks target location, announces fire order, and ensures accuracy of firing data transmitted to the howitzers. USMC batteries also include an assistant executive officer (AXO). The AXO leads the BOC, assists the battery commander during displacement and stands duty in the FDC as the FDO to enable 24-hour operations.

2-7. **Chief Fire Control Sergeant**. The Chief Fire Control Sergeant is the technical expert and trainer in the FDC. He ensures that all equipment is on hand and operational, supervises computation of all data, ensures that all appropriate records are maintained, and helps the FDO as needed. He ensures smooth performance of the FDC in 24-hour operations and functions as the FDO in the FDO's absence. The equivalent USMC billet description is Operations Chief.

2-8. **Fire Direction Computer**. The fire direction computer operates the primary means of computing firing data. He determines and announces fire commands. He also records mission-related data and other information as directed. The equivalent USMC billet description is Assistant Operations Chief (A-Ops Chief). There is an A-Ops Chief in both the FDC and the BOC.

2-9. **Fire Direction Specialist**. In a manual FDC, they serve alternately as Horizontal Control Operator (HCO), Vertical Control Operator (VCO) and Radiotelephone operator (RTO). The equivalent USMC billet description is Fire Control Man. These fire control men may perform the duties of the HCO, VCO, RTO, or driver as needed in either the FDC or BOC.

- The **HCO** constructs and maintains the primary firing chart and determines and announces chart data. Chart data consist of: Chart Range, Chart Deflection and Angle T.
- The **VCO** constructs the secondary firing chart checks chart data and determines and announces site.
- The **RTO** or driver normally the operator of the FDC vehicle. He maintains the vehicle and the FDC-associated generators. In a manual FDC, he may also act as the recorder.

2-10. Fire direction is the employment of firepower. The objectives of fire direction are to provide continuous, accurate, and responsive fires under all conditions. Flexibility must be maintained to engage all types of targets over wide frontages, to mass the fires of all available units quickly, and to engage a number and variety of targets simultaneously.

2-11. The fire direction center is the element of the gunnery team with which the commander directs artillery firepower. The accuracy, flexibility, and speed in the execution of fire missions depend on:

- Rapid and clear transmission of calls for fire.
- Rapid and accurate computations.
- Rapid and clear transmission of fire commands.
- Integration of automated and manual equipment into an efficient, mutually supporting system.
- Efficient use of communications equipment.

RELATIONSHIP BETWEEN BATTERY OR PLATOON AND BATTALION FDC

2-12. There are two modes of operation under which fire direction can be conducted: battalion directed and autonomous.

2-13. **Battalion Directed**. In battalion-directed operations, calls for fire are transmitted from the observer to the battalion FDC. The battalion FDO is responsible for tactical fire direction. A fire order is transmitted to the firing units that are responsible for technical fire direction. The battalion FDC is responsible for relaying all fire mission related messages/reports to the observer. The firing units are responsible for transmitting all fire mission related messages to the battalion FDC.

2-14. **Autonomous**. In autonomous operations, calls for fire are transmitted from the observer to the firing unit FDC. The firing unit FDC is responsible for tactical and technical fire direction. The firing unit is responsible for transmitting all fire mission related messages/reports to the observer. The battalion FDC and the battalion fire support officer (FSO) monitor the calls for fire. The battalion FDC may take over control of the mission if the target warrants the massing of two or more batteries. The battalion FDC monitors the battery's message to observer (MTO) to ensure that the battery has selected the appropriate ammunition and method of fire. The battalion FDC may change the battery's plan of attack. If the target requires battalion fire, the firing unit FDO can request reinforcing fires from the battalion FDC.

BATTALION FDC PERSONNEL

2-15. A battalion FDC is composed of a Fire Direction Officer, a Chief Fire Control Sergeant, a Fire Direction Computer, and Fire Direction Specialists. USMC battalion FDCs are composed of a Fire

Direction Officer, Operations Chief, Operations Assistants, and Fire Control Men that facilitate 24-hour operations. The Operations Chief is the equivalent of the Chief Fire Control Sergeant, and the Operations Assistants are the equivalent of the Fire Direction Computer. The Fire Control Men may perform the duties of computer, HCO, VCO, RTO, or driver as needed.

2-16. **Battalion Fire Direction Officer's Duties.** The FDO:

- Is responsible for the overall organization and functioning of the battalion FDC.
- Coordinates with the battalion operations staff officer (S-3) to ensure that all information regarding the tactical situation, unit mission, ammunition status, and commander's guidance on the method of engagement of targets and control of ammunition expenditures is known and ensures that all information is passed to battery FDOs.
- Ensures that all communications are properly established.
- Coordinates with the Chief Fire Control Sergeant concerning data input, chart verification, transfer of registration corrections, average site or altitude, terrain gun position corrections (TGPCs) sectors, and any other special instructions.
- Inspects target locations and monitors messages to observer when a mission is received by a battery FDC and intercedes when necessary.
- Controls all battalion missions.
- Supervises battalion muzzle velocity management.

2-17. **Battalion Chief Fire Control Sergeant's Duties**. The Chief Fire Control Sergeant:

- Serves as the battalion FDC's technical expert (the actual supervisor and/or trainer of battalion FDC personnel) and assumes the duties of the battalion FDO in his absence.
- Ensures that all battalion FDC equipment is operational and emplaced correctly.
- Ensures coordination of all data throughout the battalion, to include current registration settings.
- Ensures that the HCO's chart include all pertinent known data.
- Ensures that the situation map is properly posted, to include fire support coordination measures and the current tactical situation.

2-18. **Battalion Fire Direction Computer's Duties**. The assistant chief computer:

- Monitors all operations performed by the HCO.
- Supervises maintenance and care of the generators.
- Assumes the duties of the battalion Chief Fire Control Sergeant when he is absent.
- Provide communications link with the battery FDCs.
- Exchange information with the battery FDCs and pass battalion fire orders to the battery.
- Record all data pertinent to fire missions that are transmitted to their battery.
- Compute data for their battery when directed by the chief computer.
- Use their fire direction net to communicate with the observer when battalion missions are conducted.
- Assume the duties of the Fire Direction Computer when he is absent.

2-19. **Horizontal Control Operator's (HCO) Duties**. The HCO:

- Plots known data as directed by the assistant chief computer.
- Determines target location, altitude and target segmentation as required.
- Maintains equipment as required.
- Plots the initial target location when a mission is received.

2-20. **Radiotelephone Operator's Duties**. The RTO:

- Establishes and maintains communications on the battalion's command/fire direction (FD) net.
- Determines and transmits the message to observer when battalion missions are conducted on the battalion counterfire (CF) net.
- Encodes and decodes messages, target list, and fire plans.
- Ensure proper authentication of appropriate messages and all fire missions.

- Records all traffic on applicable forms (i.e. DA Form 1594 *Daily Staff Journal or Duty Officer's Log*).
- Maintains equipment as required.

Chapter 3

Ballistics

***Ballistics* is the study of the firing, flight, and effect of ammunition**. A fundamental understanding of ballistics is necessary to comprehend the factors that influence precision and accuracy and how to account for them in the determination of firing data. ***Gunnery* is the practical application of ballistics so that the desired effects are obtained by fire.** To ensure accurate fire, we must strive to account for and minimize those factors that cause round-to-round variations, particularly muzzle velocity. Ballistics can be broken down into four areas: interior, transitional, exterior, and terminal. Interior, transitional, and exterior ballistics directly affect the accuracy of artillery fire.

SECTION I: INTERIOR BALLISTICS

3-1. ***Interior ballistics* is the science that deals with the factors that affect the motion of the projectile within the tube.** The total effect of all interior ballistic factors determines the velocity at which the projectile leaves the muzzle of the tube, which directly influences the range achieved by the projectile. This velocity, called muzzle velocity (MV), is expressed in meters per second to the nearest tenths (0.1 m/s). Actual measurements of the muzzle velocities of a sample of rounds corrected for the effects of nonstandard projectile weight and propellant temperature show the performance of a specific weapon for that projectile family-propellant lot-charge combination. The resulting measurement(s) are compared to the standard muzzle velocity shown in the firing table(s). This comparison gives the variation from standard, called muzzle velocity variation (MVV), for that weapon and projectile family-propellant lot-charge combination. Application of corrections to compensate for the effects of nonstandard muzzle velocity is an important element in computing accurate firing data. (For further discussion of muzzle velocity, see Chapter 4.) The following equation for muzzle velocity is valid for our purposes:

MVV m/s = SHOOTING STRENGTH OF WPN + AMMUNITION EFFICIENCY

3-2. Tube wear, propellant efficiency, and projectile weight are the items normally accounted for in determination of a muzzle velocity. Other elements in the equation above generally have an effect not exceeding +/-1.5 m/s. As a matter of convenience, the other elements listed below are not individually measured, but their effects are realized to exist under the broader headings of shooting strength and ammunition efficiency.

SHOOTING STRENGTH OF WEAPONS
1. Tube wear
2. Manufacturer tolerances
3. Reaction to recoil

AMMUNITION EFFICIENCY
1. Propellant efficiency
2. Projectile efficiency
   a. Projectile weight (fuzed)
   b. Construction of
      (1) Rotating band or Obturating Band
      (2) Bourrelet

NATURE OF PROPELLANT AND PROJECTILE MOVEMENT

3-3. A ***propellant*** **is a low-order explosive that burns rather than detonates**. In artillery weapons using separate-loading ammunition, the propellant burns within a chamber formed by the obturator spindle assembly, powder chamber, rotating band, and base of the projectile. For cannons using semi-fixed ammunition, the chamber is formed by the shell casing and the base of the projectile. When the propellant is ignited by the primer, the burning propellant generates gases. When these gases develop enough pressure to overcome initial bore resistance, the projectile begins its forward motion.

PARTS OF THE CANNON TUBE THAT AFFECT INTERIOR BALLISTICS.

3-4. The breech recess receives the breechblock. The breech permits loading the howitzer from the rear.

3-5. The powder chamber receives the complete round of ammunition. It is the portion of the tube between the gas check seat and the centering slope (see figure 3-1 for illustration).

- The ***gas check seat*** **is the tapered surface in the rear interior of the tube on weapons firing separate-loading ammunition.** It seats the split rings of the obturating mechanism when they expand under pressure in firing. This expansion creates a metal-to-metal seal and prevents the escape of gases through the rear or the breech. Weapons firing semi-fixed ammunition do not have gas check seats since the expansion of the case against the walls of the chamber provides a gas seal for-the breech.
- The ***swiss groove*** **is the cutaway portion of the powder chamber that allows the propellant to sit flush against the obturator spindle when the breech is closed.** The swiss groove also holds the propellant in place at all angles of elevation.
- The ***centering slope*** **is the tapered portion at or near the forward end of the chamber that causes the projectile to center itself in the bore during loading.**

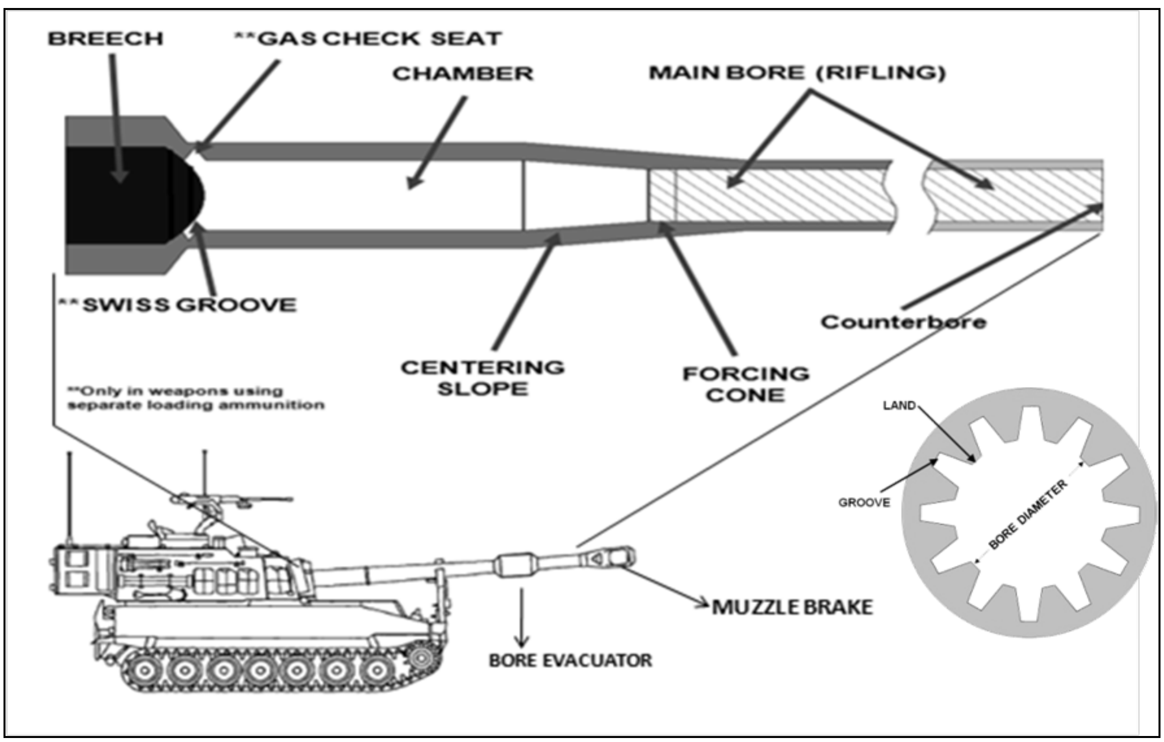


Figure 3-1. Cannon Tube.

3-6. The ***forcing cone*** **is the tapered portion near the rear of the bore that allows the rotating band to be gradually engaged by the rifling, thereby centering the projectile in the bore.**

3-7. The ***bore* is the rifled portion of the tube (lands and grooves).** It extends from the forcing cone to the muzzle. The rifled portion of the tube imparts spin to the projectile increasing stability in flight. The grooves are the depressions in the rifling. The lands are the raised portions. These parts engrave the rotating band. All United States (US) howitzers have a right-hand twist in rifling.

3-8. The **bore evacuator** is located on enclosed, self-propelled howitzers with semi-automatic breech mechanisms. It prevents contamination of the crew compartment by removing propellant gases from the bore after firing. The bore evacuator forces the gases to flow outward through the bore from a series of valves enclosed on the tube.

3-9. The caliber of a tube is the inside diameter of the tube as measured between opposite lands.

3-10. The ***counterbore* is the portion at the front of the bore from which the lands have been removed to relieve stress and prevents the tube from cracking.**

3-11. The **muzzle brake** is located at the end of the tube on some howitzers. As the projectile leaves the muzzle, the high-velocity gases strike the baffles of the muzzle brake and are deflected rearward and sideways. When striking the baffles, the gases exert a forward force on the baffles that partially counteracts and reduces the force of recoil.

PARTS OF THE PROJECTILE TUBE THAT AFFECT INTERIOR BALLISTICS.

3-12. The projectile body has several components that affect ballistics. (See figure 3-2.) Two of these affect interior ballistics-the bourrelet and the rotating band or obturating band (found on certain projectiles).

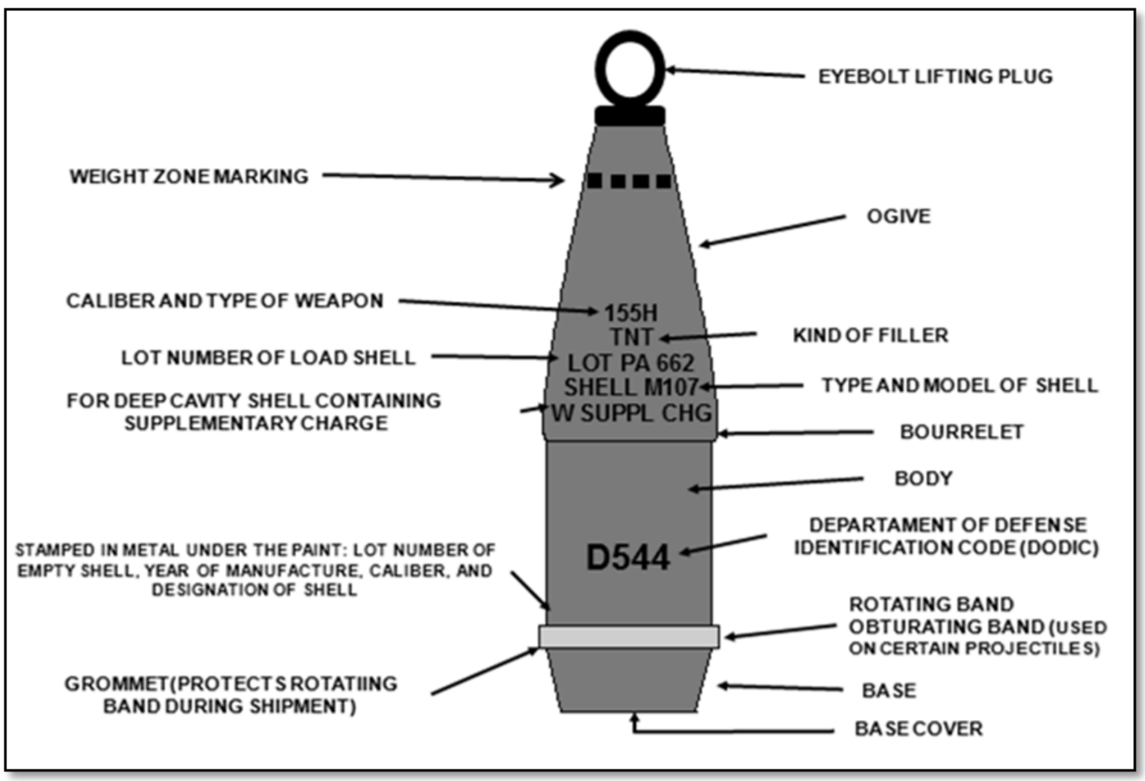


Figure 3-2. Separate Loading 155mm Projectile.

3-13. The ***bourrelet* is the widest part of the projectile and is located immediately to the rear of the ogive.** The bourrelet centers the forward part of the projectile in the tube and bears on the lands of the tube. When the projectile is fired, only the bourrelet and rotating band bear on the lands of the tube.

3-14. The ***rotating band* is a band of soft metal (copper alloy) that is securely seated around the body of the projectile.** When engaged with the forcing cones it provides forward obturation (the gas-tight seal required to develop pressure inside the tube). The rotating band prevents the escape of gas pressure from around the projectile. When the weapon is fired, the rotating band contacts the lands and grooves and is pressed between them. As the projectile travels the length of the cannon tube, over the lands and grooves, spin is imparted. The rifling for the entire length of the tube must be smooth and free of burrs and scars. This permits uniform seating of the projectile and gives a more uniform muzzle velocity.

3-15. The ***obturating band* is a plastic band on certain projectiles**. It provides forward obturation by preventing the escape of gas pressure from around the projectile.

> Note: The terms rotating band and obturating band used throughout this manual are synonymous, unless otherwise stated.

THE SEQUENCE THAT OCCURS WITHIN THE CANNON TUBE

3-16. The projectile is rammed into the cannon tube and rests on the bourrelet. The rotating band contacts the lands and grooves at the forcing cone creating forward obturation.

3-17. The propellant is inserted into the powder chamber and the breech is closed. This provides rearward obturation.

> Note: For semi-fixed ammunition, the projectile and powder canister are inserted into the cannon tube and the breech is closed. The rotating band creates forward obturation while, upon firing, the rapid expansion of gases within the canister causes the canister to expand against the powder chamber walls creating rearward obturation.

3-18. The propellant explosive train is initiated by the ignition of the primer. The primer injects hot gases and incandescent particles into the igniter. The igniter burns and creates hot gases that flow between the powder grains and ignite the grains surfaces; the igniter and propellant combustion products then act together, perpetuating the flame spread until all the powder grains are ignited.

3-19. The chamber is sealed, in the rear by the breech and obturator spindle group **(gas check seat)** and forward by the **rotating band** of the projectile, so the gases and energy created by the primer, igniter, and propellant cannot escape. This results in a dramatic increase in the pressure and temperature within the chamber. The burning rate of the propellant is roughly proportional to the pressure, so the increase in pressure is accompanied by an increase in the rate at which further gas is produced.

3-20. The rising pressure is moderated by the motion of the projectile along the barrel. **The pressure at which this motion begins is the *shot-start pressure***. The projectile will then almost immediately encounter the rifling, and the projectile will slow or stop again until the pressure has increased enough to overcome the resistance in the bore. The rotating band will be engraved to the shape of the rifling. The resistance decreases, thereby allowing the rapidly increasing pressure to accelerate the projectile.

3-21. As the projectile moves forward, it leaves behind an increasing volume to be filled by the high-pressure propellant gases. The propellant is still burning, producing high-pressure gases so rapidly that the motion of the projectile cannot fully compensate. As a result, the pressure continues to rise until the peak pressure is reached. The **peak pressure** is attained when the projectile has traveled about one-tenth of the total length of a howitzer tube.

3-22. The rate at which extra space is being created behind the rapidly accelerating projectile then exceeds the rate at which high-pressure gas is being produced; thus the pressure begins to fall. The next stage is the all-burnt position at which the burning of the propellant is completed. However, there is still considerable pressure in the tube; therefore, for the remaining motion along the bore, the projectile continues to accelerate. As it approaches the muzzle, propellant gases expand, pressure falls, and acceleration lessens. At the moment the projectile leaves the howitzer, the pressure will have been reduced to about one-sixth of the peak pressure. Only about one-third of the energy developed pushes the projectile. The other two-thirds are absorbed by the recoiling parts or lost because of heat and metal expansion.

3-23. The flow of gases following the projectile out of the muzzle provides additional acceleration for a short distance (transitional ballistics); so that the full muzzle velocity is not reached until the projectile is some distance beyond the muzzle. The noise and shock of firing are caused by the jet action of the projectile as it escapes the flow of gases and encounters the atmosphere. After this, the projectile breaks away from the influence of the gun and begins independent flight.

3-24. This entire sequence, from primer firing to muzzle exit, typically occurs within 15 milliseconds but perhaps as much as 25 milliseconds for a large artillery howitzer.

PRESSURE TRAVEL CURVES

3-25. Once the propellant ignites, gases are generated that develop enough pressure to overcome initial bore resistance, thereby moving the projectile. Two opposing forces act on a projectile within the howitzer. The first is a propelling force caused by the high-pressure propellant gases pushing on the base of the projectile. The second is a frictional force between the projectile and bore, which includes the high resistance during the engraving process that opposes the motion of the projectile. The peak pressure, together with the travel of the projectile in the bore (pressure travel curve), determines the velocity at which the projectile leaves the tube.

3-26. To analyze the desired development of pressure within the tube, we identify three types of pressure travel curves:

- An **elastic strength pressure** travel curve represents the greatest interior pressure that the construction of the tube (thickness of the wall of the powder chamber, thickness of the tube, composition of the tube or chamber, and so on) will allow. It decreases as the projectile travels toward the muzzle because the thickness of the tube decreases.
- A **permissible pressure travel curve** mirrors the elastic strength pressure travel curve and accounts for a certain factor of safety. It also decreases as the projectile travels through the tube because tube thickness decreases.
- An **actual pressure travel curve** represents the actual pressure developed during firing within the tube. Initially, pressure increases dramatically as the repelling charge explosive train initiated and the initial resistance of the rammed projectile is overcome. After that resistance is overcome, the actual pressure gradually decreases because of the concepts explained by Boyle's Law. The actual pressure should never exceed the permissible pressure.

3-27. **Initial Excessive Pressure**. This is undesirable pressure travel curve. It exceeds the elastic strength pressure and permissible pressure. Causes of this travel curve would be an obstruction in the tube, a dirty tube, an "extra" propellant placed in the chamber, an un-fuzed projectile, or a cracked projectile. See figure 3-3.

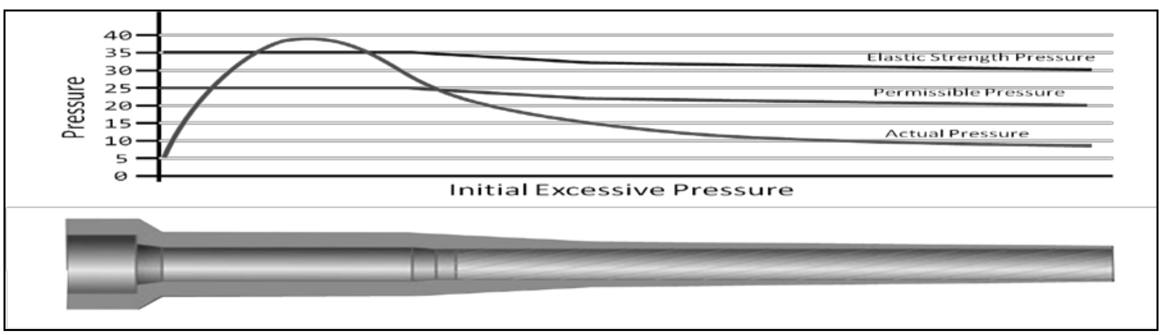


Figure 3-3. Initial Excessive Pressure.

3-28. **Delayed Excessive Pressure**. This is an undesirable pressure travel curve. It exceeds the elastic strength pressure and permissible pressure. Causes that would result in this travel curve would be using wet powder or powder reversed. See figure 3-4 on page 3-6.

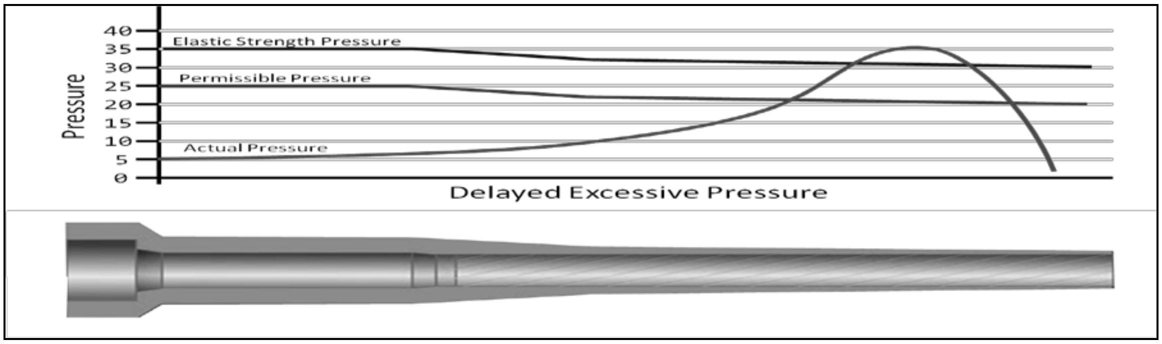


Figure 3-4. Delayed Excessive Pressure.

3-29. **Desirable Pressure Travel Curve**. This curve does not exceed permissible pressure. It develops peak pressure at about one-tenth the length of the tube. See figure 3-5.

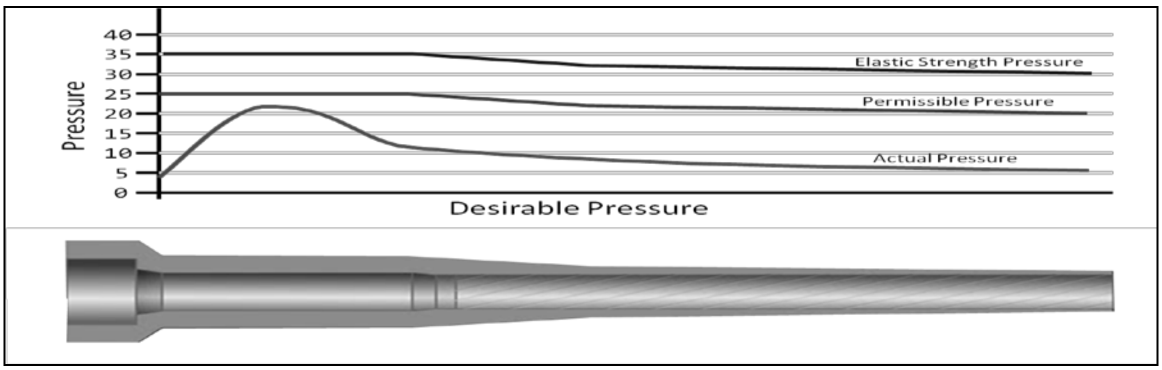


Figure 3-5. Desirable Pressure Travel Curve.

FACTORS THAT AFFECT THE VELOCITY PERFORMANCE OF A WEAPON PROJECTILE FAMILY-PROPELLANT LOT-CHARGE COMBINATION:

3-30. An increase in the rate of propellant burning increases the resulting gas pressure developed within the chamber. An example of this is the performance of the multi-perforated propellant grains used in M232A1 Modular Artillery Charge System (MACS). The result is that the propellant burns at a faster rate, more gases are produced, gas pressure is increased, and the projectile develops a greater muzzle velocity. Damage to powder grains, such as cracking and splitting from improper handling, or slight differences in the manufacturing process between different lots of the same propellant type also affect the rate of burn and thus the muzzle velocity.

3-31. An increase in the size of the chamber without a corresponding increase in the amount of propellant decreases gas pressure; as a result, muzzle velocity will be less.

3-32. Gas escaping around the projectile decreases chamber pressure.

3-33. An increase in bore resistance to projectile movement before peak pressure increases the pressure developed within the tube. Generally, this results in a dragging effect on the projectile, with a corresponding decrease in the developed muzzle velocity. Temporary variations in bore resistance can be caused by excessive deposits of residue within the cannon tube and on projectiles and by temperature differences between the inner and outer surfaces of the cannon tube.

FACTORS CAUSING NONSTANDARD VELOCITIES.

3-34. Nonstandard muzzle velocity is expressed as a variation (plus or minus so many meters per second) from the accepted standard. Round-to-round corrections for dispersion cannot be made. Each of the following factors that cause nonstandard conditions is treated as a single entity assuming no influence from related factors applicable firing tables list the standard value of muzzle velocity for each charge. These standard values are based on an assumed set of standard conditions. These values are points of departure and not absolute standards. Essentially, we cannot assume that a given weapon projectile family-propellant type-charge combination when fired will produce the standard muzzle velocity. See figure 3-6 for a graph of velocity changes by round.

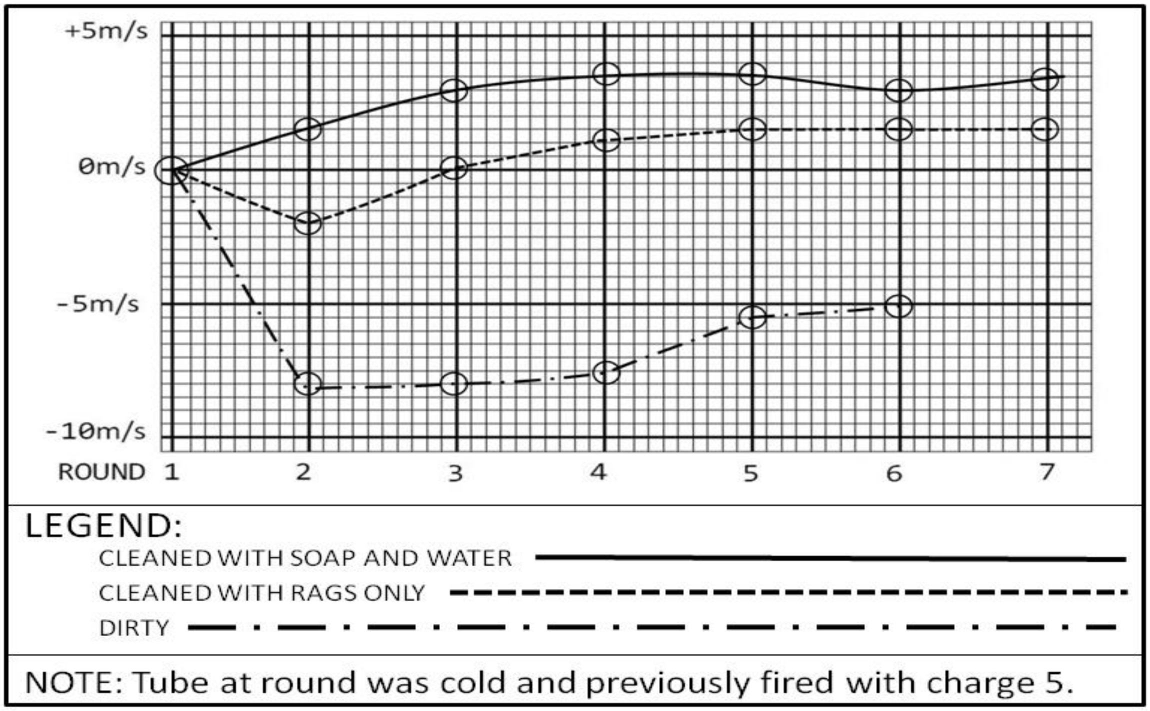


Figure 3-6. Velocity Changes.

3-35. **Velocity trends**. Not all rounds of a series fired from the same weapon and using the same ammunition lot will develop the same muzzle velocity. 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 trends (or velocity dispersion), and the magnitude varies with the cannon, charge, and tube condition at the time each round is fired. Velocity trends cannot be accurately predicted; thus, any attempt to correct for the effects of velocity trends is impractical. Generally, the magnitude and duration of velocity trends can be minimized when firing is started with a tube that is clean and completely free of oil. (See figure 3-6.)

3-36. **Ammunition lots**. Each ammunition, projectile, and propellant lot has its own mean performance level in relation to a common weapon. Although the round-to-round variations within a given lot of the same ammunition types are similar, the mean velocity developed by one lot may differ significantly in comparison to that of another lot. With separate-loading ammunition, both the projectile and propellant lots must be identified. Projectile lots allow for rapid identification of weight differences. Although other projectile factors affect achieved muzzle velocity (such as, diameter and hardness of rotating band), the cumulative effect of these elements generally does not exceed +/- 1.5 m/s. As a matter of convenience and speed, they are ignored in the computation of firing data.

3-37. **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 mean factors affecting muzzle velocity are variations in the size of the powder chamber and the interior dimensions of the bore. If a battalion equipped with new cannons fired all of them with a common lot of ammunition, a variation of +/-4 m/s between the cannon developing the greatest muzzle velocity and the cannon developing the lowest muzzle velocity would not be unusual. Calibration of all cannons allows the firing unit to compensate for small variations in the manufacture of cannon tubes and the resulting variation in developed muzzle velocity. The MVV caused by inconsistencies in tube manufacture remains constant and is valid for the life of the tube.

3-38. **Tube wear**. Continued firing of a cannon wears away portions of the bore by the actions of hot gases and chemicals and movement of the projectile within the tube. These erosive actions are more pronounced when higher charges are fired. The greater the tube wear, the more the muzzle velocity decreases. Normal wear can be minimized by careful selection of the charge and by proper cleaning of both the tube and the ammunition.

3-39. **Non-uniform ramming**. Weak, non-uniform ramming results in an unnecessary and preventable increase in the size of the dispersion pattern. Weak ramming decreases the volume of the chamber and thereby theoretically increases the pressure imparted to the projectile. This occurs because the pressure of a gas varies inversely with volume. Therefore, only a partial gain in muzzle velocity might be achieved. Of greater note is the improper seating of the projectile within the tube. Improper seating can allow some of the expanding gases to escape around the rotating band of the projectile and thus result in decreased muzzle velocity. The combined effects of a smaller chamber and escaping gases are difficult to predict. Hard, uniform ramming is desired for all rounds. When semi-fixed ammunition is fired, the principles of varying the size of the chamber and escape of gases still apply, particularly when ammunition is fired through worn tubes. When firing semi-fixed ammunition, rearward obturation is obtained by the expansion of the cartridge case against the walls of the powder chamber. Proper seating of the cartridge case is important in reducing the escape of gases.

3-40. **Rotating bands**. The ideal rotating band permits proper seating of the projectile within the cannon tube. Proper seating of the projectile allows forward obturation, uniform pressure buildup, and initial resistance to projectile movement within the tube. The rotating band is also designed to provide a minimum drag effect on the projectile once the projectile overcomes the resistance to movement and starts to move. Dirt or burrs on the rotating band may cause improper seating. This increases tube wear and contributes to velocity dispersion. If excessively worn, the lands may not engage the rotating band well enough to impart the proper spin to the projectile. Insufficient spin reduces projectile stability in flight and can result in dangerously erratic round performance. When erratic rounds occur or excessive tube wear is noted, ordnance teams should be requested to determine the serviceability of the tube.

3-41. **Propellant and projectile temperatures**. Any combustible material burns more rapidly when heated before ignition. When a propellant burns more rapidly than would be expected under standard conditions, gases are produced more rapidly and the pressure imparted to the projectile is greater. As a result, the muzzle velocity will be greater than standard and the projectile will travel farther. Table E in the tabular firing tables lists the magnitude of change in muzzle velocity resulting from a propellant temperature that is greater or less than standard. Appropriate corrections can be extracted from that table; however, such corrections are valid only if they are determined relative to the true propellant temperature. The temperature of propellant in sealed containers remains fairly uniform though not necessarily at the standard propellant temperature (70 degrees Fahrenheit). Once propellant has been unpacked, its temperature more rapidly approaches the air temperature. The time and type of exposure to the weather result in temperature variations from round to round and within the firing unit. It is currently impractical to measure propellant temperature and apply corrections for each round fired by each cannon. Positive action must be taken to maintain uniform projectile and propellant temperatures in the form of proper ammunition storage and handling procedures. Failure to do this results in erratic firing. The effect of an extreme change in projectile or propellant temperature can invalidate even the most recent corrections determined from a registration.

- Ready ammunition should be kept off the ground and protected from dirt, moisture, and direct sunlight. At least 6 inches of airspace between the ammunition and protective covering on the sides, 6 inches of dunnage on the bottom, and the roof 18 inches from the top of the stack. These precautions will allow propellant and projectile temperatures to approach the air temperature at a uniform rate throughout the firing unit.
- Propellant should be prepared in advance so that it is never necessary to fire freshly unpacked ammunition with ammunition that has been exposed to weather during a fire mission.
- Ammunition should be fired in the order in which it was unpacked.
- Propellant temperature should be determined from ready ammunition on a periodic basis, particularly if there has been a change in the air temperature.

3-42. **Moisture content of propellant**. Changes in the moisture content of propellant are caused by improper protection from the elements or improper handling of the propellant. These changes can affect muzzle velocity. Since the moisture content cannot be measured or corrected for, the propellant must be provided maximum protection from the elements and improper handling.

3-43. **Position of propellant in the chamber**. In semi-fixed ammunition, the propellant has a relatively fixed position with respect to the chamber, which is formed by the cartridge case. In separate-loading ammunition, the rate at which the propellant burns and the developed muzzle velocity depends on how the cannoneer inserts the charge. To ensure proper ignition of the propellant he must insert the charge so that the base of the propellant is flush against the obturator spindle when the breech is closed. The cannoneer ensures this by placing the propellant flush against the swiss groove (the cutaway portion in the powder chamber). The farther forward the charge is inserted, the slower the burning rate and the lower the subsequent muzzle velocity. An increase in the diameter of the propellant charge can also cause an increase in muzzle velocity. With bag charges, loose tie straps or wrappings have the effect of increasing the diameter of the propellant charge. Propellant charge wrappings should always be checked for tightness, even when the full propellant charge is used.

3-44. **Weight of projectile**. The weights of like projectiles vary within certain zones (normally termed square weight). The appropriate weight zone is stenciled on the projectile (in terms of so many squares). Some projectiles are marked with the weight in pounds. In general terms, a heavier-than-standard projectile normally experiences a decrease in muzzle velocity. This is because more of the force generated by the gases is used to overcome the initial resistance to movement. A lighter-than-standard projectile generally experiences an increase in velocity. However, when projectiles are fired with higher charges and increased ranges, heavier than standard projectiles may achieve greater ranges. Table F, in the tabular firing tables, lists correction factors for the effect of nonstandard square weights.

3-45. **Coppering**. When the projectile velocity within the bore is great, sufficient friction and heat are developed to remove the outer surface of the rotating band. Material left is a thin film of copper within the bore and is known as coppering. This phenomenon occurs in weapons that develop a high muzzle velocity and when high charges are fired. The amount of copper deposited varies with velocity. Firing higher charges increases the amount of copper deposited on the bore surfaces, whereas firing lower charges reduces the effects of coppering. Slight coppering resulting from firing a small sample of rounds at higher charges tends to increase muzzle velocity. Erratic velocity performance is a result of excessive coppering whereby the resistance of the bore to projectile movement is affected. Excessive coppering must be removed by ordnance personnel.

3-46. **Propellant residue**. Residue from burned propellant and certain chemical agents mixed with the expanding gases are deposited on the bore surface in a manner similar to coppering. Unless the tube is properly cleaned and cared for, this residue will accelerate tube wear by causing pitting and augmenting the abrasive action of the projectile.

3-47. **Tube conditioning**. The temperature of the tube has a direct bearing on the developed muzzle velocity. A cold tube offers a different resistance to projectile movement and is less susceptible to coppering, even at high velocities. In general, a cold tube yields more range dispersion; a hot tube, less range dispersion.

3-48. **Additional effects in interior ballistics**. The additional effects include tube memory and tube jump.

- Tube memory is a physical phenomenon of the cannon tube tending to react to the firing stress in the same manner for each round, even after changing charges. It seems to “remember” the muzzle velocity of the last charge fired. For example, if a fire mission with charge 4 M232A1 is followed by a fire mission with charge 2 M231, the muzzle velocity of the first round of charge 2 may be unpredictably higher. The inverse is also true.
- Tube jump occurs as the projectile tries to maintain a straight line when exiting the muzzle. This phenomenon causes the tube to jump up when fired and may cause tube displacement.

SECTION II: TRANSITIONAL BALLISTICS

3-49. ***Transitional Ballistics***. Sometimes referred to as intermediate ballistics, this **is the study of the transition from interior to exterior ballistics**. Transitional ballistics is complex and involves a number of variables that are not fully understood; therefore, it is not an exact science. What is understood is that when the projectile leaves the muzzle, it receives a slight increase in muzzle velocity from the escaping gases. Immediately after that, its velocity begins to decrease because of drag.

SECTION III: EXTERIOR BALLISTICS

3-50. **Exterior Ballistics**. ***Exterior ballistics* is the science that deals with the factors affecting the motion of a projectile after it leaves the muzzle of a howitzer.** At that instant, the total effects of interior ballistics in terms of developed muzzle velocity and spin have been imparted to the projectile. Were it not for gravity and the effects of the atmosphere, the projectile would continue indefinitely at a constant velocity along the infinite extension of the cannon tube. The discussion of exterior ballistics in the following paragraphs addresses elements of the trajectory, the trajectory in a vacuum, the trajectory within a standard atmosphere, and the factors that affect the flight of the projectile.

TRAJECTORY ELEMENTS.

3-51. The trajectory is the path traced by the center of gravity of the projectile from the origin to the level point. The elements of a trajectory are classified into three groups--intrinsic, initial, and terminal elements.

3-52. **Intrinsic elements**. Elements that are characteristic of any trajectory, by definition, are intrinsic elements. (See figure 3-7.)

- The ***origin* is the location of the center of gravity of the projectile when it leaves the muzzle**. It also denotes the center of the muzzle when the howitzer has been laid.
- The ***ascending branch* is the part of the trajectory that is traced as the projectile rises from the origin.**
- The ***summit* is the highest point of the trajectory**.
- The ***maximum ordinate* is the difference in altitude (alt) between the origin and the summit**.
- The ***descending branch* is the part of the trajectory that is traced as the projectile is falling.**
- The ***level point* is the point on the descending branch that is the same altitude as the origin**.
- The ***base of the trajectory* is the straight line from the origin to the level point**.

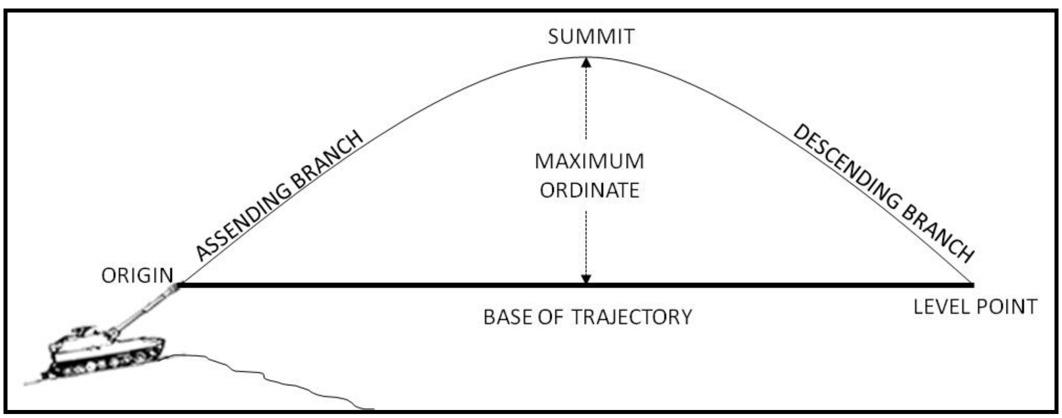


Figure 3-7. Intrinsic Elements of the Trajectory.

3-53. **Initial elements**. Elements that are characteristic at the origin of the trajectory are initial elements. (See figure 3-8 on page 3-11.)

- When the howitzer is laid, the line of elevation is the axis of the tube

- The line of departure is a line tangent to the trajectory at the instant the extended projectile leaves the tube.
- ***Jump*** **is the displacement of the line of departure from the line of elevation that exists at the instant the projectile leaves the tube**.
- **The** ***angle of site*** **is the smaller angle in a vertical plane from the base of the trajectory to a straight line joining the origin and the target.**
- ***Vertical interval*** **is the difference in altitude between the (or observer) and the target or point of burst.**
- **The** ***complementary angle of site*** **is an angle that is algebraically sum to the angle of site to compensate for the non-rigidity of the trajectory.**
- ***Site*** **is the algebraic sum of the angle of site and the complementary angle of site**. Site is computed to compensate for situations in which the target is not at the same altitude as the battery.
- ***Complementary range*** **is the number of meters (range correction) equivalent to the number of mils of complementary angle of site.**
- The ***angle of elevation*** **is the vertical angle between the base of the trajectory and the axis of the bore required for a projectile to achieve a prescribed range under standard conditions**.
- The ***quadrant elevation*** **is the angle at the origin measured from the base of the trajectory to the line of elevation. It is the algebraic sum of site and the angle of elevation**.

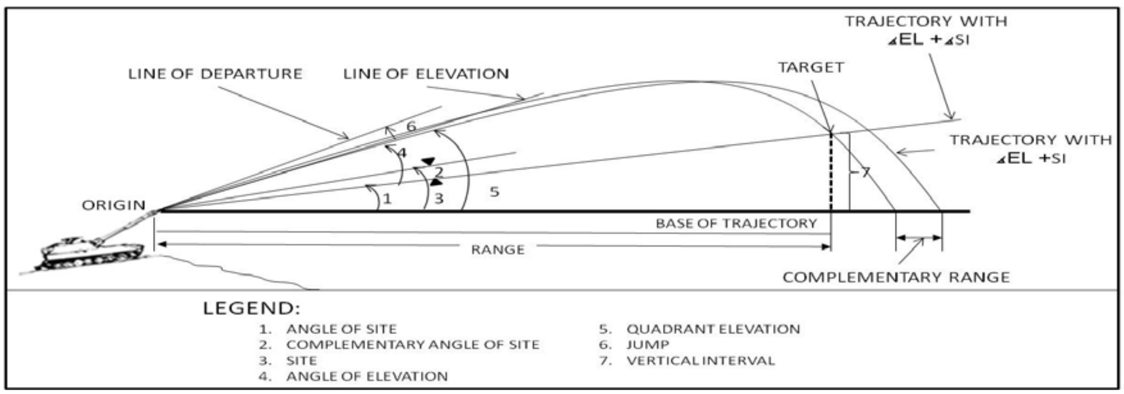


Figure 3-8. Initial Elements of the Trajectory.

3-54. **Terminal elements**. Elements that are characteristic at the point of impact are terminal elements. (See figure 3-9 on page 3-12.)

- The point of impact is the point at which the projectile strikes the target area. (The point of burst is the point at which the projectile bursts in the air.)
- The line of fall is the line tangent to the trajectory at the level
- The angle of fall is the vertical angle at the level point between the line of fall and the base of the trajectory.
- The line of impact is a line tangent to the trajectory at the point 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 angle of fall.

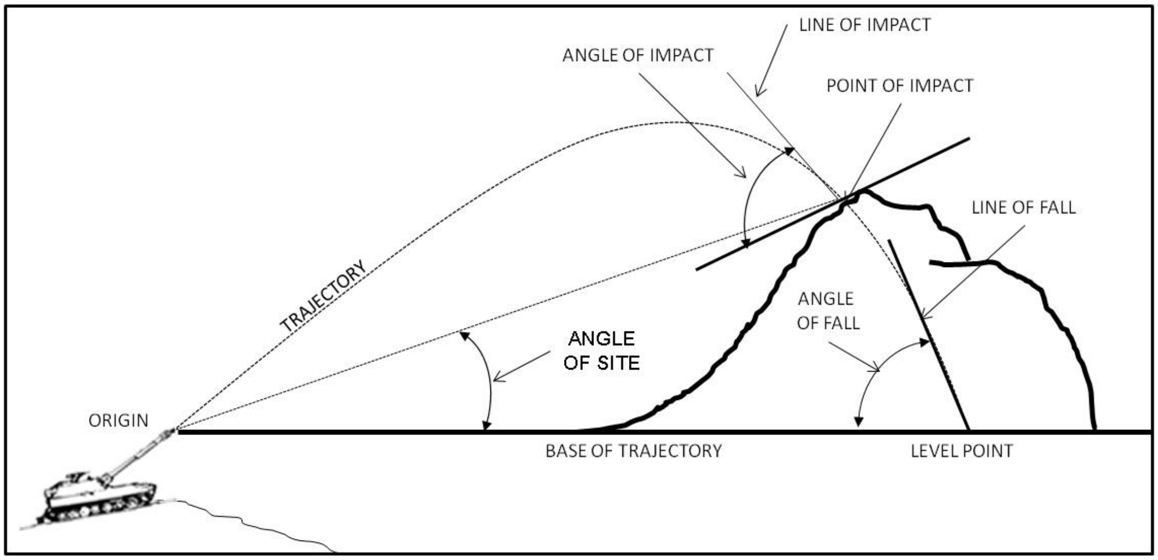


Figure 3-9. Terminal Elements of the Trajectory.

TRAJECTORY IN A VACUUM

3-55. If a round were fired in a vacuum, gravity would cause the projectile to return to the surface of the earth. The path or trajectory of the projectile would be simple to trace. All projectiles, regardless of size, shape, or weight, would follow paths of the same parabolic shape and would achieve the same range for a given muzzle velocity and quadrant elevation.

3-56. The factors used to determine the data needed to construct a firing table for firing in a vacuum are the angle of departure, muzzle velocity, and acceleration caused by the force of gravity. The initial velocity imparted to a round has two components--horizontal velocity and vertical velocity. The relative magnitudes of horizontal and vertical components vary with the angle of elevation. For example, if the elevation were zero, the initial velocity imparted to the round would be horizontal in nature and there would be no vertical component. If, on the other hand, the elevation were 1,600 mils (disregarding the effects of rotation of the earth), the initial velocity would be vertical and there would be no horizontal component.

3-57. 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 zero on the ascending branch of the trajectory and increase from zero to the initial velocity on the descending branch, Zero vertical velocity would occur at the summit of the trajectory. For every vertical velocity value on the upward leg of the ascending branch there is an equal vertical velocity value downward 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 caused by the force of gravity (9.81 m/s) affects only the vertical velocity.

TRAJECTORY IN A STANDARD ATMOSPHERE

3-58. The resistance of the air to projectile movement depends on the air movement, density, and temperature. As a point of departure for computing firing tables, assumed conditions of air density and air temperature with no wind are used. The air structure is called the standard atmosphere.

3-59. The most apparent difference between the trajectory in a vacuum and the trajectory in the standard atmosphere is a net reduction in the range achieved by the projectile. A comparison of the flight of the projectile in a vacuum and in the standard atmosphere is shown in figure 3-10 on page 3-13.

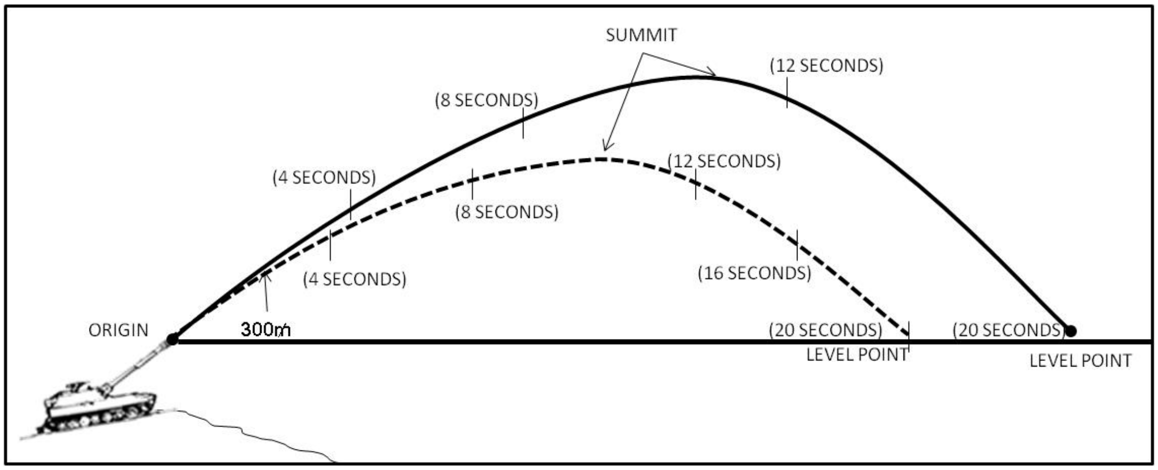


Figure 3-10. Trajectories in a Standard Atmosphere and in a Vacuum.

3-60. The difference in range is due to the horizontal velocity component in the standard atmosphere no longer being a constant value. The horizontal velocity component is continually decreased by the retarding effect of the air. The vertical velocity component is also affected by air resistance. The trajectory in the standard atmosphere has the following characteristic differences from the trajectory in a vacuum:

- The velocity at the level point is less than the velocity at the origin.
- The mean horizontal velocity of the projectile beyond the summit is less than the mean velocity before the projectile reaches the summit; therefore, the projectile travels a shorter horizontal distance. Hence, the descending branch is shorter than the ascending branch. The angle of fall is greater than the angle of elevation.
- The spin (rotational motion) initially imparted to the projectile causes it to respond differently in the standard atmosphere because of air resistance. A trajectory in the standard atmosphere, compared to a trajectory in a vacuum, will be shorter and lower at any specific point along the trajectory for the following reasons:
  - Horizontal velocity is not a constant value; it decreases with each succeeding time interval.
  - Vertical velocity is affected by both gravity and the effects of the atmosphere on the projectile.
  - The summit in a vacuum is midway between the origin and the level point; in the standard atmosphere, it is actually nearer the level point.
  - The angle of fall in a vacuum is equal to the angle of elevation; in the standard atmosphere, it is greater.

RELATION OF AIR RESISTANCE AND PROJECTILE EFFICIENCY TO STANDARD RANGE

3-61. This paragraph concerns only those factors that establish the relationship between the standard range, elevation, and achieved range.

- The standard ***(chart) range*** **is the range opposite a given elevation in the firing tables**. It is assumed to have been measured along the surface of a sphere concentric with the earth and passing through the muzzle of a weapon. For all practical purposes, standard range is the horizontal distance from the origin of the trajectory to the level point.
- **The *achieved range* is the range attained as a result of firing the cannon at a particular elevation**. If actual firing conditions duplicate the ballistic properties and met conditions on which the firing tables are based, then the achieved range and the standard range will be equal.
- The ***corrected range*** **is the range corresponding to the elevation that must be fired to reach the target**.

3-62. Air resistance affects the flight of the projectile both in range and in direction. The component of air resistance in the direction opposite 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 along the trajectory than they would be if drag was zero (as it would be in a vacuum). This decrease in velocity varies directly in magnitude with drag and inversely with the mass of the projectile. Several factors considered in the computation of drag are as follows:

- **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 drag by the same percentage. Since the air density at a specific place, time, and altitude varies widely, the standard trajectories reflected in the firing tables were computed with a fixed relationship between air density and altitude.
- **Air temperature**. Variations in air temperature cause two separate effects on a projectile. One effect is caused by the inverse relationship of density and temperature (equation of state). This effect is compensated for when density effects are considered. The second effect is regarded as the true temperature effect. It is the result of the relationship between the speed of the projectile and the speed of the air compression waves that form in front of or behind the projectile. These air compression waves move at the speed of sound, which is directly proportional to the air temperature. The relationship between the variation in air temperature and the drag on the projectile is difficult to determine. This is particularly true for supersonic projectiles since they break through the air compression waves after they are formed. As firing tables indicate, an increase in air temperature may increase, decrease, or have no effect on achieved range, depending upon the initial elevation and muzzle velocity of the weapon.
- **Projectile diameter**. Two projectiles of identical shape but of different size will not experience the same drag. For example, a large projectile will offer a larger area for the air to act upon; thus, its drag will be increased by this factor. The drag of projectiles of the same shape is assumed to be proportional to the square of the projectile diameter.
- **Drag coefficient**. The drag coefficient combines several ballistic properties of typical projectiles. These properties include yaw (the angle between the direction of motion and the axis of the projectile) and the ratio of the velocity of the projectile to the speed of sound. Drag coefficients, which have been computed for many projectile types, simplify the work of ballisticians. When a projectile varies slightly in shape from one of the typical projectile types, the drag coefficient can be determined by computing a form factor for the projectile and multiplying the drag coefficient of a typical projectile type by the form factor.
- **Ballistic coefficient**. The ballistic coefficient of a projectile is a measure of its relative efficiency in overcoming air resistance. An increase in the ballistic coefficient reduces the effect of drag and consequently increases range. The reverse is true for a decrease in the ballistic coefficient. The ballistic coefficient can be increased by increasing the ratio of the weight of the projectile to the square of its diameter. It can also be increased by improving the shape of the projectile.

DEVIATIONS FROM STANDARD CONDITIONS

3-63. Firing tables are based on actual firings of a piece and its ammunition correlated to a set of standard conditions. Actual firing conditions, however, will never equate to standard conditions. These deviations from standard conditions, if not corrected for when computing firing data will cause the projectile to impact at a point other than the desired location. Corrections for nonstandard conditions are made to improve accuracy.

- **Range effects**. Some of the deviations from standard conditions affecting range are:
  - Muzzle velocity.
  - Projectile weight.
  - Range wind.
  - Air temperature.
  - Air density.
  - Rotation of the earth.
  - Propellant temperature.

- **Deflection effects**. Some of the deviations from the standard conditions affecting deflection are:
  - Drift.
  - Crosswind.
  - Rotation of the earth.

DISPERSION AND PROBABILITY

3-64. If a number of rounds of ammunition of the same caliber, lot, and charge are fired from the same position with identical settings used for deflection and quadrant elevation, the rounds will not all impact on a single point but will fall in a scattered pattern. In discussions of artillery fire, this phenomenon is called dispersion, and the array of bursts on the ground is called the dispersion pattern.

CAUSES OF DISPERSION

3-65. The points of impact of the projectiles will be scattered both in deflection and in range. ***Dispersion*** **is the result of minor variation from round to round (caused by inherent systemic errors)** and must not be confused with variation in point of impact caused by Human Errors or Constant Errors. ***Human errors*** **are mistakes made by any member of the gunnery team** and can be minimized through training and supervision. ***Constant errors*** **are errors that are known and are constant throughout the mission**. Corrections to compensate for the effects of constant errors can be determined from the TFT. Inherent errors are beyond control or are impractical to measure. Examples of inherent errors are as follows:

- **Conditions in the bore**. The muzzle velocity achieved by a given projectile is affected by the following:
  - Variations in the weight of the projectile form of the rotating band, and moisture content and temperature of the powder grains.
  - Variations in the placement of propellant.
  - Differences in the rate of ignition of the propellant.
  - Variations in the arrangement of the powder grains contained inside the propellant increment.
  - Variations in the ramming of the projectile.
  - Variations in the temperature of the bore from round to round.

  For example, variations in the bourrelet and rotating band may cause inaccurate centering of the projectile, which can result in a loss in achieved range because of instability in flight.
- **Conditions in the carriage**. Deflection and elevation are affected by the following:
  - Play (looseness) in the mechanisms of the carriage.
  - Physical limitations of precision in setting values of deflection and quadrant elevation on the respective scales.
  - Non-uniform reactions to firing stress.
- **Conditions during flight**. The flight of the projectile may be affected by the difference in air resistance created by variations in the weight, achieved muzzle velocity, and projectile. Also, the projectile may be affected by variations in wind, air density or air pressure, and air temperature from round to round.

3-66. The distribution of bursts (dispersion pattern) in a given sample of rounds is roughly elliptical (Figure 3-11) with the long axis parallel to the line of fire.

3-67. A rectangle constructed around the dispersion area containing all usable rounds is called the dispersion rectangle. (See figure 3-11 on page 3-16.)

Note: 0.7% of rounds fired are erratic and do not impact within 4 probable errors in range (PE_R). The seven erratic rounds will impact within 5.8 $PE_{R.}$

MEAN POINT OF IMPACT

3-68. For any large number of rounds fired, the average (or mean) location of impact can be determined by drawing a diagram of the pattern of bursts as they appear on the ground. A line drawn perpendicular to the line of fire can be used to divide the sample rounds into two equal groups. Therefore, half of the rounds will be over this line when considered in relation to the weapon. The other half of the rounds will be short of this line in relation to the weapon. This dividing line represents the mean range of the sample and is called the mean range line. A second line can be drawn parallel to the line of fire, again dividing the sample into two equal groups. Half of the rounds will be to the right of this line, and half will be to the left. This line represents the mean deflection of the sample and is called the mean deflection line. (See figure 3-11.) The intersection of the two lines is the mean point of impact (MPI).

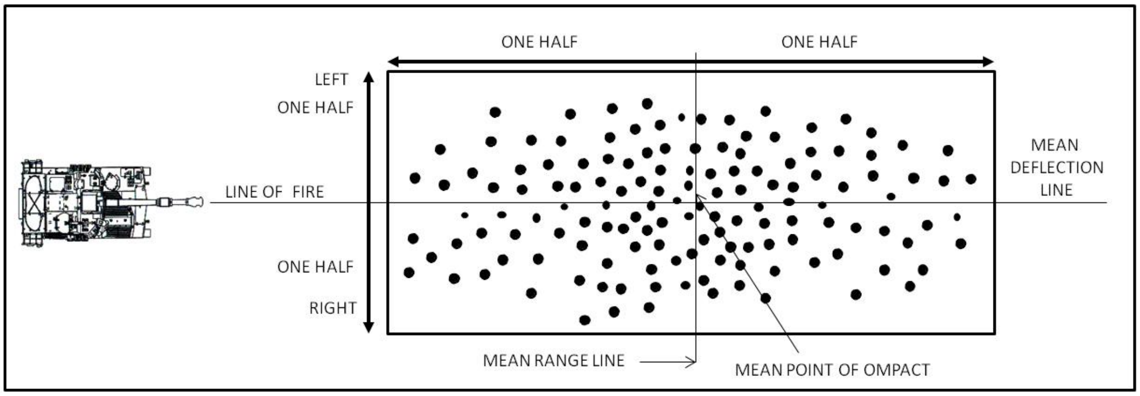
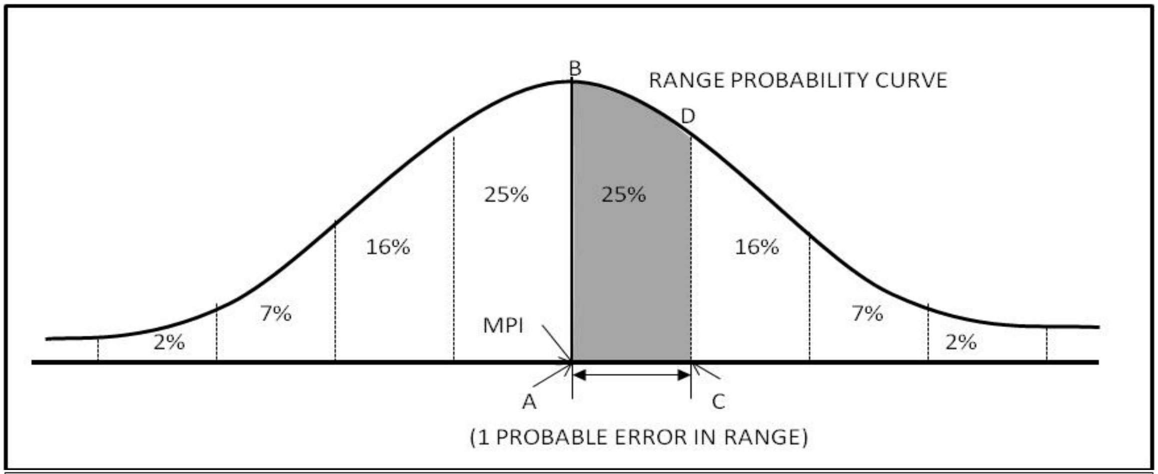


Figure 3-11. Dispersion Rectangle.

PROBABLE ERROR

3-69. ***Probable error* is nothing more than an error that is exceeded as often as it is not exceeded**. For example, in figure 3-12 (on page 3-17), consider only those rounds that have impacted over the mean range line (line AB). These rounds all manifest errors in range, since they all impacted over the mean range line. Some of the rounds are more in error than others. At a point beyond the MPI, a second line can be drawn perpendicular to the line of fire to divide the "overs" into two equal groups (line CD, figure 3-12). When the distance from the MPI to line CD is used as a measure of probable error, it is obvious that half of the overs show greater magnitude of error than the other half. This distance is one probable error in range. The range probability curve expresses the following:

- In a large number of samples, errors in excess and errors in deficiency are equally frequent (probable) as shown by the symmetry of the curve.
- The errors are not uniformly distributed. Small errors occur more frequently than large errors as shown by the greater number of occurrences near the mean point of impact.



Legend: MPI – MEAN POINT OF IMPACT

Figure 3-12. Probable Errors.

DISPERSION ZONES

3-70. If the dispersion rectangle is divided evenly into eight zones in range with the value for 1 probable error in range (PE_R) used as the unit of measure, the percentage of rounds impacting within each zone is as indicated in figure 3-13. The percentage of rounds impacting within each zone has been determined through experimentation. By definition of probable error, 50 percent of all rounds will impact within 1 probable error in range or deflection of the mean point of impact (25 percent over and 25 percent short or 25 percent left and 25 percent right).

	.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 3-13. Dispersion Zones.

RANGE PROBABLE ERROR

3-71. The values for range probable error at various ranges are given in Table G of the tabular firing tables (TFT). These values may be used as an index of the precision of the piece at a particular charge and range. The values for range probable error are listed in meters. Firing Table (FT) values have been determined on the basis of actual firing of ammunition under controlled conditions. For example, FT 155-AM-3 shows that the value of range probable error for charge 4H M232A1 at a range of 6,000 meters is 15 meters. On the basis of the dispersion rectangle, 50 percent of the rounds will impact within 15 meters (over and short) of the mean range line, 82 percent will impact within 30 meters (over and short), 96 percent will impact within 45-meters (over and short), and 100 percent of usable rounds will impact within 60 meters.

FORK

3-72. The term ***fork* is used to express the change in elevation (in mils) needed to move the mean point of impact 4 probable errors in range**. The values of fork are listed in Table F of the firing tables. For example, FT 155-AM-3 shows that the value of fork for a howitzer firing charge 4H M232A1 at a range of 6,000 meters is 1 mil. On the basis of the value for probable error in range (paragraph 3-72), adding 1 mil to the quadrant elevation would cause the MPI to move 60 meters. This is based off of the previous argument where we determined 1 PE_R for 4H M232A1 at range 6,000 meters to be 15 meters. Fork is used in the computation of safety data.

DEFLECTION PROBABLE ERROR

3-73. The values for probable error in deflection (PE_D) are listed in Table G of the firing tables. For artillery cannons, the deflection probable error is considerably smaller than the range probable error. Values for PE_D are listed in meters. With the same parameters as those used in paragraph 3-72, the deflection probable error is 3 meters. Therefore, 50 percent of the rounds will impact within 3 meters of the mean deflection line (left and right); 82 percent, within 6 meters (left and right); 96 percent, within 9 meters (left and right); and 100 percent, within 12 meters.

TIME-TO-BURST PROBABLE ERROR

3-74. The values of time-to-burst probable error (PE_{TB}) (Figure 3-15) are listed in Table G of the firing tables. Each of these values is the weighted average of the precision of a time fuze timing mechanism in relation to the actual time of flight of the projectile. For example, if a 155-millimeter (mm) howitzer fires charge 4H M231A1 at a range of 6,000 meters, the value for probable error in time to burst is 0.04 second. As in any other dispersion pattern, 50 percent of the rounds will function within 0.04 second; 82 percent, within 0.08 second; 96 percent, within 0.12 second; and 100 percent within 0.16 second of the mean fuze setting.

HEIGHT-OF-BURST PROBABLE ERROR

3-75. With the projectile fuzed to burst in the air, the height-of-burst probable error (PE_{HB}) (Figure 3-15) is the vertical component of 1 time-to-burst probable error. The height-of-burst probable error reflects the combined effects of dispersion caused by variations in the functioning of the time fuze and dispersion caused by the conditions described in paragraph 3-78 The values listed (in meters) follow the same pattern of distribution as for those discussed for range dispersion. These values are listed in Table G of the firing table.

RANGE-TO-BURST PROBABLE ERROR

3-76. Range-to-burst probable error (PE_{RB}; figure 3-14 on page 3-19) is the horizontal component of 1 time-to-burst probable error. When this value is added to or subtracted from the expected range to burst, it will produce an interval along the line of fire that should contain 50 percent of the rounds fired. These values are listed in Table G of the firing tables.

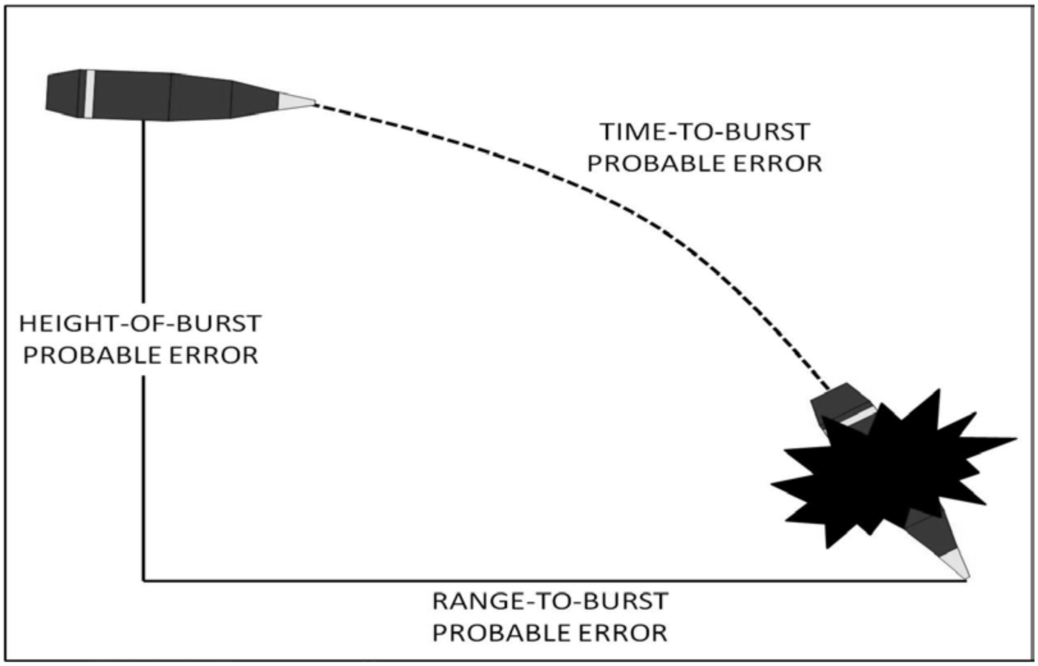


Figure 3-14. Comparison of PE_{HB}, PE_{RB}, and PE_{TB}.

SECTION IV: TERMINAL BALLISTICS

3-77. ***Terminal ballistics* may be defined as the study of the effects of projectiles on a target**. The theory of terminal ballistics is relatively new compared to the theory of internal and external ballistics. The techniques of investigation for impact on solid targets consist primarily of empirical relations (based on experiments), analytical models, and computer simulations. In terminal ballistics, we are dealing with the shock caused by the detonation of the high-explosive (HE) filler. The effects are most pronounced if the shell penetrates the surface of a target before detonation.

TARGET ANALYSIS AND MUNITION EFFECTS (WEAPONEERING)

3-78. Target analysis is the examination and evaluation of an enemy target situation to determine the most suitable weapon, ammunition, and method required to defeat, neutralize, or otherwise disrupt, delay, or limit the enemy. Not only does target analysis involve determining the amount and type of ammunition required to inflict a given damage (or casualty) level on a particular target, it also involves a continuous process of consultation and cooperation between the commander and the FDO. In Joint doctrine this is referred as weaponeering. ***Weaponeering* can be defined as the process of determining the quantity of a specific type of weapon required to achieve a specific level of target damage; considering factors such as target vulnerability, weapon effects, munitions delivery accuracy, desired effect, probability of kill (PK), weapon reliability, etc (61 JTCG/ME-88-7).**

TARGET ANALYSIS

3-79. The amount of time devoted to target analysis and the thoroughness of the analysis depends on the following:

- Amount of target information.
- Weapons and ammunition available to attack the target.
- Urgency of the engagement.

DETERMINING THE PRECEDENCE OF ATTACK

3-80. When an FDO receives a fire mission, his options include the following (see figure 3-15 for determining the precedence of attack):

- Attack the target immediately.
- Defer attacking the target until an existing fire mission is complete.
- Pass the fire mission to another FDC.
- Request reinforcing fires.
- Deny the mission.

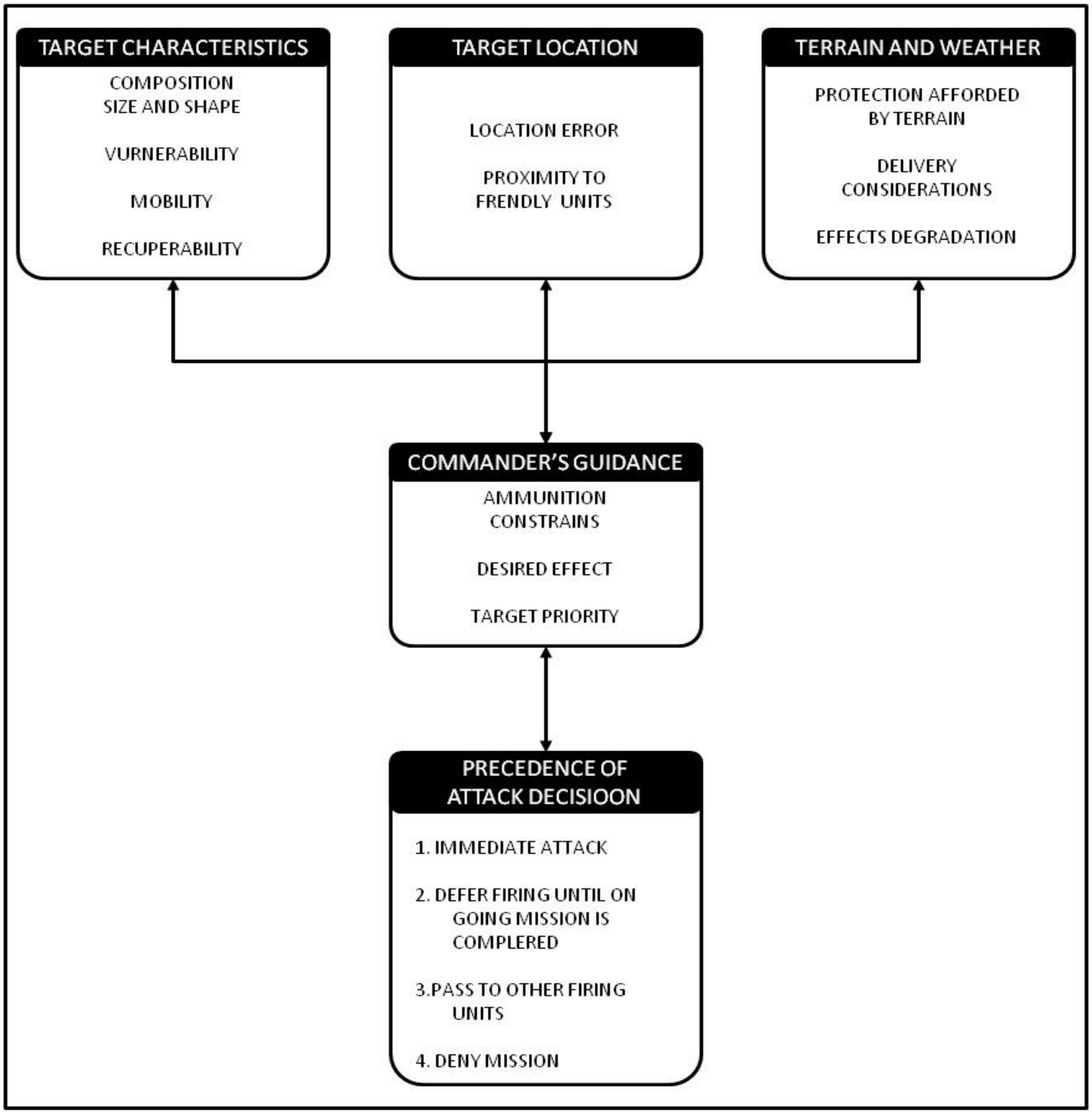


Figure 3-15. Determining the Precedence of Attack.

3-81. An FDO selects a particular precedence of attack after considering the following:

- Call for fire.
- Terrain.

- Target location.
- Weather.
- Target characteristics.
- Units available.
- Commander's criteria.
- Availability of corrections.
- Munitions effects.
- Enemy target acquisition.
- Commander's intent.
- Ammunition availability.

COMMANDER'S GUIDANCE.

3-82. **Commander's Guidance**. All phases of target analysis are conducted within constraints established by the commander. In determining the precedence for attacking a target, primary consideration is given to the commander's target priorities.

- **Attack guidance matrix**. The commander's target priorities are organized into an attack guidance matrix that lists the type of target, when to attack, degree of destruction, and any restrictions. Figure 3-16 is an example of a commander's attack guidance matrix. The following example explains how it would be used.

EXAMPLE

Your FDC received a call for fire, and the target description was an ammunition dump. While processing this mission. You received another call for fire requesting fires on an infantry platoon. Referring to the attack guidance matrix, you determine that the infantry platoon is a higher priority. In this case, you process this mission first. Upon completion of this mission, you would fire on the ammunition dump.

CATEGORY	***HIGH PAYOFF***	***WHEN***	***HOW***	***RESTRICTIONS***
1(C^3)	25,29,30,34	I	N/EW	Coordinate attack with EW
2 (FS)	1,2,5,18	I	N	Plan all calibers greater than 122mm
3(MAN)	46,48,50,51	I	10%	
4(ADA)	63,64	A	N	
5(ENGR)	69,70	P	N	Not high-payoff target
6(RSTA)	14,16,17,84,85,107	A	D	Not high-payoff target
7(REC)	91,92	A	S/EW	Coordinate attack with EW
8(N/NH)	77,79	P	D	Forward targets to division
9(POL)	115,116	A	D	
10(AMMO)	120,121	A	N	
11(MAINT)		A	S	
12(LIFT)		A	S	
13(LOG)	118	A	N	Not high-payoff target

LEGEND:
A= as acquired; ADA= Air defense artillery; C^3= Command, control, and communications; D= Destroy; engr= engineer; FS= fire support
I= immediate; log= logistics; man= maneuver; N= neutralized
N= Neutralized; REC= radio electronic combat; RSTA= reconnaissance, surveillance and target acquisition; S= suppress

Figure 3-16. Attack Guidance Matrix Example.

Note: For a more detailed discussion on the attack guidance matrix, see ATP 3-09.42.

- **Target effects categories**. On the basis of ammunition constraints, a commander also specifies the type of effects he desires against specific target categories. The three target effects categories are as follows:
- **Destruction**. Destruction puts the target out of action permanently. 30 percent casualties or materiel damage inflicted during a short time span normally renders a unit permanently ineffective. Direct hits are required to destroy hard materiel targets. Targets must be located by accurate map inspection, indirect fire adjustment, or a TA device. Destruction usually requires a large amount of ammunition from many units.
- **Neutralization**. Neutralization of a target knocks the target out of the battle temporarily. Casualties of 10 percent or more neutralize a unit. The unit is effective again when the casualties are replaced and/or damage is repaired. Neutralization fires are delivered against targets located by accurate map inspection, indirect fire adjustment, or a TA device. The assets required to neutralize a target vary according to the type and size of the target and the weapon-ammunition combination.
- **Suppression**. Suppression of a target limits the ability of enemy personnel to perform their mission. Firing HE, variable time (VT) fuze reduces the combat effectiveness of personnel and armored targets by creating apprehension and surprise and by causing tracked vehicles to button up. Smoke is used to blind or confuse. The effect of suppressive fires usually lasts only as long as the fires are continued. This type of fire is used against likely, suspected, or inaccurately located enemy units where time is essential. It can be delivered by small delivery units or means and requires little ammunition.

TARGET CHARACTERISTICS.

3-83. Targets encountered on the battlefield vary considerably in composition, degree of protection, shape, mobility, and recuperability. For simplicity, targets are divided into four categories (table 3-1) to compare the effectiveness of particular weapons and rounds. Examples are listed for each category. Under certain conditions, some examples could be listed in more than one category. For example, a motorized rifle battalion could be listed under the first category and the fourth category.

Table 3-1. Categories of Targets.

CATEGORY	***EXAMPLE***
Area (Personnel)	Squad Platoon Battery/Company
Small (Personnel)	Observation post Small Patrol Command Post
Small (Material) (Point)	Tank Armored personnel carrier Bunker, machine gun
Area(Materiel)	Armored formation Truck park Ammunition Dump

3-84. For personnel targets in particular, the posture of the target is extremely important. Normally, target postures used for personnel targets are standing, prone, and in fighting positions. For computation, it is assumed that the personnel are wearing helmets and that personnel in fighting positions are in a crouching position. In describing posture of a target, consider the protection afforded by the terrain. For example, an infantry platoon may be attacking in a standing posture. However, irregular terrain may provide protection equivalent to the prone position. Usually, personnel targets seek a more protective posture during an engagement; for example, from a standing to a prone position. This change is called posture sequencing. Posture sequencing causes considerable degradation of effects as additional volleys are fired and is the reason for the continual emphasis on surprise or mass fires. For the purposes of analysis, personnel targets in the offense are considered to be one-half standing and one-half prone during the first volley of fire and all prone for subsequent volleys. In a defensive configuration, personnel targets are considered to be one-half prone and one-half in fighting positions during the initial volley and all in fighting positions for subsequent volleys.

3-85. A target must be analyzed to determine its weak points. Where the target is most vulnerable and what fires will best exploit its weaknesses are influenced by the degree of damage desired. Often there is a tendency to overkill the target when less combat power would suffice. On the basis of the commander's Guidance criteria, the FDO must ascertain the degree of effects needed (destruction, neutralization, suppression) to support the tactical plan. The acceptable degree of damage is the level that yields a significant military advantage. For example, fire from a heavily protected machine-gun emplacement may be silenced by obscuration through smoke and subsequent engagement by direct fire as opposed to the expenditure of a large number of HE rounds required for its destruction.

- **Target location**. The FDO must check the target location relative to friendly forces, fire support coordinating measures, zones of fire, and registration transfer limits. Target location accuracy is also considered. The range affects the choice of units to fire and charge selection. The terrain around the target may influence ammo selection or type of trajectory. High intervening crests may require selection of a lower charge or high angle.
- **Target characteristics**. The size of the target affects the number of units to fire, the type of sheaf, the selection of ammo, and the number of rounds in the fire for effect. The type of target (troops, vehicles, hard, soft) influences the ammo type and amount, the priority placed on the mission, and whether surprise fire (for example, time on target) is possible.
- **Ammo availability**. The FDO must consider the amount and type of ammunition available and the controlled supply rate.
- **Units available**. The number of units available not only affects which units are used, but also the type of attack. Sweep and/or zone fire or other techniques may be needed to cover large targets when enough units are not available.
- **Commander's Guidance or commander's intent**. Restrictions on ammo, operations order (OPORD), and SOPs may govern the selection of units and ammunition, target priority, and method of attack.
- **Call for fire**. The FDO must consider the observer's request carefully since he is observing the target and talks directly to the maneuver commander. The observer's requests honored when possible. The call for fire will also include information on the target activity (for example, attacking, defending, and digging in).
- **Munitions effects**. The FDO most often relies on the Commander Guidance or experience.
- **Availability of corrections**. The availability of corrections to firing data for non-standard conditions is a guiding factor in the choice of charge and munitions, since it directly affects the ability to provide accurate first round fire for effect.
- **Enemy target acquisition** capability. Knowledge of the current enemy counter-battery radar and sound ranging capabilities allows the FDO to attack the target in a manner most likely to evade detection.
- **Terrain**. The terrain in the target area has a direct effect on the vulnerability of the target. Rugged terrain affords considerable natural cover and makes target location difficult. Certain terrain provides complete protection from some angles of approach but not others and thus influences the unit and munitions to be employed. The nature of the vegetation in the target area should be considered when selecting ammunition.
- **Weathe**r. Weather is of little consequence in evaluating a target to attack with fuze quick or time. However, precipitation and wind are of particular importance in evaluating a target to attack with improved conventional munitions (ICM), smoke, family of scatterable mines (FASCAM), or illumination projectiles. Low clouds, thick fog, surface water, and rain degrade the effectiveness of VT fuze.

DETERMINING MOST SUITABLE WEAPON AND AMMUNITION

3-86. When an FDO decides to attack a target, he selects a weapon-ammunition combination that achieves the desired effect with a minimum expenditure of available ammo. Figure 3-17 depicts weapon-ammunition selection.

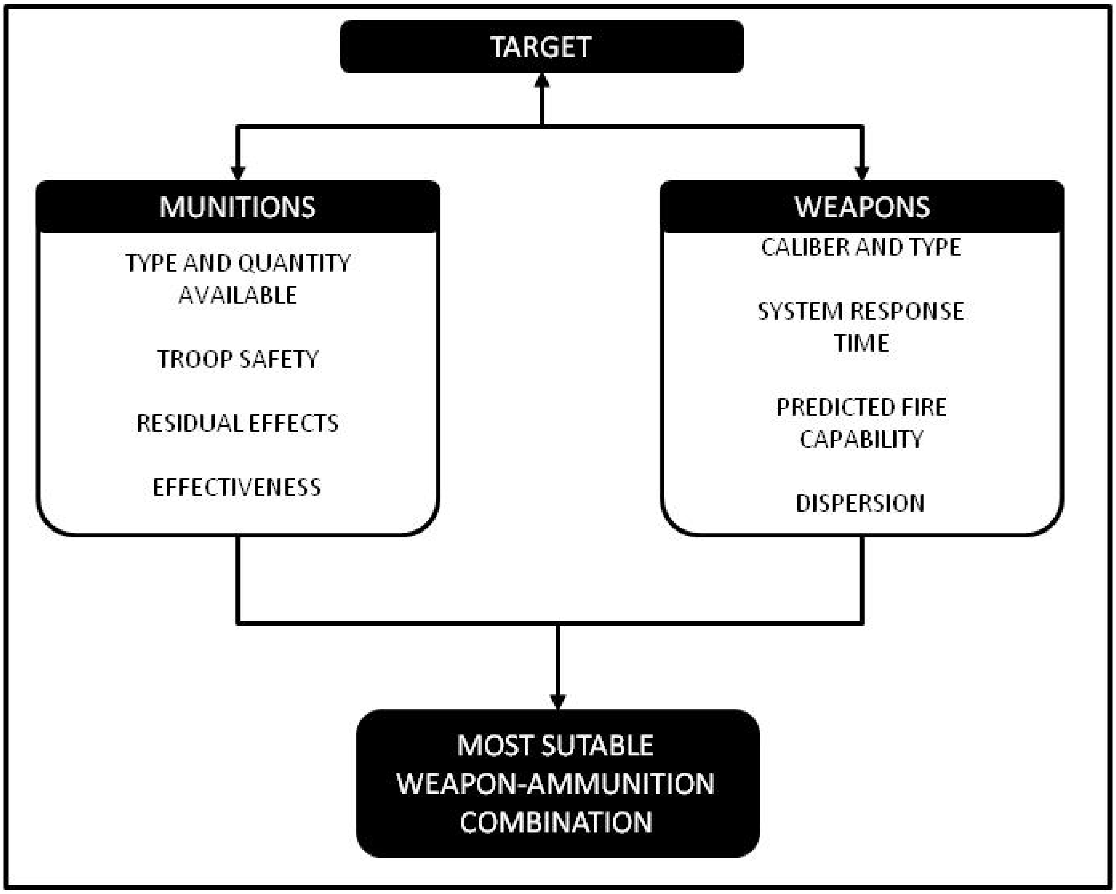


Figure 3-17. Weapon-Ammunition Selection.

MUNITIONS.

3-87. **Type and quantity available**. The nature of the target, its surroundings, and the desired effects dictate the type and amount of ammo to use. For a detailed discussion of ammo and fuzes, refer to Technical Manual (TM) 43-0001-28. The ammo resupply system sometimes rules out the best ammo selection. For example, extensive smoke fires may be needed to screen maneuver movement, but such fires may cause a resupply problem. Some fires require more ammo than others. Suppression and neutralization fires normally use less ammo than destruction fires. ***Destruction fire*** **is 1. An element of the method of engagement portion of the call for fire requesting destruction fire. 2. Fire delivered for the sole purpose of destroying materiel.**

3-88. **Troop safety**. Troop safety is a major concern in considering the weapon-ammunition selection for firing close-in targets. The FDO must ensure that fires do not endanger friendly troops, equipment, and facilities.

3-89. **Residual effects in target area**. The supported unit must be advised of the residual effects from certain munitions. For example, the self-destruct times from FASCAM munitions may preclude the desired movement of supported units through a particular area. Weather changes may alter choices of certain munitions (smoke, illumination, and white phosphorous). The incendiary effects of certain munitions may make areas untenable for supported forces. However, these effects can also deny the enemy use of selected terrain.

3-90. **Effectiveness**. When properly delivered against appropriate targets, artillery fire support can be the decisive factor in a battle. The FDO must ensure that the desired result is attained from every mission. To match a munitions to a target, the FDO must know what damage a munitions can produce and the damage required to defeat the target. The lethality of munitions must be matched to the specific vulnerability of the target. Thus, the FDO must understand the damage potential (blast, cratering, fragmentation, incendiary, and penetration) of specific munitions. Specific information regarding the effects of various munitions is found in the appropriate Joint Munitions Effectiveness Manual/Air-to-Surface (JMEM/AS) WEAPONEERING GUIDE 61 Joint Technical Coordination Group/Munitions Effectiveness (JTCG/ME) 88-7.

WEAPONS.

3-91. **Caliber and type available**. In certain instances, an FDO may control the fires of reinforcing (R) or general support reinforcing (GSR) units that fire a different caliber. The FDO must have a thorough knowledge of the characteristics, capabilities, and vulnerabilities of each weapon system. Weapons with slow rates of fire and poor delivery accuracy are best suited for long-range fires. Weapons with rapid rates of fire and good delivery accuracy are suited for close fires.

3-92. **System response time**. An FDO must ascertain the urgency of each fire mission. **A *fire mission* is 1. The specific assignment given to a fire unit as part of a definite plan. 2. An order used to alert the weapon/battery area and indicate that the message following is a call for fire.** Small and medium weapons have a quicker firing response time than heavy weapons. Fire missions transmitted by the brigade combat team's field artillery battalion to reinforcing or GSR units require more processing time than those transmitted directly to the firing batteries of the battalion.

3-93. **Predicted fire capability**. The FDO must know the current survey, registration, and met status of all firing units under his control. FFE missions should be assigned to units that have the best predicted fire capability.

DETERMINING THE METHOD OF ATTACK

3-94. The final step in the FDO's target analysis is the selection of a method of attack. The FDO selects a method of attack that ensures target area coverage and desired target effects. To determine the best method of attack, the FDO must consider aim-points, density, and duration of fire; Figure 3-18 shows the method-of-attack selection considerations.

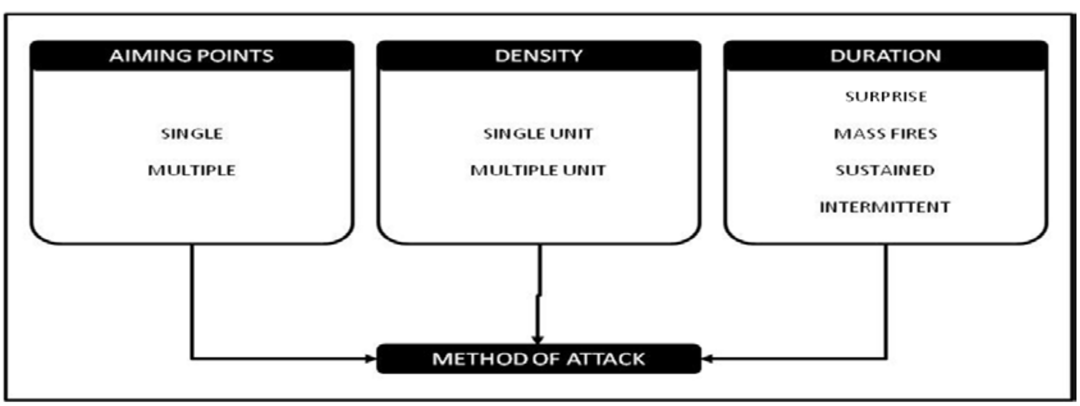


Figure 3-18. Considerations in Selecting a Method of Attack.

3-95. To determine the best method of attack, the FDO must consider:

- **Aim-points**. Normally, the size of the area to be attacked depends on the size of the target or the size of the area in which the target location is known or suspected. A single aiming point in the center of the target is used to attack small targets. For attacking large targets, multiple aim-points are designated to distribute the fires and ensure adequate coverage. Appendix G gives procedures for establishing multiple aim-points.

- **Density**. For most targets, uniform density of fires is needed. Several techniques for indirect fire weapons produce such results. These include zone and sweep fires either from a single unit or simultaneous attack by multiple units on different portions of the target.
- **Duration**. Accurate surprise fires produce the most effective results. Time on target procedures place initial rounds from all units on the target at the same time and achieve the greatest surprise. While intense fires of short duration generally produce the best results, the tactical situation may require that fires be continued over a longer period of time. Some examples are harassing and interdiction fires, screening smoke, continuous illumination, and suppressive fires supporting a maneuver final assault on an objective.

PREDICTING WEAPONS AND MUNITIONS EFFECTS

3-96. The most important step in performing target analysis (weaponeering) is determining the number and type of rounds required to produce the desired effects on a target. The time available to perform the target analysis largely determines the tools used to predict effects. An analyst at the division fire support level can use the JMEM/AS for guidance while the FDO at battalion or battery level, because of time constraints, can use the Commander Guidance.

JOINT MUNITIONS EFFECTIVENESS MANUALS WEAPONEERING SYSTEM (JWS)

3-97. **Overview**. Joint Munitions Effectiveness Manuals Weaponeering System (JWS) is a complete guide to conventional weaponeering. Its purpose is to provide all essential references to produce weapons effectiveness for conventional weapons. The JWS product contains the information from many of the JTCG/AS JMEMs and Special Reports in a content-based, hyperlink configuration. Many of the JMEM/AS manuals are no longer being published separately. Users are directed to the JWS product. Also included are the databases and applications needed to look up or produce weapons effects estimates. The information on the following topics and weaponeering applications are included on the JWS product.

3-98. **Characteristics**. For detailed characteristics of various types of inventory nonnuclear weapons, see Weapons of JWS. Data are presented for general-purpose (GP) bombs, clusters, guns and rockets, fire and incendiary bombs, and special-purpose weapons, as well as, weapon fuzes.

3-99. **Included Data**. Data include a description of the weapon or warhead; carriage and suspension data; detailed information on warhead fragmentation, to include number of fragments, mass, and velocity for polar zones 0 to 180 degrees (0 degrees represents the nose of the warhead); explosive type and weight; and line drawings of the weapon showing length, diameter, and center of gravity. A detailed explanation of fragmentation and blast phenomena is provided in “General-Purpose (GP) Munitions” in Weapons of JWS.

3-100. **Compatibility and Reliability**. Weapon fuzing reliability and compatibility data are given for all combinations of inventory items. Programs with available data are provided below.

QUICK REFERENCE TABLES

3-101. If JMEMs are not available, the FDO can use the guide for cannon attack of typical targets (table 3-2 on page 3-27). The table lists selected personnel and materiel targets and indicates the order of effectiveness for each shell-fuze combination. Targets not indicted should be equated to targets that are listed. The table can be used for all calibers.

Table 3-2. Guide for Cannon Attack of Typical Targets.

TARGET TYPE	OBSERVATION	WEAPONS	PROJECTILE	HE FUZE	RESULT DESIRED	REMARKS
PERSONNEL						
In Open or In fighting position without overhead cover	Observed and/or unobserved	All	HE	Proximity (VT), Time	Destruction	Massing is required. [1] TOT missions are most effective. First volley is most effective.
		All	HE	Proximity (VT), Time	Neutralization	Massing required except for small targets.
		All	HE	Quick, proximity Time	Suppression	Response time is critical against active targets. Preferred fuze is proximity
		All	APICM	M577	Destruction	Massing is required on large target. TOT missions are most effective.
		All	APICM		Neutralization	Cannon battery volleys are sufficient.
In Fighting position with overhead cover	Observed	All	HE	Quick/delay (ricochet)	Neutralization	Massing is required. TOT mission are most effective. Consider use of WP to drive personnel out of fighting positions.
		All	HE	Proximity, Time, delay, quick	Suppression	Response time is critical against active targets. Proximity fuze is proffered. Consider use of smoke for obscuration.
		All	APICM	M577	Neutralization	Massing is required. TOT mission are most effective.
		All	APICM	M577	Suppression	Consider use of ICM on intermittent basis for increased effectiveness.
In dugouts or caves	Observed	All (preferably 155mm or larger)	HE	Delay/quick	Destruction	Use direct fire or assault techniques. Fire HE quick at intervals to clear away camouflage, earth cover, and rubble
Attacking battery position	Observed	105mm ALL	Beehive HE APICM	Time	Destruction	Set fuze to detonated on the ascending branch of the trajectory for close in defense of battery area
VEHICLES[2]						
Tanks	Observed	All	HE	Proximity, Time	Suppression	Fire projectile HE to force tanks to button up and personnel outside to take cover or disperse. WP may blind vehicles drivers, and fires maybe started from incendiary effect on outside fuel tank. WP or fires may obscure adjustment. DPICM is preferred munitions for unobserved fire.
	Observed and/or unobserved	155mm	DPICM	M577	Suppression	
	Observed	155mm	FASCAM	M577	N/A	Both anti-tank and anti-personnel projectiles should be used.
	Observed	155mm	Copperhead	N/A	Destruction	
	Direct Fire	105mm	HEP, HEP-T, HEAT	N/A	Destruction	
Armored Personnel Carriers	Observed	All	HE	Proximity, Time	Suppression	Force vehicles to button up and personnel outside to take cover or disperse
	Observed and/or unobserved	155 mm	APICM DPICM	M577	Neutralization	

Table 3-2. Guide for Cannon Attack of Typical Targets (continued).

TARGET TYPE	*OBSERVATION*	*WEAPONS*	*PROJECTILE*	*HE FUZE*	*RESULT DESIRED*	*REMARKS*
		155mm	FASCAM	M577	N/A	See remarks for Tanks.
	Observed	155mm	Copperhead	N/A	Destruction	
Trucks	Observed and/or unobserved	All	HE	Proximity, Time	Destruction	ICM is preferred munitions
		155 mm	DPICM	M577	Destruction	
WEAPONS						
Anti-tank missile	Observed	All	HE	Quick	Suppression	Response time is critical. Intermittent fire may be required. Change to fuze proximity or DPICM for materiel damage if anti-tank guided missile platform on BRDM is raised.
AIR DEFENSE						
ZSU-23-4, SA6	Observed and/or unobserved	All	HE	Proximity	Firepower kill	Smoke may also be used to obscure gunner's line of sight to friendly aircraft. ICM is preferred munition. Consider converge sheaf if weapon is point target and accurately located
		155mm	DPICM	M577	Firepower kill	
SA8,9	Observed	All	HE	Quick	Suppression	Response time is critical. Intermittent fire may be required.
		All	HE	Quick	Firepower kill	See above
Towed FA, Mortars, multiple rocket launcher	Unobserved	All	HE, WP	Proximity, Time	Firepower kill	WP is used to ignite materiel. See personnel targets for result desired.
		All	APICM	M577		See personnel targets section for result desired. TOT mission are most effective. Massing is usually required.
		155mm	FASCAM	M577	N/A	USE ADAM projectile in conjunction with HE or ICM for sustained effects.
Self-propelled FA battery	Unobserved	All	HE, WP	Proximity, Time	Suppression	WP is used to ignite materiel
		155 mm	DPICM	M577	Suppression	ICM is preferred munition.
		155mm	FASCAM	M577	N/A	Use ADAM projectile in conjunction with HE or ICM for sustained effects.
Surface to surface missile	Unobserved	155 mm	HE	Proximity, Time	Firepower kill	Use converge sheaf if time and target location accuracy permit. TLE in excess of 200 meters requires massing of fires. ICM is preferred munition.
			DPICM	M577	Firepower kill	
MISCELLANEOUS						
Radar	Unobserved	All	HE	Quick, time, proximity	Firepower kill	Use converged sheaf if time and target location accuracy permit. TLE in excess of 200 meters requires massing of fires. ICM is preferred munition.
		155mm	DPICM	M577		
Artillery command and observation post	Observed	All	HE	Quick	Suppression	Intermittent fire may be required. HE is preferred munition when response time is critical.
		155mm	DPICM	M577		
Command post	Unobserved	All	HE	Proximity, Time	Neutralization or destruction	Use ADAM for sustained effects. When target contains personnel and flight materiel targets, DPICM is preferred munition.
		155mm	DPICM	M577	N/A	

Table 3-2. Guide for Cannon Attack of Typical Targets (continued).

TARGET TYPE	*OBSERVATION*	*WEAPONS*	*PROJECTILE*	*HE FUZE*	*RESULT DESIRED*	*REMARKS*
Supply Installation	Unobserved	All	HE, WP	Quick	Fires	Large target location errors require massing to ensure target converge.
Boats	Observed	All	HE	Time	Suppression	Attack as moving personnel target
Bridge	Observed and/or unobserved	All (preferably 155mm)	HE	Quick, concrete piercing, delay	Destruction	Direction of fire preferably with long axis of the bridge. Destruction of permanent bridges is best accomplished by knocking out bridge support. Use fuze quick for wooden or pontoon bridges.
	Observed	155mm	Copperhead	N/A		
Fortifications	Observed	All (preferably 155mm)	HE	Quick, concrete piercing, delay	Destruction	Use highest practical charge in assault and direct fire.
		155mm	Copperhead	N/A		

[1]Target, regardless of the type, with an estimated target radius greater than 150 meters usually require massing for effective attack.

[2]The first objective of firing on moving vehicles is to stop the movement. For purpose, a deep bracket is established so that the target will not move out of the initial bracket during adjustment. Speed on 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 arrived at that point when a vehicle is passing it. A firing unit, if available, may fire at different points on the road simultaneously.

Legend:
ADAM – Area Denial Artillery Munition
APICM – Anti-personnel Improved Conventional Munition
DPICM – Dual Purpose Improved Conventional Munition
FA – field artillery
FASCAM – Family of Scatterable Mines
HE – High Explosive
HEAT – High Explosive Anti-tank
HEP – High Explosive Plastic
HEP-T – High Explosive Plastic – Tracer
ICM – Improved Conventional Munition
MM - millimeter
TLE – Target Location Error
TOT – Time on Target
VT – Variable Time
WP – White Phosphorous

3-102. The expected area of coverage table (table 3-3) can be used to determine the appropriate size of a battery one volley or battalion one volley of both HE and ICM for the various caliber weapon systems. The FDO can use table 3-3 to determine the size target that can be attacked by use of battery or battalion volleys. The density of coverage is not considered, but the density of coverage of ICM is much greater than that of HE.

Table 3-3. Expected Area of Coverage (Meters).

Munitions	*105mm*	*155mm*
APICM (Anti-personnel Improved Conventional Munition)	Battery 1 Round Battalion 1 Round	Battery 1 Round Battalion 1 Round
Square	250 x 250 380 x 380	266 x 266 390 x 390
Circle (radius)	140 215	150 220
High Explosive	Battery 1 Round Battalion 1 Round	Battery 1 Round Battalion 1 Round
Square	248 x 248 380 x 380	275 x 275 390 x 390
Circle (radius)	140 215	155 220

3-103. The expected fraction of casualties or personnel table (table 3-4) can be used to determine the optimum method of attacking a personnel target of 50 meters radius to achieve the commander's criteria. Table 3-4 cannot be used for material targets.

Table 3-4. Expected Percentage of Casualties or Personnel.

PROJECTILE	IF TARGET RADIUS IS 50 METERS, THEN			
		APICM	HE/VT	HE/PD
105mm	Battery 1 Round Battalion 1 Round	07 20	07 20	04 12
155mm	Battery 1 Round Battalion 1 Round	15 35	05 16	03 11
Legend: APICM – Anti-personnel Improved Conventional Munition HE – High Explosive mm - millimeter PD – Point Detonating VT – Variable Time				

MUNITIONS EFFECTS

3-104. The various munitions effects are described below, by munition type. Considerations include howitzer availability and fuze combinations.

HIGH EXPLOSIVE (HE).

3-105. **High Explosive**. The use of the HE with its many different fuze combinations (point-detonating [PD]-Super-quick or Delay, Time, or variable time [VT]) is very effective against personnel targets except when they have a high degree of protection. The HE projectile is available for the 105-mm and 155-mm howitzers.

HIGH EXPLOSIVE ROCKET-ASSISTED PROJECTILES (HERA)

3-106. **HERA Projectile**. This projectile has two distinct advantages over normal HE--increased range and fragmentation. The rocket-assisted projectile (RAP) round is primarily used against antipersonnel and material targets at increased ranges. The RAP round is available for the 105-mm and 155-mm howitzers. They are designed to extend the range of the howitzers. The basic rocket-assisted projectiles are filled with HE material. They produce blast and fragmentation in the target area. Computation procedures for all basic HE RAPs are identical. Firing tables may be available for both the rocket on and rocket off mode, depending on the projectile.

SMOKE

3-107. **Smoke**. There are four different types of smoke in our inventory: Hexachloroethane (HC) smoke, colored smoke, white phosphorus, and M825/M825A smoke. The three types of smoke projectiles area as follows:

- **Hexachloroethane** (HC) smoke projectiles are available for 105-mm and 155-mm howitzers. They are used for screening, obscuration, spotting, and signaling purposes. The projectile has no casualty-producing effects. This base-ejection projectile is ballistically similar to the M107 family of projectile. It is fitted with a base ejecting time fuze. The round expels smoke canisters that emit smoke for a period of 40 to 90seconds.
- **Burster-type white phosphorus**. White phosphorus projectiles are available for 105-mm and 155-mm howitzers. They are bursting-tube type projectiles that can be fired with point-detonating (PD) or bursting time fuzes. The projectile has an incendiary-producing effect and is ballistically similar to the HE (105mm) or M107 (155mm) family of projectile. Normally, shell white phosphorous (WP) is employed for its incendiary effect. The projectile also can be used for screening, spotting, and signaling purposes.
- **M825/A1 white phosphorus**. The M825/A1 WP projectile is an FA-delivered 155-mm base-ejection projectile designed to produce a smoke screen on the ground for duration of 5 to15

minutes. It consists of two major components--the projectile carrier and the payload. The projectile carrier delivers the payload to the target. The payload consists of 116 WP-saturated felt wedges. The smoke screen is produced when a predetermined fuze action causes ejection of the payload from the projectile. After ejection, the WP-saturated felt wedges in the payload fall to the ground in an elliptical pattern. Each wedge then becomes a point or source of smoke. The M825/A1 is ballistically similar to the M795 family of projectiles.

ILLUMINATION

3-108. **Visible light (VL) Illumination**. The illumination projectile is primarily used for night attack or defense, as a ground marking round for a particular target, and for harassment. The illumination projectile is available for the 105-mm and 155-mm howitzers.

3-109. **Infrared (IR) illumination** provides illumination that is visible through night sights, but not to the naked eye. The 155-mm infrared (IR) illumination round provides infrared illumination out to 17 kilometers for a minimum of 120 seconds.

ANTIPERSONNEL IMPROVED CONVENTIONAL MUNITIONS

3-110. **Antipersonnel Improved Conventional Munitions (APICM)**. This projectile contains antipersonnel grenades (the number varies depending on the caliber of the weapon) which are extremely effective on antipersonnel targets. Antipersonnel improved conventional munitions (APICM) is available for 105-mm and 155-mm howitzers. The APICM (see figure 3-19) are most effective against unwarned, exposed personnel. When the fuze functions, an expelling charge forces the grenades out through the base of the projectile. Small vanes on each grenade flip upward, arming the grenade and stabilizing it in flight. When the striker plate on the base of the grenade contacts the ground, the grenade is hurled upward four to six feet and detonates. M449 APICM dispersion pattern is generally elliptical in shape. The dispersion pattern covers approximately 100 meters by 60 meters. APICM is no longer manufactured but is still held in war reserve.

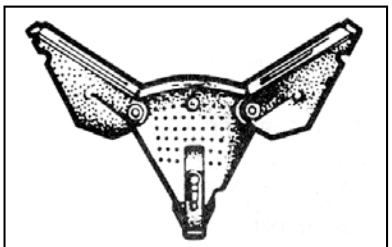


Figure 3-19. APICM grenades.

DUAL-PURPOSE IMPROVED CONVENTIONAL MUNITIONS

3-111. **Dual-Purpose Improved Conventional Munitions (DPICM)**. This projectile contains antipersonnel and anti-material grenades (see figure 3-20 on page 3-32). This projectile was designed for use against equipment, lightly armored vehicles, and personnel. Dual-purpose improved conventional munitions (DPICM) is available for both the 105-mm and 155-mm howitzer. Dual-purpose improved conventional munitions are base-ejection, payload-carrying projectiles. These projectiles are fired with base ejecting time fuzes and are filled with dual-purpose grenades. During flight, the base of the projectile is blown off and centrifugal force disperses the grenades radically from the projectile line of flight. After the grenade is ejected, a ribbon streamer arms and stabilizes it. On impact, a shaped charge that can pierce light armor is detonated. The surrounding steel case fragments are very effective against personnel as well. DPICM dispersion generally changes shape from elliptical at minimum ranges and lower charges to almost circular at maximum ranges. At minimum ranges, the dimensions are approximately 50 meters by 100 meters. At maximum ranges, they are approximately 100 meters by 120 meters.

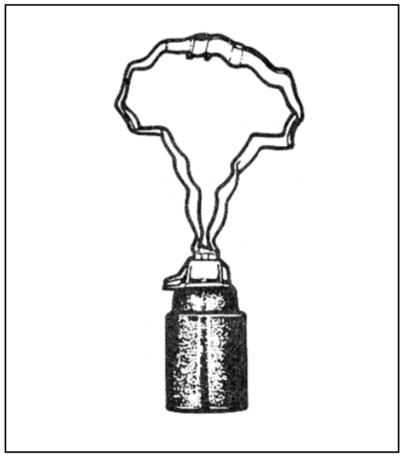


Figure 3-20. 155-mm DPICM grenade.

3-112. Table 3-5 describes the various improved conventional munition projectiles.

Table 3-5. Improved Conventional Munitions

Weapon	*Projectile*	*Number of Grenades*
Antipersonnel ICM		
155-mm (Figure 3-19)	M449	60
Dual-purpose ICM		
155-mm (Figure 3-20)	M483A1	88
155-mm	M864	72
105-mm	M915	42
MLRS	M26 Rocket	644 M77
MLRS	ER MLRS	518 XM85
MLRS	GMLRS	400+ XM85
Legend: ER—extended range; GMLRS—guided multiple launch rocket system; ICM—improved conventional munition; mm—millimeter; MLRS—multiple launch rocket system		

BASE BURN ROUND

3-113. **Base Burn**. Some munitions incorporate base burn (also known as Based Bleed) technology to increase its range. Base burn technology was developed to reduce the amount of base drag on a projectile, thereby increasing the achieved range. The drag is reduced by a (base) burner unit located on the base of the projectile. Once ignited, the base burner unit bleeds hot gas which causes the flow of air at the base to be less turbulent. The decrease in turbulence causes less base drag. (Base drag accounts for about 50 percent of total drag.) The amount of thrust produced by the base burner unit is negligible and does not serve the same function as the rocket motor on RAP.

3-114. The M864 base burn DPICM has a larger dispersion pattern than that of the M438A1 DPICM despite having fewer grenades. However, because it is designed for employment at longer ranges, which produces a steep angle of fall, the dispersion pattern is typically circular. At its designed ranges, the dispersion pattern covers approximately 150 meters by 150 meters. The projectile will not be used for training; all assets will become war reserve. Data may be computed manually by using FT 155-AU-PAD and FT 155-ADD-U-PAD.

FAMILY OF SCATTERABLE MINES

3-115. **Family of Scatterable Mines (FASCAM)**. There are two types of artillery delivered mines: Area Denial Artillery Munition (ADAM) and Remote Anti-Amor Mine (RAAMS). The ADAM was developed for use against personnel targets, to deny terrain, and to block avenues of approach. RAAMS was developed for use against armored targets. Both the ADAM and RAAMS have preset self-destruct times of either short (within 4 hours) or long (within 48 hours). FASCAM is available for the 155-mm howitzer only. The family of scatterable mines adds new dimension to mine warfare, providing the maneuver commander with a rapid, flexible means of delaying, harassing, paralyzing, canalizing, or wearing down the enemy forces in both offensive and defensive operations. Mines can force the enemy into kill zones, change their direction of attack, spend time in clearing operations, or take evasive actions. FASCAM presents an array of air and FA-delivered scatterable mines available to maneuver force commanders. The two types of FA-delivered scatterable mines are ADAM and RAAMS. RAAMS Projectiles

3-116. Use RAAMS projectiles to delay or disrupt threat formations and maneuver or to reinforce existing obstacles. A 155-mm howitzer fires the RAAMS projectile which base ejects anti-armor mines (see figure 3-21) over the target area. After a short delay to allow for mine freefall, impact, and roll, the magnetically fuzed mines arm themselves. Any metallic object such as a tank or self-propelled vehicle passing over the mines will cause the mines to detonate. Random mines have anti-disturbance features that cause the mines to detonate if they are moved or picked up. If not detonated, RAAMS mines begin to self destruct (SD) after 80 percent of the factory set SD time elapses. The probability of a live mine existing past its stated SD time is 0.001. Upon arming field artillery delivered scatterable mines perform a self test. All mines that fail the self test SD immediately. The SD time for the munitions are:

- The M718 and M718A1 projectiles have a long SD time (48 hours).
- The M741 and M741A1 projectiles have a short SD time (4 hours).

Note. The United States is aligning its anti-personnel landmines (APL) policy outside the Korean Peninsula with the key requirements of the Ottawa Convention, the international treaty prohibiting the use, stockpiling, production, and transfer of APL, which more than 160 countries have joined, including all of our North Atlantic Treaty Organization (NATO) Allies. This means that the US will not employ the ADAM-S and ADAM-L projectiles outside the Korean Peninsula

Most RAAMS (and ADAM) mines arm in two minutes. Product improved mines (type designated A1 arm in 45 seconds).

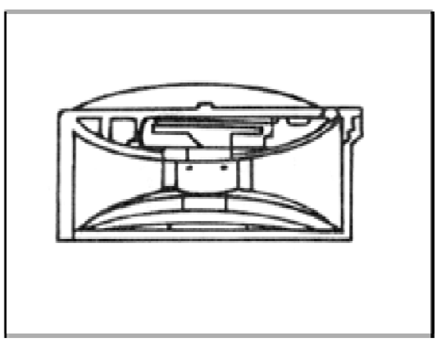


Figure 3-21. RAAMS mine.

3-117. Use ADAM mines against personnel, dismounted personnel in an armored attack, or on existing antitank obstacles to hinder dismounted breaching. When employed against a threat that has a dismounted breaching capability, deliver ADAM mines directly on top of a RAAMS minefield. ADAM rounds are always the last rounds fired when used in conjunction with RAAMS or other munitions. This prevents the accidental destruction of the ADAM munitions by other munitions.

3-118. A 155-mm howitzer fires the ADAM projectile which base ejects 36 antipersonnel mines (see figure 3-22 on page 3-34) over the target area. When an ADAM mine comes to rest on the ground, several tripwire sensors are deployed out to a maximum distance of 20 feet. When a sensor is disturbed or tripped, it propels a small ball like munitions two to eight feet upward. The munition detonates and scatters approximately 600 1.5 grain steel fragments in all directions. If not detonated, the ADAM mines will begin to SD after 80 percent of the factory set SD time elapses. The destruct times for the munitions are:

- The M692 projectile has a long SD time (48 hours).
- The M731 projectile has a short SD time (4 hours).

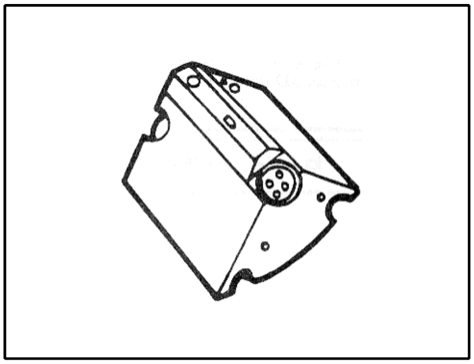


Figure 3-22. ADAM mine.

SENSE AND DESTROY ARMOR (SADARM M898)

3-119. The M898 Sense and Destroy Armor (SADARM) projectile is a base ejecting munition carrying a payload of two target sensing sub-munitions. The projectile is a member of the M795 family. The technical fire direction computations are similar to those used for the ADAM projectile, in that low level wind corrections must be applied to the firing solution (because of the high Height of Burst) in order to place the payload at the optimal location over the target area. SADARM is no longer manufactured but is still held in war reserve

EXCALIBUR

3-120. The M982 Excalibur is a family of 155-mm fire and forgets global positioning system (GPS)/internal measurement unit guided projectiles that use a jam resistant GPS receiver and a guidance package that enables the projectile to fly with GPS accuracy to preprogrammed aim-points independent of range. The M982 projectile uses a gliding airframe to achieve extended range. The M982 employs a non-ballistic flight path, which reduces the ability of counter-battery radars to accurately locate the firing unit and enhances friendly force survivability. Excalibur delivers a high explosive warhead out to ranges between 8 and 37.5 kilometers. Excalibur has three fuze options: point detonating, delay and proximity with a height of burst (HOB) of 3.7 meters.

3-121. Excalibur is only fired at high angle fire. This allows maximum acquisition time for the GPS receivers and guidance components, and for corrections along the guided portion of the trajectory. High angle fire optimizes the ranges Excalibur can achieve, due in large part to the projectile’s aerodynamic design and features that allow the projectile to “glide”, thus achieving greater range than a purely ballistic trajectory projectile. The Excalibur’s guidance system corrects its flight path for optimum attack angle and precision attack on the target.

3-122. Once near the target location, Excalibur performs a top down maneuver that allows for a nearly vertical attack angle on the target. Excalibur does not require laser designation and cannot be guided onto the target by a laser. It is not designed to destroy buildings or as a tank killer. The Excalibur projectile has roughly the equivalent explosive power of a standard M107 artillery projectile. The unitary warhead has a hardened casing that enables it to penetrate 4” of reinforced concrete before detonating (fuze delay).

PRECISION GUIDANCE KIT (PGK)

3-123. The Precision Guidance Kit (PGK) is comprised of the M1156 multioption fuze. The PGK is a low cost fuze alternative designed to increase effectiveness by ensuring rounds impact at or near the input target coordinates and are within the lethal radius of the round. This achieves increased efficiency with fewer rounds needed to achieve desired results. The PGK enhances accuracy of M549A1 or M795 155-mm artillery projectiles with the aid of global positioning system acquisition and guidance. This fuze allows for closer support of friendly forces and reduces the overall logistics burden by providing a near-precision capability to M549A1 or M795 high explosive cannon artillery projectiles. For more information on the PGK, see TB 9-1390-226-13.

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Chapter 4

Muzzle Velocity Management

Two howitzers of the same caliber, firing the same ammunition, charge and elevation, will seldom deliver fire at exactly the same range. The achieved muzzle velocity is the result of forces acting on the projectile within the cannon tube. To obtain accurate artillery fire, the performance of the weapon projectile family-propellant lot-charge combination must be known. If it is not known, the result can be reduced effects on the target or friendly casualties (for example, danger close, final protective fire [FPF], converged sheafs, and so on). Firing tables provide standard muzzle velocities for a standard weapon firing standard ammunition under standard conditions. However, muzzle velocities achieved in actual firing may differ from the standard muzzle velocities because of variations in the manufacture of the weapon and ammunition, wear in the weapon tube, projectile weight, propellant temperature, propellant lot efficiency, or a combination of these factors. The Muzzle Velocity System (MVS) enables a firing unit to continually update muzzle velocity data. This chapter describes muzzle velocity management with the MVS as well as predictive techniques.

SECTION I: MUZZLE VELOCITY TERMS

4-1. *Muzzle velocity* (MV)-the velocity achieved by a projectile as it leaves the muzzle of the weapon (measured in 0.1 meters per second).

4-2. ***Standard muzzle velocity*-An established muzzle velocity used for comparison.** It is dependent upon the weapon system, propellant type, charge, and projectile family. It is also referred to as reference muzzle velocity. Standard muzzle velocities can be referenced in the Tabular Firing Tables.

4-3. *Muzzle velocity variation* (MVV)-the change in muzzle velocity of a weapon (expressed in ±0.1 meters per second) from the standard muzzle velocity or arbitrary selected standard.

4-4. **Projectile family**-a group of projectiles that have exact or very similar ballistic characteristics. Within the projectile family the projectiles' external shape, mass, center of gravity, moment of inertia, and surface finish are similar. If we were to fire an infinite number of rounds, their mean point of impact would be within 1 PE_R and PE_D of the mean point of impact of the family head projectile.

4-5. **Propellant type**-the nomenclature of the propellant used for a particular charge.

4-6. **Charge group**-the charges within each propellant type associated with a projectile family, within which MVVs can be determined. (See table 4-1 on page 4-4). This has been referred to as propellant model or powder model in the past and in other references. In separate-loading ammunition (155-mm) these terms are synonymous, but in semi-fixed ammunition (105-mm), three charge groups are within a propellant type. Charge groups may change depending on the projectile family.

4-7. **Preferred charges**-the charges preferred for measuring and transferring muzzle velocities. These charges produce consistent predictable muzzle velocities. The MVVs they produce should not vary more than (±1.5 meters per second for the same charge or other charges of the same charge group. Therefore, the MVV determined for one charge of a propellant type will be similar (±1.5 m/s) to another charge of the same propellant type and lot. Preferred charges are identified in table 4-1 (on page 4-4).

4-8. **Restricted charges**-those charges within a charge group to which it is not preferred to transfer measured MVVs or for which it is not authorized to fire (is based on the weapon Technical Manual [TM]).

The performance of a restricted charge is not indicative of the performance of other charges within the charge group.

4-9. **Adjacent charge**-charges within a charge group which are one charge increment greater or less than the charge calibrated. Used in the conduct of a calibration and subsequent lot inference techniques.

4-10. **Propellant lot**-a group of propellants made by the same manufacturer at the same location with the same ingredients.

4-11. ***Calibration* -is the process of measuring the muzzle velocity of a weapon and then performing a comparison between the muzzle velocity achieved by a given howitzer and the accepted standard**. There are two types of calibration--absolute and comparative (see figure 4-1).

- In **absolute calibration**, the weapon's achieved muzzle velocity is compared to the firing table reference muzzle velocity (also known as Standard Muzzle Velocity).
- In a **comparative calibration**, the achieved muzzle velocities of two or more weapons are compared to an arbitrarily selected standard from the performance of a group of weapons being calibrated together.

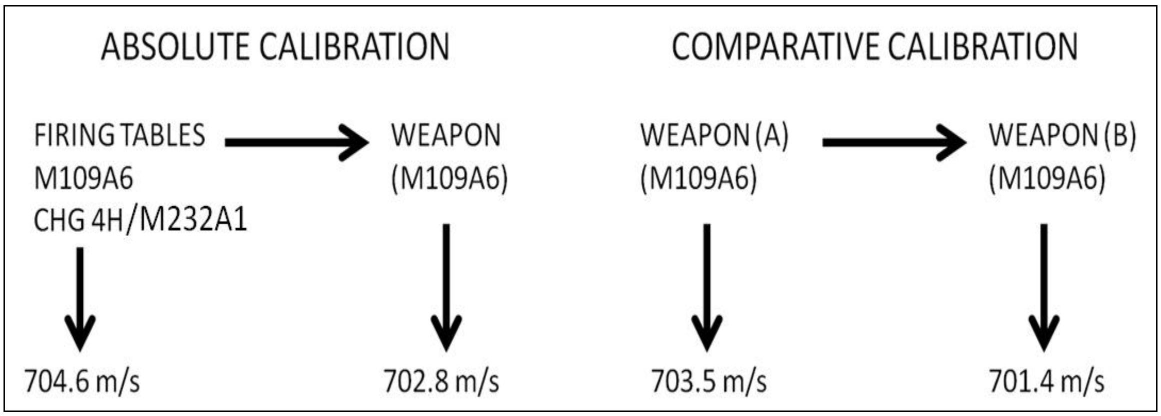


Figure 4-1. Comparative and Absolute Calibration results.

4-12. **Inferred calibration**- the MV of a weapon is determined through mathematical procedures by using data from a first lot calibration (baseline data) and the relative efficiency of a second lot of propellant.

4-13. **Muzzle Velocity System (MVS)** - The MVS is a MV measurement system, which operates on the Doppler principle. The system is based on an X-band transceiver and a MV processor. The purpose of the MVS is to provide an accurate MV reading for a projectile fired from the howitzer. This information can be used to provide a reasonable estimate of the average MV for rounds to be fired for a new fire mission; thereby improving the possibility of first round effects on the target. It is used to measure the speed of the projectile as it leaves the muzzle of a weapon. It can determine MVVs. Additionally the MVS can apply corrections for non-standard conditions and determine a calibrated MVV.

- Paladin Digital Fire Control System (PDFCS) Muzzle Velocity System (MVS). This is a replacement for the M90 Velocimeter. It is used on the Paladin weapon system and is an integrated component of the PDFCS. This system was formally known as the M93. See Appendix K of the ATP 3-09.70
- The M94 is a MVS used in towed M119A2/A3 (105mm) and M777A2 howitzers. For more information see TM 9-1290-364-14&P.

Note: USMC unit use the Muzzle Velocity Sensor System (MVSS).

4-14. *Muzzle Velocity System (MVS) Readout average*- is the average MV measured by the MVS which has not been corrected for standard projectile square weight and standard propellant temperature.

4-15. ***Calibrated muzzle velocity*- is an MVS readout average that has been corrected to standard projectile square weight and propellant temperature**. **MVV= Calibrated MV- Standard MV.**

4-16. *Historical muzzle velocity*- is a calibrated muzzle velocity which has been recorded in a muzzle velocity logbook.

4-17. ***Erosion*- is the wear in a howitzer tube that is the result of firing rounds**. It is measured from a pullover gauge reading (POG), which is described in inches, or estimated by computing the equivalent full charges (EFC) for erosion. This is determined by multiplying the number of rounds fired with a given charge and the number of EFCs per round for that charge and projectile. The table used to compute EFC's is found in the introduction of the Tabular Firing Table (TFT)

4-18. ***Shooting strength*-is the reduction in the achieved muzzle velocity of a howitzer overtime caused by erosion**, which is a function of erosion and projectile family ballistics.

4-19. ***Ammunition efficiency*- is the change in velocity which is the sum of the projectile efficiency and propellant efficiency**.

4-20. ***Projectile efficiency*- is the known deviations from the standard for a particular projectile which affect the achieved velocity**. For example, a high-explosive (HE) Ml07 projectile which weighs 3◙ (93.9 pounds), vice the standard 4◙ (95.0 pounds), would have a predictable change in velocity, depending on the charge fired.

4-21. ***Propellant efficiency*-is the known deviations from the standard for a particular propellant which affect the velocity of the projectile**. For example, a lot of M232A1 propellant may perform differently than the standard for that propellant type but is still acceptable for firing.

Table 4-1. Projectile Families, Propellant Types, and Charge Groups.

PROJECTILE FAMILY	PROPELLANT	CHARGE GROUPS	PREFERRED CHARGES
105 MM			
HE (M1)	M67	1-2	1-2
		3-5	3-5
		6-7	6-7
DPICM (M915)	M200	Single Increment (8)	Single Increment (8)
RAP (M927)	M67	7	7
RAP (M548)	M176	3-5	3-5
		6-7	6-7
RAP (M913)	M229	Single Increment (8)	Single Increment (8)
155 MM			
HE (M107)	M3A1	2-5	3-5
	M231	1-2	N/A
	M4A2	3-7	5-7
	M232/A1	3-4	4
	M119A1	8	8
	M119A2	7	7
HE (M795)	M3A1	3-5	3-5
	M231	1-2	N/A
	M4A2	4-7	5-7
	M232/A1	3-5	4
	M119A1	8	8
	M119A2	7	7
	M203A1	8	8
RAP (M549)	M4A2	7	7
	M232/A1	3-5	4
	M119A1	8	8
	M119A2	7	7
	M203A1	8S	8S
DPICM (M864)	M4A2	7	7
	M232/A1	3-5	4
	M119A1	8	8
	M119A2	7	7
	M203A1	8S	8S
EXCALIBUR (M982)	M232/A1	3-4	4
EXCALIBUR (M982A1)	M232/A1	3-4	4
Legend: HE = High Explosive; MM – millimeter; DPICM = Dual-Purpose Improved Conventional Munition; RAP = Rocket Assisted Projectile			

SECTION II: CORRECTION TABLES AND FORMS

MUZZLE VELOCITY CORRECTION TABLES (MVCT)

4-22. The Muzzle Velocity Correction Tables (MVCT) are published for the information and guidance of personnel whose responsibility is the use of data generated by the MVS. The correction tables contain data to correct the readout average to what it would have been if the reading had been determined with a standard square-weight projectile and a standard propellant temperature. The information in the tables was compiled from Fire Control Inputs (FCI's) maintained by the Firing Tables and Ballistics Division (FTaB). ***Fire control* is all operations connected with the planning, preparation, and actual application of fire on a target.**

4-23. The muzzle velocity readout from a MVS is the projectile velocity at the muzzle for the projectile weight and propellant temperature at the time of firing. This muzzle velocity must be corrected to the muzzle velocity that would have been read for standard projectile weight and propellant temperature. The MVS tables contain muzzle velocity corrections due to nonstandard projectile weight and propellant temperature for weapon, projectile and propelling charge combinations.

4-24. Parts of the MVCT include:

- Cover
- Table of contents.
- Introduction.
- Muzzle Velocity Correction Tables
  - **Section Cover Sheet** (See figure 4-2 on page 4-6) The Section cover of the MVCT provides information concerning the weapon system(s) and projectile(s) to which data in the section apply. Several projectiles may be listed on the cover if they are within the same projectile family because of ballistic similarity. Also provide fuze weight corrections.

Note: The MVCT-2 is used as the example throughout this section. Figure 4-2 (on page 4-6) shows a portion of the Section 5 cover found on page 33 of the MVCT-2

Note: The calibrated muzzle velocity is the summation of the average muzzle velocity readout and corrections due to the nonstandard projectile square weight and propellant temperature (derived using interpolation if necessary). Corrections for any difference in fuze weight must also be incorporated. The table located at the bottom of the section cover must be used with the proper projectile/fuze combinations. Before entering the correction table, projectile square weight must be adjusted for differences in fuze weight as indicated by the table. To find the corrections for adjusted projectile square weight with a ½ square increment, interpolate between the corrections for the higher and lower values

Note: The Standard muzzle velocities are based on the M557 fuze. However, some Tabular Firing Tables (TFT) are based on the M739A1 fuze. Therefore, the standard muzzle velocities in those TFT were adjusted for the fuzed projectile weight.

  - **Standard Muzzle Velocity**- after the Section Cover the MVCT lists the standard muzzle velocities. This standard MV could also be found in the appropriated TFT (See figure 4-2 on page 4-6).

MVCT-2

SECTION 5

Cannon, 155mm Howitzer, M199
on
Howitzer, Medium, Towed, 155mm, M198
and
Cannon, 155mm Howitzer, M284
on
Howitzer, Medium, Self-Propelled, 155mm, M109A5/A6
and
Cannon, 155mm Howitzer, M776
on
Howitzer, Medium, Towed, 155mm, M777/A1/A2
Firing
Projectile, HE, M107

The muzzle velocity correction tables are also applicable to the following cartridges:

Projectile, Smoke, WP, M110, M110A1, M110A2
Projectile, Smoke, BE, M116A1 (HC)
Projectile, Illuminating, M485A2 and M485A1
Projectile, HE, APICM, M449A1

NOTE: The following table must be used with the proper projectile/fuze combinations. Before entering the correction table, projectile square weight must be adjusted for differences in fuze weight as indicated by the following table:

Fuze	Correction
M767, M767A1, M732A2, M762, M762A1	-1 SQ
M582, M582A1, M739, M739A1, M732, M782, M577, M577A1	- ½ SQ
M564, M557, M728, M565	0 SQ
MK399 MOD 1	+ ½ SQ

NOTE: Manual aiming data for the above weapon-projectile combination may be found in FT 155-AM-2 (bag charges) and FT 155-AM-3 (MACS and 7R, M119A2).

33

MVCT-2

Projectile, HE, M107
Projectile, Smoke, WP, M110, M110A1, M110A2
Projectile, Smoke, BE, M116A1 (HC)

Charge	Standard Muzzle Velocity m/s		
	Howitzer		
	M198	M109A5/A6	M777/A1/A2
M119A1 Propelling Charge			
8	688	681	687
M119A2 Propelling Charge			
7R	690	683	689
MACS, M231 Propelling Charge			
1L	311	310	310
2L	453	451	452
MACS, M232 Propelling Charge			
3H	564	558	560
4H	696	688	692
MACS, M232A1 Propelling Charge			
3H	590	584	586
4H	711	703	707

35

Figure 4-2. Section Cover and Standard MV Example.

- **Correction Tables**. The correction tables are separated by Weapon System, Projectile Family, Propellant Model, and Charge. In the muzzle velocity correction table, the projectile weight and propellant temperature are expressed to 1 square, 10° Fahrenheit and 5.6° Celsius respectively. In general, plus signs are omitted from these tables. Therefore, numbers without signs are to be considered positive. To determine correction factor **enter MVCT for the appropriate weapon system and projectile family. Locate the page containing the table for the same charge fired in the calibration.** Enter the table with the average propellant temperature and the weight of the projectile fired (ensure that fuze correction is applied if required). Interpolate to the nearest ± 0.1 m/s (See figure 4-3 on page 4-7) to determine the value to correct the readout average to standard.

Note: When temperatures are greater than 130° use the last listed value

Howitzer, 155mm, M198, M109A5/A6 and M777/A1/A2

PROJ, HE, M107 PROPELLANT, M232A1 4H

Corrections to Muzzle Velocity in Meters per Second to Compensate for Differences in Projectile Weight and Propellant Temperature								
Temp of Prop	Projectile Weight in Squares							Temp of Prop
°F	1 SQ	2 SQ	3 SQ	4 SQ*	5 SQ	6 SQ	7 SQ	°C
−40	10.0	12.3	14.7	17.1	19.5	21.9	24.3	−40.0
−30	8.3	10.6	13.0	15.4	17.8	20.2	22.6	−34.4
−20	6.6	9.0	11.4	13.8	16.2	18.6	21.0	−28.9
−10	5.0	7.4	9.8	12.2	14.6	17.0	19.4	−23.3
0	3.5	5.9	8.3	10.7	13.1	15.5	17.9	−17.8
10	2.0	4.4	6.8	9.3	11.7	14.1	16.5	−12.2
20	0.5	2.9	5.4	7.8	10.2	12.6	15.0	−6.7
30	−1.0	1.5	3.9	6.3	8.7	11.1	13.6	−1.1
40	−2.5	−0.1	2.4	4.8	7.2	9.6	12.1	4.4
50	−4.0	−1.6	0.8	3.3	5.7	8.1	10.6	10.0
60	−5.6	−3.2	−0.8	1.7	4.1	6.5	9.0	15.6
70	−7.3	−4.9	−2.4	0.0	2.4	4.9	7.3	21.1
80	−9.1	−6.7	−4.2	−1.8	0.7	3.1	5.6	26.7
90	−11.0	−8.5	−6.1	−3.6	−1.2	1.3	3.8	32.2
100	−13.0	−10.5	−8.1	−5.6	−3.1	−0.7	1.8	37.8
110	−15.1	−12.6	−10.2	−7.7	−5.2	−2.8	−0.3	43.3
120	−17.4	−14.9	−12.5	−10.0	−7.5	−5.0	−2.6	48.9
130	−19.9	−17.4	−14.9	−12.4	−9.9	−7.5	−5.0	54.4

*Standard Projectile Weight

Figure 4-3. Correction Table Charge 4H M232A1, for M107 Projectile Family.

DA FORM 4982-1 M90 VELOCIMETER WORK SHEET

4-25. DA Form 4982-1 M90 Velocimeter Work Sheet (figure 4-4 on page 4-8) is used to determine the calibrated muzzle velocity by correcting for variations in projectile square weight and propellant temperature from the standard. It is divided into four major sections. These sections are

- **Administrative information**. In this section the projectile family-propellant lot charge combination is recorded.
- **Calibration Data**. In this section the howitzer(s) tube and temperature information at the time of firing is recorded.
- **Muzzle Velocity System Readout**. In this section the readout and average values are recorded.
- **Muzzle Velocity Computations**. In this section corrections determined form the MVCT are recorded and applied by the algebraic sum of the readout average and the correction factor. Also there is a remark portion in which computations could be recorded as necessary.

M90 VELOCIMETER WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC.

CHARGE GROUP M232A1	DATE AND TIME 280815FEB2015	PROJECTILE FAMILY M107
PROJECTILE MODEL M107DC	POWDER LOT NUMBER IOP09B-031026	PROJECTILE WEIGHT 5 Square

CALIBRATION DATA

ITEMS *a*	GUN 1 CHARGE *b*	GUN 2 CHARGE *c*	GUN 3 CHARGE *d*	GUN 4 CHARGE *e*	GUN 5 CHARGE *f*	GUN 6 CHARGE *g*	GUN 7 CHARGE *h*	GUN 8 CHARGE *i*
1. WEAPON BUMPER NUMBER	A21	A23	A25	A27				
2. WEAPON TUBE NUMBER	1122	2233	3344	4455				
3. STARTING POWDER TEMPERATURE	70	60	61	67				
4. ENDING POWDER TEMPERATURE	70	60	62	68				
5. AVERAGE POWDER TEMPERATURE	70	60	62	68				
M90 VELOCIMETER READOUT								
ROUND 1	702.1	690.0	700.1	704.5				
ROUND 2	708.6	695.5	699.3	706.0				
ROUND 3	703.4	695.2	699.7	704.0				
ROUND 4	702.8	696.7	701.5	705.4				
ROUND 5	702.8	695.0	698.0	705.4				
ROUND 6	701.1	697.2	701.0	704.9				
ROUND 7	702.0	696.0						
ROUND 8								
READOUT AVERAGE	702.4	695.9	699.9	705.0				
MUZZLE VELOCITY COMPUTATION								
6. MUZZLE VELOCITY CORRECTION FOR NONSTANDARD CONDITIONS	+2.4	+4.1	+3.8	+2.7				
7. CALIBRATED MUZZLE VELOCITY	704.8	700.0	703.7	707.7				
8. NUMBER OF WARMUP ROUNDS FIRED	2	2	2	2				

REMARKS

DA FORM 4982-1, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Figure 4-4. M90 Velocimeter Work Sheet.

DA FORM 4982 MUZZLE VELOCITY RECORD

4-26. DA Form 4982 Muzzle Velocity Record (figure 4-5) is the record of a calibration kept in the battery or platoon muzzle velocity log book. The top part of the form **(FIRST-LOT CALIBRATION)** is used to determine the weapon MVV for a specific charge, when corrected to standard. The lower part of the form (**SECOND-LOT CALIBRATION AND SECOND-LOT INFERENCE)** is used to infer muzzle velocity data for a second lot of propellant and/or ammunition.

MUZZLE VELOCITY RECORD

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

DATE 280815SFEB13

PROPELLANT TYPE: M232A1

FIRST-LOT CALIBRATION

SHELL: M107DC FAMILY: M107	FIRST POWDER LOT NUMBER IOP09B-031026	GUN NUMBER/CHARGE FIRED							
ITEMS		1/ 4H	2/4H	3/4H	4/4H	5/	6/	7/	8/
1. WEAPON BUMPER NUMBER		A21	A23	A25	A27				
2. WEAPON TUBE NUMBER		1122	2233	3344	4455				
3. FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY(FROM TFT)		703.0	703.0	703.0	703.0				
4. CALIBRATED MUZZLE VELOCITY		704.8	700.0	703.7	707.7				
5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE4 – LINE3 = LINE5)		+1.8	-3.0	+0.7	+4.7				

SECOND-LOT CALIBRATION

SHELL: M107DC FAMILY: M107	SECOND POWDER LOT NUMBER IOP09F-031027	GUN NUMBER/CHARGE FIRED						DATE: 121130SMAR13	
ITEMS		1/4H	2/	3/	4/	5/	6/	7/	8/
6. SECOND-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TFT)		703.0							
7. SECOND-LOT CALIBRATED MUZZLE VELOCITY		698.3							
8. SECOND-LOT PIECE MUZZLE VELOCITY VARIATION (LINE7 – LINE6 = LINE8)		-4.7							
9. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE5)		+1.8							
10. CHANGE IN MUZZLE VELOCITY VARIATION (LINE8 – LINE9 = LINE10)		-6.5							

SECOND-LOT INFERENCE

11. SECOND-LOT STANDARD MUZZLE VELOCITY (FROM TFT)	703.0	703.0	703.0	703.0				
12. CHANGE IN MUZZLE VELOCITY VARIATION (LINE10)	-6.5	-6.5	-6.5	-6.5				
13. FIRST-LOT MUZZLE VELOCITY VARIATION (LINE5)	+1.8	-3.0	+0.7	+4.7				
14. SECOND-LOT CALIBRATED MUZZLE VELOCITY VARIATION (LINE12 + LINE13 = LINE14)	-4.7	-9.5	-5.8	-1.8				
15. CALIBRATED MUZZLE VELOCITY (LINE11 + LINE 14 = LINE 15)	698.3	693.5	697.2	701.2				

REMARKS

DA FORM 4982, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Figure 4-5. Muzzle Velocity Record.

SECTION III: TECHNIQUES TO DETERMINE MUZZLE VELOCITY VARIATIONS

4-27. Three techniques can be used to determine muzzle velocity variations within the firing unit. The accuracy and complexity of these different techniques varies greatly. Each of the techniques must be understood and applied correctly to the tactical situation. The following order of preference can be used as a guideline. The techniques are listed in order of decreasing preference.

- First Lot Calibration (baseline calibration).
- Subsequent lot inferred calibration.
- Predictive muzzle velocity techniques.

Note: Muzzle Velocities achieved in actual firing differ from the standard muzzle velocities as a result FDC should not assume standard muzzle velocity

FIRST LOT CALIBRATION (BASELINE CALIBRATION).

DETERMINATION OF CALIBRATED MUZZLE VELOCITY DA FORM 4982-1

4-28. **Determine calibration data**. The howitzer section provides admin information and MVS readout values to the FDC. Normally, data from **six usable rounds**, all preferably fired within **20 minutes**, are used to ensure the most accurate calibration data. These six rounds can be from any fire mission conducted by the firing unit. Specially conducted calibration missions are not required. If the howitzer tube is cold (that is, has not been engaged in firing or in low air temperatures) the firing of **warm-up rounds is recommended**. Fewer than six rounds can be used. In these situations, the calibration validity is reduced in the same way that the validity of a registration is reduced when the number of rounds fired is less than normal. In these situations, refer to Chapter 10, Table 10-1 for validity information and the effect of reduced rounds on the calibration data. Powder temperature differences between rounds decrease the validity of the calibration. To reduce powder temperature changes from round to round, use proper propellant handling and storing procedures in the firing unit and fire all rounds measured for a calibration within a 20-minute period. Follow these procedures in the calibration of all weapons. The FDC will collect the MVS readout values and calibrated MV from the section chiefs and record the values on DA Form 4982. FDC will also collect the MVS determined MVV and record it on DA Form 4982 for all weapons. The FDO is responsible to verify/validate the data received by the section chief.

Note: The MVS can determine MVV and apply corrections for non-standard conditions to determine calibrated MV. The step mentioned in this section can be used to verify/validate MVS data

4-29. **Determine MVS readout average**. The FDO inspects the readout values for all rounds and deletes any invalid readout values, those exceeding the readout average by ±3.0 m/s. This ±3.0 m/s approximates 4 PE_R in the target area for the given charge. The FDC personnel then determine the new readout average for the usable rounds by adding all usable readout values and dividing the sum by the number of usable rounds. This value includes the effects of non-standard propellant temperature and projectile weight.

4-30. **Determination of calibrated MV**. The MVS readout average is not used in its original form because it includes the effects of projectile weight and propellant temperature on the muzzle velocity. The MV can be used when the corrections for projectile weight and propellant temperature are applied by extracting the value from the appropriate table in the MVCT manual and applying that value to the readout average. The result is the calibrated muzzle velocity for the weapon.

4-31. **Complete MVS worksheet**. Once the velocity of the rounds fired has been determined, FDC personnel are responsible for verifying and completing the DA Form 4982-l and place into the unit muzzle velocity logbook.

COMPLETE THE MUZZLE VELOCITY RECORD (DA FORM 4982).

4-32. DA Form 4982 is the record of a calibration kept in the battery or platoon muzzle velocity log book. For future reference, place the completed muzzle velocity record into the unit muzzle velocity logbook under the appropriate weapon projectile family-propellant type-charge group.

4-33. The determined MVV is used in the solution of concurrent met technique and subsequent met application and terrain gun position corrections. The lower part of the form (SECOND-LOT CALIBRATION AND SECOND-LOT INFERENCE) is used to infer muzzle velocity data for a second lot of propellant and/or ammunition.

SUBSEQUENT LOT INFERRED CALIBRATION.

4-34. Inferred subsequent lot calibration techniques allow a firing unit to quickly update muzzle velocity information for a given projectile family-propellant lot combination, when firing a new lot of propellant. Subsequent lot calibration is used to isolate the difference in efficiency between two propellant lots for one howitzer firing the same projectile family. This difference is applied to the first lot calibration data for the other howitzers to determine calibration data for the second lot. This technique can be used when the situation does not permit the calibration of the new lot with all guns.

4-35. To accomplish this technique, the following requirements must be met:

- Calibration of the first lot must be completed for the entire unit.
- Calibration of a second lot must be completed for one gun.
- Subsequent lot should be calibrated with the same or adjacent charge.

4-36. A calibration should be completed with all howitzers as soon as the situation allows.

PREDICTIVE MUZZLE VELOCITY TECHNIQUE.

4-37. While it is not practical to predict (within ±0.1 m/s) the velocity of every round, it is possible to approximate velocities to within ±1 or ±2 m/s with current available information. This may be useful when calibration is not possible, when updating calibration data, or when trying to increase the accuracy of inferred MV techniques.

4-38. When calibration is not possible, the shooting strength of the howitzer can be used as the MVV. While this may be enough when no other data are available, it is important to understand that an MVV consists of more than just shooting strength. An equation can be created for determining an MVV by using its basic parts.

MVV= SHOOTING STRENGTH + AMMUNITION EFFICIENCY + ROUND TO ROUND VARIATION

4-39. If all three elements are known, it is possible to determine a value for MVV. It is neither practical nor necessary to quantify round-to-round variation. This element is usually small and subject to rapid change. Projectile efficiency, as a part of ammunition efficiency, is accounted for in solving the concurrent and subsequent met techniques. Therefore, if the round-to-round variation and the projectile efficiency are eliminated from the equation, the howitzer shooting strength and the propellant efficiency of the propellant lot to be fired can approximate the MVV.

MVV= SHOOTING STRENGTH + PROPELLANT EFFICIENCY

4-40. If calibration is not possible, adding the propellant efficiency to the shooting strength will result in a more accurate MVV for determining firing data than if the shooting strength is considered alone. This MVV can be used as the MVV for manual fire missions. Each howitzer has a value for shooting strength for each projectile family. Also, the value of propellant efficiency applies to any projectile family with which the propellant lot is fired.

ESTIMATING SHOOTING STRENGTH

4-41. There may be times when calibration is not possible. If the MVS is not available or there is not time to conduct a calibration, it may be necessary to determine the shooting strength of the howitzer by other means. The shooting strength of a howitzer can be determined by using pullover gauge readings (POG) and/or erosion EFC service round effects with the appropriate TFT for the weapon-projectile-propelling charge combination to be fired. DA Form 2408-4, Weapon Record Data, provides the information to determine the shooting strength of each howitzer. (See figure 4-6.)

1. Tube Serial 3344 | 2. Cannon Type, Model or Series 155mm M284 | 3. ORGANIZATION (UIC/UNIT) A BTRY, 4-27th FA | 4. SPECIAL LIFE DATA

5. End Item Identification How Med SP 155mm M109A6 | 6. RDS/EFC COMPUTATION

7. Cannon Serial 1856 | 8. Retubings 0 | 9. Rebushings 0

Cumulative EFC RDS fired for Cannon:

SAMPLE

10. Date	Projectile Type	Zone or Charge	Rounds Fired	EFC RDS Fired	Cumulative RDS fired	Remaining Life (EFC RDS)	Remarks: Recoill Exercise (RE), Gage or Velocity Reading, Safety Inspection (SI)	Signature
11Jan13					1329			
17Jan13							Borescoped and pullover 6.147	AMLLM
27Jan13	HE M107DC	4H	200					AMLLM

Legend: BTRY – battery; EFC – effective full charge; FA – field artillery; HE – high explosive; How – howitzer; MED – medium; RDS – rounds; SP – self-propelled; UIC – unit identification code

Figure 4-6. Digital Weapon Record Data.

4-42. The shooting strength is obtained by determining the most recent pullover gauge (POG) reading from the weapon's DA Form 2408-4 (E) (Weapon Record Data or The Gun Book) and converting that to a loss in Muzzle Velocity by entering the appropriate TFT for the weapon system and projectile family. (Ensure you use the appropriate TFT for your weapon system and projectile family). If the howitzer has fired since the last POG reading, you must first convert the POG reading to effective full charges (EFCs) and then add the EFCs for those rounds fired since the last POG reading before converting that total number of predicted EFCs to a predicted loss in Muzzle Velocity (Note: Shooting Strength will always be negative)

4-43. The number of EFCs for those rounds fired since the last POG is determined by multiplying the number of rounds fired for a specific projectile and propellant by the equivalent erosion effect in decimals for the charge fired listed in the introduction of the TFT. Different projectile families have different TFTs and consequently different values for equivalent erosion effect in decimals.

4-44. Pullover gauge readings can be determined regularly by the maintenance section in conjunction with borescoping the howitzer. The most accurate technique is to combine the pullover gauge reading and the erosion EFCs fired after the pullover gauge reading to determine an expected loss in muzzle velocity. The most recent pullover gauge reading or total erosion EFCs may be used to determine the approximate loss in muzzle velocity.

PROPELLANT EFFICIENCIES.

4-45. **Propellant efficiency (PE)** is known deviations from the standard for a particular propellant which affect the velocity of the projectile. The propellant efficiency information (see example in figure 4-7 on page 4-13) contains data useable with predictive muzzle velocity techniques. The information is a result of the initial acceptance test of the specific propellant lot fired at the time the entire lot of propellant was purchased by the government. The first two numbers (i.e. 03 in IOP09M-031030) generally indicate the year the propellant lot was produced. Some lots are quite old and storage location and conditions over time may have reduced the accuracy of the propellant efficiency as a predictive measure. Nonetheless, the propellant efficiencies are a valuable tool to the FDO in improving the accuracy of his unit when calibration information is not yet available for a particular propellant lot. This information is not intended to be a substitute for calibrating a "new" lot of propellant that your unit receives, rather it should be used only until you can calibrate one gun with the "new" lot and eventually establish a baseline with that lot as time and the tactical situation permit. (This is in accordance with the order of preference for calibration or muzzle velocity variation information). Propellant efficiencies will prove extremely valuable in a situation where you receive a new lot of propellant that you have not previously calibrated your howitzers with. In this situation, if you will not have the opportunity to calibrate the new lot prior to firing for its intended use, you should use the column labeled "Propellant Efficiency", with the charge closest to the one you will fire, and apply it in the following equation:

MUZZLE VELOCITY VARIATION = SHOOTING STRENGTH + PROPELLANT EFFICIENCY

MVV= SS + PE

DODIC	Model	LOT #	Charge-3H (m/s)	Charge-4H (m/s)	Charge-5H (m/s)	
DA13	M232A1	GDB09J-031035	+1.2	+3.0	(-0.6)	
DA13	M232A1	GDB09M-031037	(-1.6)	(-2.8)	(-3.3)	
DA13	M232A1	GDB10A-031038	(-4.4)	(-2.5)	(-3.6)	
DA13	M232A1	GDB10C-031039	(-5.6)	(-4.4)	(-5.1)	
DA13	M232A1	GDB10D-031023	+1.8	+0.9	(-2.4)	
DA13	M232A1	GDB10E-031040	(-2.9)	(-3.7)	(-4.6)	
DA13	M232A1	GDB10F-031042	(-3.0)	(-3.1)	(-3.1)	
DA13	M232A1	GDB10H-031043	(-0.4)	(-1.0)	(-1.2)	
DA13	M232A1	GDB10J-031044	(-0.5)	(-0.4)	(-1.7)	**
DA13	M232A1	GDB10L-031045	(-0.8)	(-1.5)	(-4.7)	**
DA13	M232A1	GDB10M-031046	+2.8	(-0.2)	(-0.6)	**
DA13	M232A1	GDB11B-031047	(-0.7)	(-1.4)	(-1.0)	**
DA13	M232A1	GDB11C-031048	(-4.0)	(-3.8)	(-5.3)	**
DA13	M232A1	GDB11D-031049	(-5.8)	(-1.8)	(-5.0)	**
DA13	M232A1	GDB11F-031050	(-7.2)	(-7.1)	(-8.1)	**
DA13	M232A1	GDB11G-031052	(-4.1)	(-4.0)	(-3.8)	**
DA13	M232A1	GDB11H-031053	(-0.9)	+0.5	(-4.3)	**
DA13	M232A1	GDB11J-031054	+1.5	+0.1	+1.2	**
DA13	M232A1	GDB11L-031055	+1.6	+0.4	(-1.3)	**
DA13	M232A1	IOP08J-031024	+2.7	+1.8	(-0.3)	
DA13	M232A1	IOP08K-031024	+3.7	+3.3	+0.7	
DA13	M232A1	IOP08L-031025	+4.1	+4.8	+2.4	
DA13	M232A1	IOP09B-031026	+6.5	+5.9	+2.9	
DA13	M232A1	IOP09F-031027	+2.8	+2.3	(-0.8)	
DA13	M232A1	IOP09H-031028	(-1.9)	0.0	(-1.1)	
DA13	M232A1	IOP09K-031029	+1.6	+1.2	+3.6	
DA13	M232A1	IOP09M-031030	+1.3	+1.0	+1.1	

** new for v5-02

Figure 4-7. MACS Propellant Efficiencies (PE) Example.

Note: DO NOT USE Figure 4-7 to predict MVV's for firing.

SECTION IV: EXAMPLES OF THE TECHNIQUES USED TO DETERMINE MUZZLE VELOCITY

COMPLETE M90 VELOCIMETER WORKSHEET (DA FORM 4982-1)

4-46. Complete M90 Velocimeter worksheet. Step Action Drill for DA Form 4982-1. This will include the steps in table 4-2 on page 4-14. A completed DA Form 4982-1 is shown in figure 4-8 on page 4-15.

Table 4-2. Steps for Completing DA Form 4982-1.

STEP	***ACTION***
1	Verify the admin data.
2	Verify the weapon bumper number.
3	Verify the weapon tube number.
4	Verify the starting powder temperature for each howitzer.
5	Verify the ending powder temperature for each howitzer.
6	Determine and record the average powder temperature for each howitzer to the nearest degree.
7	Verify the MVS readout by round for each howitzer.
8	Average all the usable measured muzzle velocities for each howitzer.
9	Compare the average of the usable measured muzzle velocities with each measured muzzle velocity for each howitzer.
10	If any measured muzzle velocity is more than ±3.0 m/s from the average, discard it. Discarding more than one velocity at a time may be necessary.
11	If any muzzle velocities were discarded, repeat steps 8 through 10 above. If no further rounds are discarded, this is the readout average.
12	Record the readout average for each howitzer.
13	Locate the portion of the MVCT for the weapon system fired.
14	Locate the portion of the MVCT for the projectile family of the projectile fired.
15	Locate the page of the MVCT for the charge of the propellant type used.
16	Find the projectile ◙ weight across the top of the table. Note: To find the corrections for adjusted projectile square weight with a ½ square increment due to fuze correction, interpolate between the corrections for the higher and lower values (for an example see Table 4-3 on page 4-16)
17	Find the average powder temperature on the left or right edge of the table.
18	Find where the projectile weight and the powder temperature intersect in the table. This is the correction for the nonstandard condition(s). Note**:** If the average powder temperature is not listed but is within the temperatures listed, interpolation is required. If it is not within the temperatures listed, then use the last listed value (that is, -40° or +130°F).
19	Determine and record the calibrated muzzle velocity by algebraically applying the correction determined in step 18 to the readout average from step 12.
Legend: F – farenheit m/s – meters per second MVCT – muzzle velocity coreection tables MVS – muzzle velocity system	

M90 VELOCIMETER WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC.

CHARGE GROUP M232A1	DATE AND TIME 280815FEB2015	PROJECTILE FAMILY M107
PROJECTILE MODEL M107DC	POWDER LOT NUMBER IOP09B-031026	PROJECTILE WEIGHT 5 Square

CALIBRATION DATA

ITEMS *a*	GUN 1 CHARGE *b*	GUN 2 CHARGE *c*	GUN 3 CHARGE *d*	GUN 4 CHARGE *e*	GUN 5 CHARGE *f*	GUN 6 CHARGE *g*	GUN 7 CHARGE *h*	GUN 8 CHARGE *i*
1. WEAPON BUMPER NUMBER	A21	A23	A25	A27				
2. WEAPON TUBE NUMBER	1122	2233	3344	4455				
3. STARTING POWDER TEMPERATURE	70	60	61	67				
4. ENDING POWDER TEMPERATURE	70	60	62	68				
5. AVERAGE POWDER TEMPERATURE	70	60	62	68				
M90 VELOCIMETER READOUT								
ROUND 1	702.1	690.0	700.1	704.5				
ROUND 2	708.6	695.5	699.3	706.0				
ROUND 3	703.4	695.2	699.7	704.0				
ROUND 4	702.8	696.7	701.5	705.4				
ROUND 5	702.8	695.0	698.0	705.4				
ROUND 6	701.1	697.2	701.0	704.9				
ROUND 7	702.0	696.0						
ROUND 8								
READOUT AVERAGE	702.4	695.9	699.9	705.0				
MUZZLE VELOCITY COMPUTATION								
6. MUZZLE VELOCITY CORRECTION FOR NONSTANDARD CONDITIONS	+2.4	+4.1	+3.8	+2.7				
7. CALIBRATED MUZZLE VELOCITY	704.8	700.0	703.7	707.7				
8. NUMBER OF WARMUP ROUNDS FIRED	2	2	2	2				

REMARKS

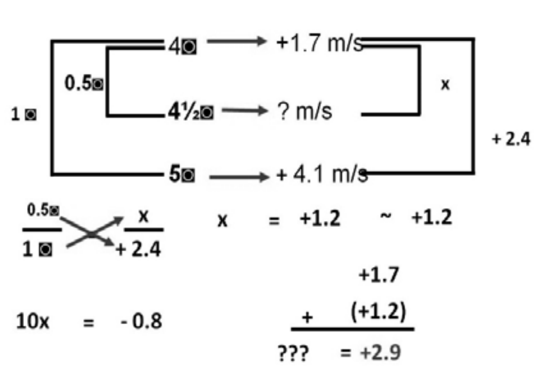
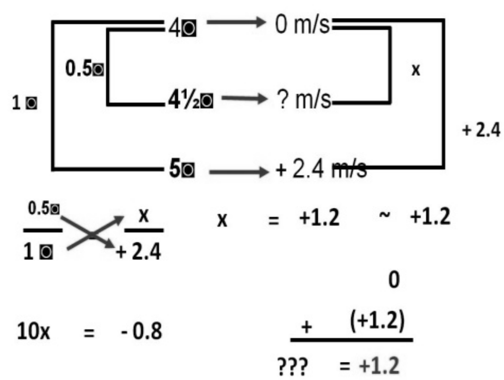
#1)	#1)	#2)	#2)	#3)	#4)
703.5	702.4	694.9	695.9	699.9	705.0
+ 3.0	+ 3.0	+ 3.0	+ 3.0	+ 3.0	+ 3.0
706.5	705.4	697.9	698.9	702.9	708.0
703.5	702.4	694.9	695.9	699.9	705.0
- 3.0	- 3.0	- 3.0	- 3.0	- 3.0	- 3.0
700.5	699.4	691.9	692.9	696.9	702.0

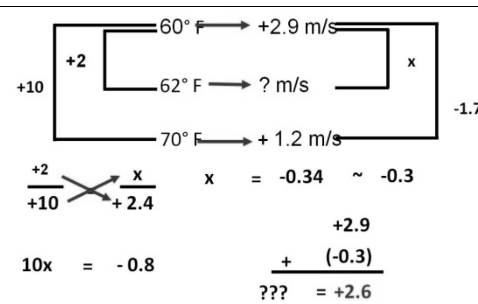
DA FORM 4982-1, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Figure 4-8. M90 Velocimeter Worksheet Example.

4-47. Table 4-3 (on page 4-16) explains the process to account for the projectile half-square weight when it is other than standard.

Table 4-3. Example Determining ½◙ Correcting for Fuze.

<table>
<tr><th>STEP</th><th colspan="2">ACTION</th></tr>
<tr><td>1</td><td colspan="2">Identify the Known Data: Howitzer M109A6 Bumper # A25
Projectile M107
Propellant Charge M232A1, 4H
Projectile Weight 5 SQ
Average Propellant Temperature 62° F
Average Muzzle Velocity Readout 699.9 m/s
Fuze M782</td></tr>
<tr><td>2</td><td colspan="2">Fuze Correction:
Before entering the muzzle velocity correction tables, the projectile weight must also be corrected for any differences in fuze weight. From the known data above:
M782 fuze → - ½◙ (fuze table page 33 MVCT-2 See Figure 4-2)
(5◙-½◙= 4½◙) 4½◙</td></tr>
<tr><td>3</td><td colspan="2">Interpolation Technique: Interpolate between 4◙ and 5◙ to determine the ½◙ correction factors for the listed values (page 57 MVCT-2 See Figure 4-3)and interpolate as follows:</td></tr>
<tr><td>3a</td><td>½ Square Weight Correction for 60° F
4◙ 0 m/s
4½◙ ? m/s
5◙ 4.1 m/s

</td><td>½ Square Weight Correction for 70° F
4◙ 0 m/s
4½◙ ? m/s
5◙ 2.4 m/s

</td></tr>
<tr><td>3b</td><td>Temperature Correction for 4½◙
60° F +2.9 m/s
62° F ? m/s
70° F +1.2 m/s

Muzzle Velocity Correction = +2.6 m/s</td><td>
</td></tr>
<tr><td>4</td><td colspan="2">Determine Calibrated MV.
Calibrated MV= MEASURE MV + CORRECTIONS
699.9m/s + (+2.6m/s)
Calibrated MV= 702.5 m/s</td></tr>
</table>

COMPLETE THE MUZZLE VELOCITY RECORD (DA FORM 4982)

4-48. Complete the Muzzle Velocity Record (DA form 4982). Table 4-4 provides the steps for completing DA Form 4982, and figure 4-9 shows the potion of the form completed through the first nine steps.

Table 4-4. Completing DA Form 4982 for a First-Lot Calibration.

STEP	***Reference***	***ACTION***
1	DATE and POWDER MODEL blocks.	Record date and powder model in the appropriate blocks in the upper right comer of the form.
2	SHELL/FAMILY block.	Record the projectile model and family.
3	FIRST POWDER LOT NUMBER block.	Record the manufacturer's number that identifies this particular lot of powder.
4	GUN NUMBER/CHARGE FIRED block.	Record the particular charge increment fired next to the appropriate weapon number.
5	WEAPON BUMPER NUMBER block (Line 1).	Record the weapon bumper number.
6	WEAPON TUBE NUMBER block (Line 2).	Record the serial number of the tube.
7	FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY block (Line 3).	From the TFT, extract the standard MV for the charge fired in the calibration.
8	CALIBRATED MUZZLE VELOCITY block (Line 4).	Record the calibrated muzzle velocity from line 7 of the MVS work sheet.
9	FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (Line 5).	Compare the calibrated MV to the standard MV, and record the MVV (line 4 - line 3 = MVV).
Legend: MV – muzzle velocity MVS – muzzle velocity system MVV – muzzle velocity variation TFT – tabular firing tables		

MUZZLE VELOCITY RECORD
For use of this form, see TC 3-09.81; the proponent agency is TRADOC

DATE 280815SFEB13
PROPELLANT TYPE: M232A1

FIRST-LOT CALIBRATION

SHELL: M107DC
FAMILY: M107
FIRST POWDER LOT NUMBER IOP09B-031026

ITEMS	GUN NUMBER/CHARGE FIRED							
	1/ 4H	2/4H	3/4H	4/4H	5/	6/	7/	8/
1. WEAPON BUMPER NUMBER	A21	A23	A25	A27				
2. WEAPON TUBE NUMBER	1122	2233	3344	4455				
3. FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY(FROM TFT)	703.0	703.0	703.0	703.0				
4. CALIBRATED MUZZLE VELOCITY	704.8	700.0	703.7	707.7				
5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE4 – LINE3 = LINE5)	+1.8	-3.0	+0.7	+4.7				

SAMPLE

Figure 4-9. DA Form 4982 Muzzle Velocity Record for a first lot calibration.

SUBSEQUENT LOT INFERRED CALIBRATION

4-49. Subsequent Lot Inferred Calibration. Table 4-5 provides the steps for conducting a subsequent lot calibration. Figure 4-10 (on page 4-19) shows DA Form 4982-1 completed for a second-lot inferred calibration. Figure 4-11 on page 4-20 shows DA Form 4982 completed for a second-lot inferred calibration.

Table 4-5. Completing DA Form 4982 for Subsequent Lot Calibration.

STEP	Reference	ACTION
1	Calibration, first lot. Conduct a calibration for all howitzers for the first lot of propellant. Complete DA Form 4982-1 in accordance with Table 4-2 (on page 4-14).	
2	Calibration, second lot. Conduct a calibration for one howitzer for the second lot of propellant. Complete DA Form 4982-1 in accordance with Table 4-2 (on page 4-14).	
3	Administrative information	Record the admin information on DA Form 4982, to include the date, powder model, shell/family, and first powder lot number.
4	FIRST-LOT CALIBRATION section	Record the data from the first calibration for each howitzer on lines 1 through 5 from the first DA Form 4982 (Figure 4-9 on page 4-17).
5	SECOND-LOT CALIBRATION section	Enter the date, time, and powder lot number.
6	SHELL/FAMILY block	Enter the projectile model and family
7	SECOND-LOT POWDER GROUP block	Enter the second-lot powder group
8	GUN NUMBER/CHARGE FIRED block	Enter the calibrated charge fired for the howitzer
9	SECOND-LOT CHARGE STANDARD MUZZLE VELOCITY block (Line 6).	Enter the second-lot standard muzzle velocity for the calibrated charge.
10	SECOND-LOT CALIBRATED MUZZLE VELOCITY block (Line 7).	Enter the second-lot calibrated muzzle velocity from line 7 of the MVS work sheet.
11	SECOND-LOT PIECE MUZZLE VELOCITY VARIATION block (Line 8).	Compute the second-lot muzzle velocity variation (line 7 – line 6 = line 8).
12	FIRST-LOT PIECE MUZZLE VELOCITY VARIATION block (Line 9).	Enter the first-lot piece muzzle velocity variation from line 5.
13	CHANGE IN MUZZLE VELOCITY VARIATION (Line 10).	Determine the change in muzzle velocity variation from the first lot to the second lot (line 8 – line 9 = line 10).
14	SECOND-LOT STANDARD MUZZLE VELOCITY block (Line 11).	For all weapons, enter the second-lot standard muzzle velocity from the TFT.
15	CHANGE IN MUZZLE VELOCITY VARIATION block (Line 12).	Enter the change in muzzle velocity variation from line 10 from the weapon that calibrated the second lot. This value allows us to compensate for propellant efficiency differences between the two lots
16	FIRST-LOT MUZZLE VELOCITY VARIATION block (Line 13).	Enter the first-lot muzzle velocity variation for each weapon from line 5.
17	SECOND-LOT CALIBRATED MUZZLE VELOCITY VARIATION block (Line 14).	Record the sums of lines 12 and 13. This gives an inferred muzzle velocity variation to be used for the second lot for each gun (line 12 + line 13 = line 14).
18	CALIBRATED MUZZLE VELOCITY (Line 15).	Record the sum of lines 11 and 14. (Apply the inferred MVV plus the standard MV from the TFT to determine an MV.) These are **inferred muzzle velocities** (line 11 + line 14 = line 15).
Legend: DA – Department of the Army MV – muzzle velocity MVS – muzzle velocity system MVV – muzzle velocity variation TFT – tabular firing tables		

M90 VELOCIMETER WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC.

CHARGE GROUP	DATE AND TIME	PROJECTILE FAMILY
M232A1 Charge 4H	121130MAR2015	M107
PROJECTILE MODEL	**POWDER LOT NUMBER**	**PROJECTILE WEIGHT**
M107DC	IOP09F-031027	5 Square

CALIBRATION DATA

ITEMS *a*	GUN 1 CHARGE *b*	GUN 2 CHARGE *c*	GUN 3 CHARGE *d*	GUN 4 CHARGE *e*	GUN 5 CHARGE *f*	GUN 6 CHARGE *g*	GUN 7 CHARGE *h*	GUN 8 CHARGE *i*
1. WEAPON BUMPER NUMBER	A21							
2. WEAPON TUBE NUMBER	1122							
3. STARTING POWDER TEMPERATURE	78							
4. ENDING POWDER TEMPERATURE	82							
5. AVERAGE POWDER TEMPERATURE	80							
M90 VELOCIMETER READOUT								
ROUND 1	696.9							
ROUND 2	697.0							
ROUND 3	697.2							
ROUND 4	698.6							
ROUND 5	698.1							
ROUND 6	697.8							
ROUND 7								
ROUND 8								
READOUT AVERAGE	697.6							
MUZZLE VELOCITY COMPUTATION								
6. MUZZLE VELOCITY CORRECTION FOR NONSTANDARD CONDITIONS	+0.7							
7. CALIBRATED MUZZLE VELOCITY	698.3							
8. NUMBER OF WARMUP ROUNDS FIRED	2							

REMARKS

#1) 697.6
+ 3.0
700.6

697.6
- 3.0
694.6

DA FORM 4982-1, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Figure 4-10. M90 Velocimeter Work Sheet for Second-Lot Inferred Calibration.

MUZZLE VELOCITY RECORD

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

DATE **280815SFEB13**

PROPELLANT TYPE: **M232A1**

FIRST-LOT CALIBRATION

SHELL: **M107DC**
FAMILY: **M107**

FIRST POWDER LOT NUMBER **IOP09B-031026**

GUN NUMBER/CHARGE FIRED

ITEMS	1/4H	2/4H	3/4H	4/4H	5/	6/	7/	8/
1. WEAPON BUMPER NUMBER	A21	A23	A25	A27				
2. WEAPON TUBE NUMBER	1122	2233	3344	4455				
3. FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TFT)	703.0	703.0	703.0	703.0				
4. CALIBRATED MUZZLE VELOCITY	704.8	700.0	703.7	707.7				
5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE4 – LINE3 = LINE5)	+1.8	-3.0	+0.7	+4.7				

SECOND-LOT CALIBRATION

SHELL: **M107DC**
FAMILY: **M107**

SECOND POWDER LOT NUMBER **IOP09F-031027**

GUN NUMBER/CHARGE FIRED

DATE: **121130SMAR13**

ITEMS	1/4H	2/	3/	4/	5/	6/	7/	8/
6. SECOND-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TFT)	703.0							
7. SECOND-LOT CALIBRATED MUZZLE VELOCITY	698.3							
8. SECOND-LOT PIECE MUZZLE VELOCITY VARIATION (LINE7 – LINE6 = LINE8)	-4.7							
9. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE5)	+1.8							
10. CHANGE IN MUZZLE VELOCITY VARIATION (LINE8 – LINE9 = LINE10)	-6.5							

SECOND-LOT INFERENCE

ITEMS	1	2	3	4	5	6	7	8
11. SECOND-LOT STANDARD MUZZLE VELOCITY (FROM TFT)	703.0	703.0	703.0	703.0				
12. CHANGE IN MUZZLE VELOCITY VARIATION (LINE10)	-6.5	-6.5	-6.5	-6.5				
13. FIRST-LOT MUZZLE VELOCITY VARIATION (LINE5)	+1.8	-3.0	+0.7	+4.7				
14. SECOND-LOT CALIBRATED MUZZLE VELOCITY VARIATION (LINE12 + LINE13 = LINE14)	-4.7	-9.5	-5.8	-1.8				
15. CALIBRATED MUZZLE VELOCITY (LINE11 + LINE 14 = LINE 15)	698.3	693.5	697.2	701.2				

REMARKS

DA FORM 4982, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Figure 4-11. Muzzle Velocity Record for Second-Lot Inferred Calibration.

DETERMINATION OF SHOOTING STRENGTH

4-50. DA Form 2408-4 provides the information to determine the shooting strength of each howitzer. (See table 4-6.)

Table 4-6. Determination of Shooting Strength.

<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td>1</td><td>Determine the pullover gauge reading from DA Form 2408-4 for the specific howitzer if available.
See figure 4-6 on page 4-12. DA Form 2408-4 the Pullover gauge reading is 6.147</td></tr>
<tr><td>2</td><td>Determine the equivalent number of EFCs by entering the Approximate Losses in Muzzle Velocity table for the correct weapon in the introduction of the appropriate TFT (figure 4-12). Extract the number of EFCs equivalent to the pullover gauge reading. Interpolate as necessary
Note: Ensure that you select the table based on the propellant model you plan on firing. Since the TFT might have multiple tables for Approximate Losses in Muzzle Velocity.
FT 155-AM-3
The following tables may be used as a guide in estimating muzzle velocity departures from the firing table standard due to uniform wear in cannons: M185 and M199, M284 and M776.
Approximate Losses in Muzzle Velocity
155mm Howitzer, Cannons: M199, M284 and M776; Charges: 7R and 4H (M232 and M232A1)
<table>
<tr><th>Number of equivalent full service rounds (erosion)</th><th>Wear measurement (inches)*</th><th>Muzzle Velocity Loss (m/s)</th></tr>
<tr><td>0</td><td>6.100</td><td>0.0</td></tr>
<tr><td>100</td><td>6.107</td><td>0.8</td></tr>
<tr><td>200</td><td>6.114</td><td>1.6</td></tr>
<tr><td>300</td><td>6.121</td><td>2.4</td></tr>
<tr><td>400</td><td>6.127</td><td>3.0</td></tr>
<tr><td>500</td><td>6.134</td><td>3.9</td></tr>
<tr><td>600</td><td>6.141</td><td>4.7</td></tr>
<tr><td>700</td><td>6.147</td><td>5.4</td></tr>
<tr><td>800</td><td>6.154</td><td>6.2</td></tr>
<tr><td>900</td><td>6.160</td><td>7.0</td></tr>
<tr><td>1000</td><td>6.166</td><td>7.6</td></tr>
<tr><td>1100</td><td>6.171</td><td>8.2</td></tr>
<tr><td>1200</td><td>6.176</td><td>8.9</td></tr>
<tr><td>1300</td><td>6.180</td><td>9.5</td></tr>
<tr><td>1400</td><td>6.184</td><td>10.3</td></tr>
<tr><td>1500</td><td>6.188</td><td>11.2</td></tr>
<tr><td>1600</td><td>6.191</td><td>12.0</td></tr>
<tr><td>1700</td><td>6.194</td><td>12.9</td></tr>
<tr><td>1800</td><td>6.197</td><td>14.0</td></tr>
<tr><td>1900</td><td>6.199</td><td>14.7</td></tr>
<tr><td>2000</td><td>6.200</td><td>15.2</td></tr>
<tr><td>2100</td><td>6.201</td><td>15.5</td></tr>
<tr><td>2200</td><td>6.202</td><td>16.3</td></tr>
<tr><td>2300</td><td>6.203</td><td>16.7</td></tr>
<tr><td>2400</td><td>6.204</td><td>17.3</td></tr>
<tr><td>2500</td><td>6.205</td><td>18.0</td></tr>
</table>
* The wear measurement is taken 41.75 inches forward of the rear face of the tube.
Figure 4-12. Approximate Losses in Muzzle Velocity.
For the POG (Wear measurement) value of 6.147 the EFC value is 700.</td></tr>
<tr><td></td><td>Note: If POG is the last entry in DA Form 2408-4, determine shooting strength (SS) by interpolating from the Wear Measurement column to the Muzzle Velocity loss column.</td></tr>
</table>

Table 4-6. Determination of Shooting Strength (continued).

STEP	ACTION
3	Determine the total number of erosion EFCs since the pullover reading. Multiply the number of rounds fire by the erosion factor for the appropriate projectile-propellant charge combination. If unknown, use the pullover gauge reading. Based on Figure 4-6 on page 4-12, DA Form 2408-4 after the last POG the howitzer fired 200 round of charge 4H With this information we refer to Equivalent Service Round Table in the respective TFT and determine the erosion factor (see figure 4-13).

Charge	Zone	Fatigue Life		Erosion Life	
		No. of rds equivalent in fatigue to one full chg	Equivalent fatigue effect in decimals	No. of rds equivalent in erosion to one full chg	Equivalent erosion effect in decimals
Cannon, 155mm Howitzer, M185[(a)]					
M119A2	7R	1.00	1.00	1.00	1.00
Cannons, 155mm Howitzer, M199[(b)], M284[(c)], M776[(d)]					
M119A2	7R	4.00	0.25	2.00	0.50
M232	4H	4.00	0.25	2.00	0.50
M232	3H	10.00	0.10	5.00	0.20
M232A1	4H	4.00	0.25	2.00	0.50
M232A1	3H	10.00	0.10	5.00	0.20
M231	2L	6.67	0.15	20.00	0.05
M231	1L	20.00	0.05	100.00	0.01

Figure 4-13. Equivalent Full Service Rounds Table

Notice that for this table the erosion factors are the same for the M232 and M232A1 4H

The value of 0.50 is multiplied by the number of rounds fired (200).

EFC from rounds fired = EFC Erosion Factor X Number of rounds fired

0.50 X 200=100 EFCs from the rounds fired

Note: Raw mathematical values will be determined while solving for the EFC equivalencies only to be expressed to the nearest full EFC when solving for shooting strength in the final solution of the problem.

STEP	ACTION
4	Determine the equivalent cumulative number of EFCs for the specific howitzer by adding the value in step 2 to the value in step 3 For our example, 700 was the EFCs from the POG 6.147 and 100 EFC from the rounds fired 700+100= 800 EFCs

Table 4-6. Determination of Shooting Strength (continued).

<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td>5</td><td>
Determine the loss in muzzle velocity by entering the table (figure 4-14 on page 4-23) with the equivalent cumulative number of EFCs; Interpolate as necessary.

FT 155-AM-3

The following tables may be used as a guide in estimating muzzle velocity departures from the firing table standard due to uniform wear in cannons: M185 and M199, M284 and M776.

Approximate Losses in Muzzle Velocity

155mm Howitzer, Cannons: M199, M284 and M776; Charges: 7R and 4H (M232 and M232A1)

<table>
<tr><th>Number of equivalent full service rounds (erosion)</th><th>Wear measurement (inches)*</th><th>Muzzle Velocity Loss (m/s)</th></tr>
<tr><td>0</td><td>6.100</td><td>0.0</td></tr>
<tr><td>100</td><td>6.107</td><td>0.8</td></tr>
<tr><td>200</td><td>6.114</td><td>1.6</td></tr>
<tr><td>300</td><td>6.121</td><td>2.4</td></tr>
<tr><td>400</td><td>6.127</td><td>3.0</td></tr>
<tr><td>500</td><td>6.134</td><td>3.9</td></tr>
<tr><td>600</td><td>6.141</td><td>4.7</td></tr>
<tr><td>700</td><td>6.147</td><td>5.4</td></tr>
<tr><td>800</td><td>6.154</td><td>6.2</td></tr>
<tr><td>900</td><td>6.160</td><td>7.0</td></tr>
<tr><td>1000</td><td>6.166</td><td>7.6</td></tr>
<tr><td>1100</td><td>6.171</td><td>8.2</td></tr>
<tr><td>1200</td><td>6.176</td><td>8.9</td></tr>
<tr><td>1300</td><td>6.180</td><td>9.5</td></tr>
<tr><td>1400</td><td>6.184</td><td>10.3</td></tr>
<tr><td>1500</td><td>6.188</td><td>11.2</td></tr>
<tr><td>1600</td><td>6.191</td><td>12.0</td></tr>
<tr><td>1700</td><td>6.194</td><td>12.9</td></tr>
<tr><td>1800</td><td>6.197</td><td>14.0</td></tr>
<tr><td>1900</td><td>6.199</td><td>14.7</td></tr>
<tr><td>2000</td><td>6.200</td><td>15.2</td></tr>
<tr><td>2100</td><td>6.201</td><td>15.5</td></tr>
<tr><td>2200</td><td>6.202</td><td>16.3</td></tr>
<tr><td>2300</td><td>6.203</td><td>16.7</td></tr>
<tr><td>2400</td><td>6.204</td><td>17.3</td></tr>
<tr><td>2500</td><td>6.205</td><td>18.0</td></tr>
</table>
* The wear measurement is taken 41.75 inches forward of the rear face of the tube.

Figure 4-14. Approximate Losses in Muzzle Velocity

The Cumulative EFCs is 800, so we can determine a SS of -6.2 m/s from the Muzzle Velocity Loss column.
Note: SS is always negative.
</td></tr>
<tr><td>6</td><td>The value determined approximates the shooting strength of the howitzer and can be used as the MVV if no propellant efficiencies are available. Repeat step 1-6 for all howitzers and projectile families to be fire.</td></tr>
</table>

Table 4-6. Determination of Shooting Strength (continued).

STEP	***ACTION***
7	Refer to the MVV Log Book Propellant Efficiency Tab (figure 4-15) and identify the Propellant Model, then the propellant lot and then the appropriated charge and extract the propellant efficiency.

DODIC	Model	LOT #	Charge-3H (m/s)	Charge-4H (m/s)	Charge-5H (m/s)
DA13	M232A1	IOP08J-031024	+2.7	+1.8	(-0.3)
DA13	M232A1	IOP08K-031024	+3.7	+3.3	+0.7
DA13	M232A1	IOP08L-031025	+4.1	+4.8	+2.4
DA13	M232A1	IOP09B-031026	+6.5	+5.9	+2.9
DA13	M232A1	IOP09F-031027	+2.8	+2.3	(-0.8)
DA13	M232A1	IOP09H-031028	(-1.9)	0.0	(-1.1)
DA13	M232A1	IOP09K-031029	+1.6	+1.2	+3.6
DA13	M232A1	IOP09M-031030	+1.3	+1.0	+1.1

** new for v5-02

Figure 4-15. MACS Propellant Efficiencies (PE) Example

Note: DO NOT USE Figure 4-15 to predict MVV's for firing.

STEP	***ACTION***
	Based on our Propellant Model M232A1,and lot IOP09B-031026 firing Charge 4H you would determine a PE of +5.9m/s
8	Determine MVV with Shooting Strength and Propellant Efficiency. MVV is also determine by the algebraic sum of the Shooting Strength and Propellant Efficiency MVV= SS + PE Example SS=-6.2m/s (Step 5) PE= +5.9m/s(Step 7) MVV= -6.2m/s + (+5.9m/s) MVV= -0.3 m/s
Legend: DODIC – Department of Defense Identification Code EFC – effective full charge m/s – meters per second MVV – muzzle velocity variation No. – number PE – propellent efficiency POG – pull over gauge rds – rounds SS – shooting strength TFT – tabular firing tables	

SECTION V: MUZZLE VELOCITY MANAGEMENT

4-51. Muzzle velocity management is the process of tracking the differences in muzzle velocity between the expected muzzle velocity, based on projectile weight, propellant temperature and cannon wear, and the measured muzzle velocity obtained from muzzle velocity system. The goal of muzzle velocity data management is to provide an accurate estimate of the average muzzle velocity for a particular fire mission, based on the weapon, projectile, propellant lot, propelling charge, cannon wear, propellant temperature and projectile weight.

4-52. Three techniques can be used to determine muzzle velocity within the firing unit. The accuracy and complexity of these different techniques varies greatly. Each of the techniques must be understood and applied correctly to the tactical situation. The following is the order of preference and should be used as a guideline. **The techniques are listed in order of decreasing preference**.

- First Lot Calibration (baseline calibration).
- Predictive muzzle velocity techniques (when available).
  - MVV= Shooting Strength (SS) + Propellant Efficiency (PE)
  - Apply SS
  - Apply PE
- Subsequent lot inferred calibration.

TRANSFERRING MVVS

4-53. Ideally, every charge should be calibrated. However, this may not always be feasible. Therefore, the calibration of a few charges, one within each charge group that results in an MVV applicable to other charges within a charge group, is imperative. For calibration purposes, there are two categories of charges within a charge group. These are preferred charges and restricted charges. The following guidance is established as an order of preference when selecting a charge to calibrate:

- If you know the charge you will be firing calibrate that charge.
- If the charge you will be shooting is unknown, calibrate the middle charge of the preferred charge group.
- Calibration data determined should only be applied to a subsequent fire mission when the mission meets the following requirement:
  - It is the same calibrated howitzer
  - Firing the same calibrated projectile family
  - Firing the same calibrated propellant lot.
  - Once calibration data are determined for a particular charge, these data can be transferred to other charges in the same lot. The order of preference for transferring bag charges (i.e. M3A1 and M4A2) is as follows:
    - Same Charge.
    - Transfer down 1 charge.
    - Transfer up 1 charge.
    - Transfer down 2 charges.
    - Transfer up 2 charges.
    - Transfer to any preferred charge.
    - Transfer from preferred to restrictive charge.
    - Apply to restricted charge only if calibrated with same restrictive charge.
  - The rules for transferring MACS vary from those for the bag charges listed above. The restriction of transferring MVVs to another charge within the same lot remains the same. The order of preference for transferring MACS charges is as follows:
    - All lots of M231 are restricted charges and therefore not preferred to transfer MVVs up or down between 1L and 2L.
    - All lots of M232 are the charge groups from 3H to 5H, with the preferred charge being 4H for transferring MVVs up or down between 3H and 5H.
    - All lots of M232A1 are the charge groups from 3H to 5H, with the preffered charge being 4H for transferring MVVs up or down between 3H and 5H.

Note: Shooting strength and ammo efficiency make up the achieved MV. With higher charges, there is more erosion but less variance in ammo efficiency. For lower charges, there is less erosion but more variance in ammo efficiency. Therefore, the general overall effect is less variance when transferring down as opposed to up.

Note: MVVs should not be transferred from a restricted charge to any other charge on the basis of the nature (large round-to-round variances) of restricted charges.

UPDATING PROPELLANT EFFICIENCIES DATA

4-54. Once determined, the calibration data represent the best indicator of the expected MVV. But the MVV is not valid forever since the howitzer shooting strength changes as more rounds are fired. Calibration data can be made indefinitely valid if the shooting strength of the howitzer is determined at the time of calibration. The shooting strength is subtracted from the MVV and this will provide an accurate PE that can be use later. This is done by modifying the formula MVV= SS+ PE. It is important to isolate the propellant efficiencies (MVV – Shooting Strength = Propellant Efficiency) after an MVV has been captured for a specific howitzer. This math procedure may be performed in the bottom "Remarks" field of the DA Form 4982. If logged correctly, isolating propellant efficiencies may provide the battery or battalion a more accurate MVV when only predictive MVV's are possible (see table 4-7). An accurate propellant efficiency may provide a more accurate MVV than just calculating shooting strength.

Table 4-7. Determining Unit PE After a Calibration.

<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td>1</td><td>Record First Lot calibration (figure 4-16) as described in Table 4-4 on page 4-17.
<table>
<tr><td>5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE4 – LINE3 = LINE5)</td><td>-5.2</td><td>-3.5</td><td>-1.2</td><td>0.3</td><td></td><td></td><td></td><td></td></tr>
</table>
Figure 4-16. Muzzle Velocity Record for a First Lot Calibration, Line 5.</td></tr>
<tr><td>2</td><td>In the lower computational space record formula: PE = MVV – SS (See below Figure 4-17).</td></tr>
<tr><td>3</td><td>Determine an accurate SS for each weapon. As discussed in Table 4-6 on page 4-21.</td></tr>
<tr><td>4</td><td>Determine PE for each gun and battery average PE (figure 4-17).
<table>
<tr><th colspan="5">REMARKS</th></tr>
<tr><td></td><td>#1</td><td>#2</td><td>#3</td><td>#4</td></tr>
<tr><td>MVV</td><td>-5.2</td><td>-3.5</td><td>-1.5</td><td>-0.3</td></tr>
<tr><td>- SS</td><td>- (-3.9)</td><td>- (-2.0)</td><td>- (-0.6)</td><td>- (-2.4)</td></tr>
<tr><td>PE</td><td>-1.3</td><td>-1.5</td><td>-0.9</td><td>+2.1</td></tr>
</table>
DA FORM 4982-R
Figure 4-17. Muzzle Velocity Record Remarks Block.</td></tr>
<tr><td></td><td>Note: Disregard a PE outside (±) 3 m/s from battery average. is disregarded and re-average battery without the disregarded PE</td></tr>
<tr><td>5</td><td>Determine The average PE for this example is -1.3 m/s</td></tr>
<tr><td colspan="2">Legend: m/s – meters per second MVV – muzzle velocity variation PE – propellent efficiency SS – shooting strength</td></tr>
</table>

Note: Propellant efficiency values are transferable since they are independent of a shooting strength, variable and may provide more accurate data to enable massing of fires when conducting battalion level missions

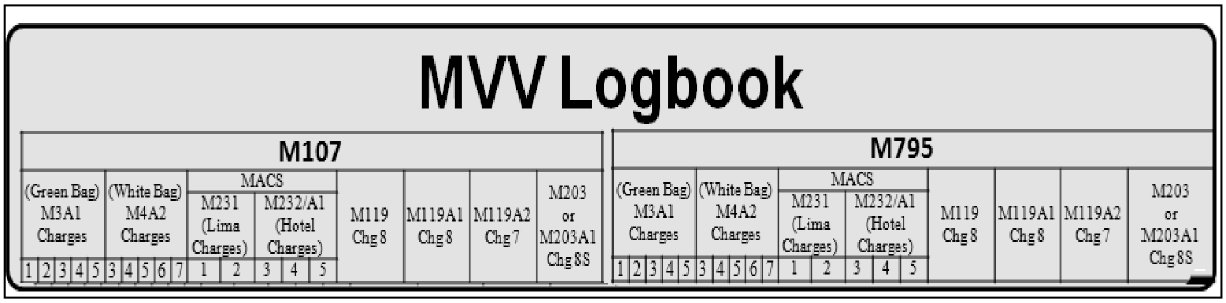
MVV LOGBOOK

4-55. Once MV data have been determined, these data are used for numerous techniques. MV data must be recorded on DA Form 4982 which is then filed in an MV logbook. The MV logbook allows for quick referencing of howitzer performance when firing a particular projectile family-propellant lot-charge combination. Historical MV's from the MVV logbook can be applied to missions if they match the projectile-family-propellant lot-charge combination. If not a match, they may be transferred according to the order of preference found later in this chapter. Using historical MV's may be more accurate than predictive MVV techniques. The major sections in the MV logbook are for the projectile families. Each one of the sections should be tabbed for each authorized propellant type-charge group for the projectile family. See figures 4-18 and 4-19 (page 4-27) below for an example of FDC Record keeping:

- Organizing the logbook. The FDO separates the major portions of his logbook by projectile families.

Figure 4-18. Muzzle Velocity Variation (MVV) Logbook Major Tabs.

- Tabbing the logbook. Each section (Projectile Family) of the MVV logbook is tabbed with all possible powder models.



Legend: Chg – charge MACS – modular artillery charge system

Figure 4-19. Muzzle Velocity Variation (MVV) Logbook Tabs.

FREQUENCY OF CALIBRATION

4-56. Ideally, calibration occurs continuously. If that is impractical or impossible, the following methods identify when to consider calibrating.

4-57. **Initial Receipt or Retubing**. All new howitzers of a given caliber and model will not necessarily develop the same muzzle velocity because of the tolerances that are allowed in the size of the powder chamber and in the dimensions of the bore. Therefore, howitzers should be calibrated as soon as possible after receipt or when retubed. Muzzle velocities should be recorded on DA Form 4982 and DA Form 4982-1 with accurate bumper number and weapon tube numbers for proper logging.

4-58. **Change in Propellant Lot**. Calibration should be conducted as soon as possible after an uncalibrated propellant lot is received.

4-59. **New Projectile Family**. Calibration should be conducted if a new projectile; for example, M825A1 smoke (projectile family M795), is received for which there are no previous MV records for that projectile family.

4-60. **Annually**. Any piece in service should be recalibrated at least annually. The primary factor contributing to the loss in muzzle velocity for a piece is the number of rounds that have been fired through the tube and the charges used in firing them. Higher charges increase tube wear, which, in turn, tends to decrease muzzle velocity. Guns, because of their higher velocities, tend to display tube wear more quickly than howitzers. If a great deal of firing takes place, recalibration will be needed more often than annually. Methods of determining when recalibration may be needed are outlined below. The following situations assume that firing takes place with a previously calibrated projectile family-propellant lot.

4-61. **Changes in velocity error (VE)**. If an accurate record of the changes in velocity error (VE) determined from concurrent met solutions is maintained, it may be used as a guide for determining the need for recalibration. When the velocity loss since the last calibration is equivalent to 2 range probable errors, the need for recalibration is indicated. (An indicator of this is a loss of +/-1.5 m/s, which generally approximates 2 probable errors in range.)

4-62. **Tube Wear**. The extent of tube wear near the beginning of the rifling of the bore indicates the loss in muzzle velocity and the remaining tube life. Precise measurement of the distance between the lands in the bore near the start of the rifling can be made with a pullover gauge. Field maintenance has this gauge and makes the measurement. The wear measurement, when compared with the data in the “wear” table (Approximate Losses in Muzzle Velocity table) in the introduction of each firing table, can be used in estimating the loss in muzzle velocity.

4-63. **EFCs**. A change in the number of erosion EFC service rounds as depicted in the weapon record book may also indicate a need for recalibration. (Refer to paragraph 4-3 for more information about EFCs.) The change in erosion EFC rounds compared with data in the Approximate Losses in Muzzle Velocity table (in the introduction of each TFT) that corresponds to a loss of 1.5 m/s in muzzle velocity may indicate a need for recalibration. A loss of 1.5 m/s in MV generally equates to the effects of 2 probable errors in range (2 PE_R)

Chapter 5

Fire Mission Messages

The processing of a fire mission involves three essential messages. These are the fire order, message to observer, and fire commands. These messages contain the necessary information to tactically engage the target, control the mission, and transmit technical fire direction to the howitzers.

SECTION I: FIRE ORDER

5-1. In the fire order, the FDO specifies how the target will be attacked. This is tactical fire direction.

OVERVIEW

5-2. When the FDC receives a call for fire (CFF), the FDO must determine if and how the target will be attacked. This decision (part of tactical fire direction) may be made at the battalion or battery or platoon FDC. In battalion missions, the battalion FDO is responsible for issuing the fire order. In autonomous operations, the battery or platoon FDO is responsible for issuing the fire order. A fire order is the FDO's decision on what unit(s) will fire and how much and what type of ammunition will be fired. It is based on the FDO's analysis of the target.

TARGET ATTACK CONSIDERATIONS

5-3. In determining how, if at all, to attack a target, the FDO must consider several factors.

- **Location of the Target**. The FDO must check the location relative to friendly forces, fire support coordination measures, and zones of responsibility. Target location accuracy must also be considered. The range to the target will affect the choice of unit(s) to fire and charge. The terrain around the target may influence ammunition selection and type of trajectory. High intermediate crests may require selection of a lower charge or high-angle fire.
- **Nature of the Target**. The size and type of target (for example, troops, vehicles, hard, soft, and so on) will affect the following:
- **Number of units to fire**.
- **Type of sheaf**.
- **Selection of ammunition**.
- **Number of rounds in fire for effect**.
  - Priority.
  - Whether surprise fire (for example, time on target [TOT]) is possible.
- **Ammunition Available**. The FDO must consider the amount and type of ammunition available and the controlled supply rate (CSR).
- **Units Available**. The number of units available will not only affect which units will be used, but also the type of attack. Sweep and/or zone fire or other techniques may be needed to cover large targets when enough units are not available.
- **Commander's Guidance** or Standard operating procedures. Restrictions on ammunition, the operations order, and SOPs may govern the selection of units and ammunition, target priority, and method of attack. While developing his guidance he may refer to Joint Munitions Effectiveness Manual Weaponeering System (JWS) to determine the type munitions and volume of fire to be delivered.

- **Call for Fire**. The FDO must consider the observer's request carefully since he is observing the target communicates directly with the maneuver commander. The observer's request should be honored when possible.
- **Munitions Effects**. The FDO will rely most often on the attack guidance matrixes, commander's guidance, and/or experience.
- **Availability of Corrections**. The availability of corrections to firing data for nonstandard conditions is a guiding factor in the choice of charge and munitions, since it directly affects accuracy.
- **Enemy Target Acquisition Capability**. Knowledge of the current enemy counter battery radar and sound-ranging capabilities allows the FDO to attack the target in a manner most likely to avoid detection of the unit's location.

FIRE ORDER ELEMENTS

5-4. In autonomous operations, the battery or platoon FDO must issue a fire order. The fire order will address all information needed to conduct the mission. The fire order consists of 10 elements and is issued in the following prescribed sequence (see figure 5-1).

ELEMENTS
UNIT TO FIRE
ADJUSTING ELEMENT AND/OR METHOD OF FIRE, OF THE ADJUSTING ELEMENT. Projectile in adjustment Lot and charge in adjustment Fuze in adjustment
BASIS FOR CORRECTIONS
DISTRIBUTION
SPECIAL INSTRUCTIONS
METHOD OF FIRE FOR EFFECT
PROJECTILE IN EFFECT
AMMUNITION LOT AND CHARGE IN EFFECT
FUZE IN EFFECT
TARGET NUMBER

Figure 5-1. Fire Order Elements.

Note: If not standardized by unit SOP, the elements in figure 5-1 will be addressed in the fire order.

5-5. **UNIT TO FIRE**. Indicates the units to follow the mission and to fire for effect. Normally, BATTERY or PLATOON is announced as the unit to fire.

5-6. **ADJUSTING ELEMENT AND/OR METHOD OF FIRE OF THE ADJUSTING ELEMENT** (if applicable). Indicates the howitzer(s) that will adjust. Normally, the base piece (BP) is selected and will fire one round in adjustment.

- **Projectile in adjustment**. This is the type of shell to be fired by the adjusting howitzer in an adjust-fire mission.
- **Lot and charge in adjustment**. This is the ammunition lot (for the shell and propellant in separate loading ammunition and for the shell in semi-fixed loading ammunition) and the charge to be fired by the adjusting howitzer in an adjust-fire mission.
- **Fuze in adjustment**. This is the type of fuze to be fired by the adjusting howitzer in an adjust-fire mission.

5-7. **BASIS FOR CORRECTIONS**. This element dictates how data will be determined. Normally, the fastest method is designated.

5-8. **DISTRIBUTION**. This element describes the pattern of bursts (sheaf) in or around the target area. There are four basic types of sheaf's that may be obtained with TGPCs and special corrections.

- **Converged sheaf**. All weapons have the same aim-point.
- **Parallel sheaf**. Is assumed that a parallel sheaf will resembles the arrangement of the pieces in the firing position.
- **Open sheaf**. Aim-points are separated by one effective burst width. Figure 5-2 on page 5-4 shows sheaf widths for an open sheaf. The open sheaf width equals the number of howitzers multiplied by the projectile effective burst width. The line is perpendicular to the Gun Target Line (GTL).
- **Special sheafs**. Special sheaf's are sheaf's other than parallel, converged, or open.
  - **Linear**. The sheaf is described by a length and attitude or by two grids. Aim-points are evenly distributed along the length of the sheaf along the attitude specified.
  - **Rectangular**. The sheaf is described by a length, width, and attitude. Aim-points are evenly distributed along two lines equal to the length and parallel to the attitude specified.

Note: When the length is greater or equal to five time the width, the target is linear.

  - **Circular**. The sheaf is described by a grid and a radius. Aim-points are evenly distributed on a concentric circle half the radius specified.
  - **Irregular**. The sheaf is described by a series of grids. Aim-points are evenly distributed along the length of the sheaf. The sheaf computed may vary from the assumed sheaf on the basis of the number of howitzers available, target size, attitude, and description received from the observer (OBS). If the FDO desires a sheaf other than the assumed sheaf, he will announce it here.

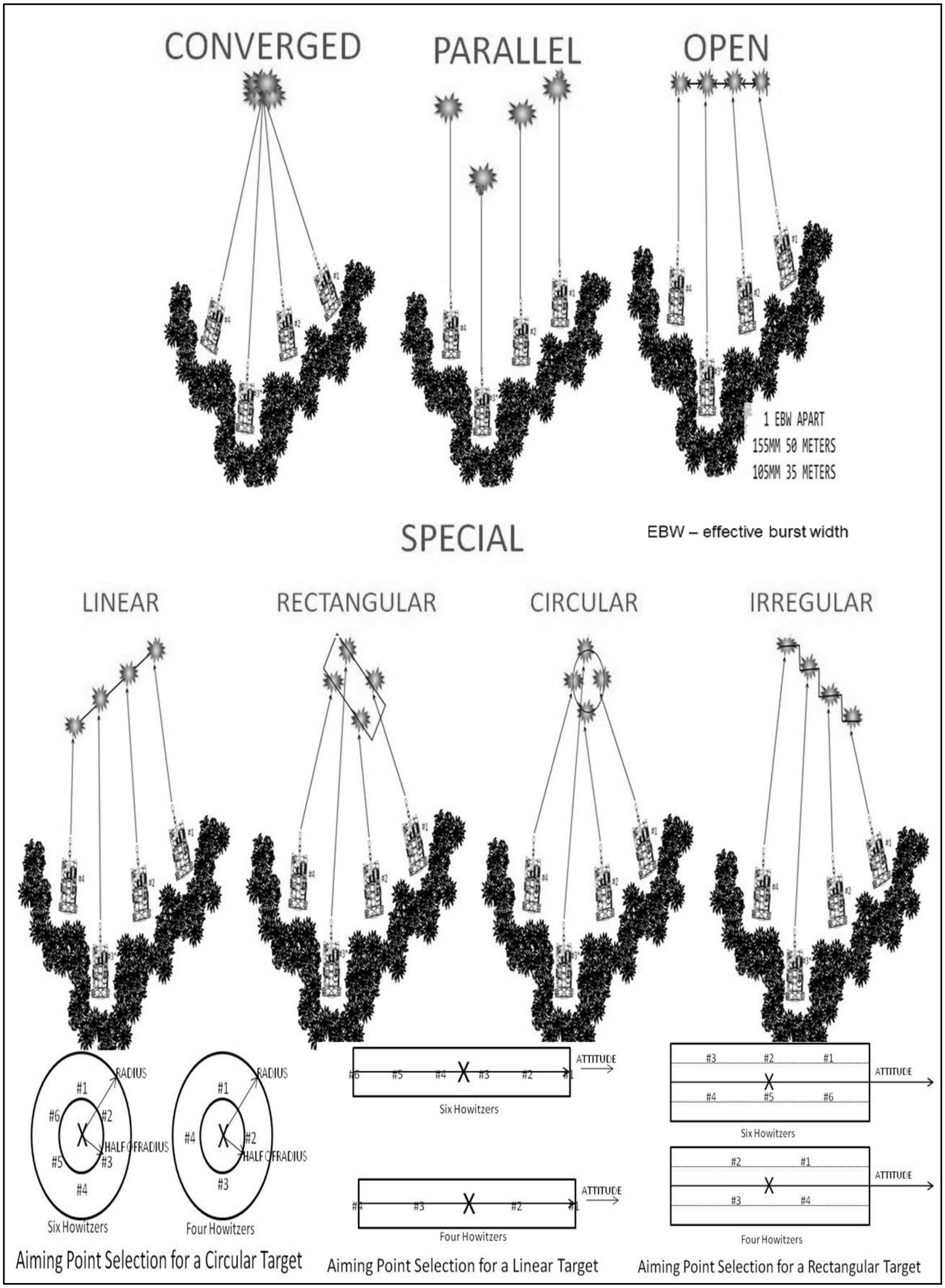


Figure 5-2. Sheaf Distributions.

5-9. **SPECIAL INSTRUCTIONS**. This element is any method of control or coordinating instructions deemed appropriate by the FDO.

5-10. **METHOD OF FIRE FOR EFFECT**. This element indicates the number of rounds in the fire for effect phase of a mission. This element will always be announced by the FDO.

5-11. **PROJECTILE IN EFFECT**. This element is the projectile to be fired in effect.

5-12. **AMMUNITION LOT AND CHARGE IN EFFECT**. This element is the ammunition lot(s) and charge used in fire for effect.

5-13. **FUZE IN EFFECT**. This element is the fuze to be fired in effect.

5-14. **TARGET NUMBER**. This element is the specific target number assigned to a fire mission.

BATTERY OR PLATOON FIRE ORDER

5-15. The guidance in table 5-1 will be used in issuing the fire order.

Table 5-1. Battery or Platoon Fire Order.

STEP	***ACTION***
1	**UNIT TO FIRE**. This element is the unit that the FDO desires to fire in the effect. In an adjust-fire mission, the unit to fire will be those howitzers that follow the mission. The possible selections for are: BTRY (battery) PLT (platoon) LEFT CENTER RIGHT Any howitzer number or combination of gun numbers.
2	**ADJUSTING ELEMENT AND/OR MOF** **Projectile in adj** **Lot and charge in adj** **Fuze in adj** This element indicates that the howitzer that will conduct the adjustment in the adjust fire mission and the number and type of rounds to be fire per tube for each adjustment. The possible selections for are: BTRY PLT LEFT CENTER RIGHT Any howitzer number or combination of howitzers. In an adjust-fire mission, it may be necessary to adjust with a projectile other than HE. When that happens, the projectile, lot, and fuze to be fired in adjustment will be addressed by the FDO as part of the method of fire in adjustment. The possible selections are: ANY NUMBER OF ROUNDS (usually one round) PROJECTILE (usually HE) LOT AND CHG FUZE (usually QUICK)

Table 5-1. Battery or Platoon Fire Order (continued).

STEP	***ACTION***
3	**BASIS FOR CORRECTIONS**. This element indicates the method that will be used to compute firing data for the mission. The possible selections for are: Use Digital System Use TFT (Tabular Firing Tables) Use GFT (Graphical Firing Tables) Met + Velocity Error Usually the Fastest Technique is Used.
4	**DISTRIBUTION**. This element indicates describes the desired pattern of burst (sheaf) in the target area. The possible selections for are: PARALLEL CONVERGED OPEN SPECIAL Additional information may be required for situations in which a special sheaf is to be fired. Immediately following the announcement of **SPECIAL**, any additional instructions concerning the sheaf will be announced. This pertains especially to family of scatterable mines (FASCAM) procedures. For example, the announcement **SPECIAL 3 AIMPOINTS**.
	NOTE: Converge, Open, and Special sheaf will required that special instruction of **SPECIAL CORRECTIONS** be announced in the fire-for-effect stage of this mission.
5	**SPECIAL INSTRUCTIONS**. This element provides a place for the FDO to control the time of opening fire and special methods of attacks. When more than one special instruction applies, restrictive commands should be announced first. The possible selections for are discussed below. **WHEN READY (WR) is not a special instruction**. It is the standard time of opening fire unless a special instruction is imposed. This indicates that the howitzer may fire at the section chief's command after receiving quadrant. **AT MY COMMAND (AMC)** is a restrictive command that allows the FDO to control the time of firing from the FDC. When announce in the special instructions of the fire order, AMC will indicate that each round in the adjustment stage and the first volley of fire for effect will be at the FDC's command. AMC will be announced to the howitzer as a special instruction in the fire commands. **BY PIECE AT MY COMMAND (BPAMC)** is a restrictive command that allows the FDO to control the time of firing by howitzer at the FDC's command. BPAMC is announced as special instruction in the fire command. **BY ROUND AT MY COMMAND (BRAMC)** is a restrictive command that allows the FDO to control the time of firing of a group of rounds by volley. BRAMC is announced to the howitzer as special instruction in the fire commands and will pertain to all stages of the mission. **BY PIECE, BY ROUND, AT MY COMMAND (BPBRAMC)** is a restrictive command which combines both BY PIECE and BY ROUND AT MY COMMAND control. BPBRAMC is announced as a special instruction the fire commands.

Table 5-1. Battery or Platoon Fire Order (continued).

STEP	***ACTION***
5	**TIME ON TARGET (TOT)** is a restrictive command that allow the FDO to control the time of firing by indicating the time the rounds will impact at the target area. This technique uses a precise determination of the time of flight from battery to the target. When a Time on Target (TOT) is desired the FDC determines the Time To Fire (TTF) by subtracting the time of flight from the TOT. **The FDC will announce AMC to the howitzer as a special instruction in the fire commands and will control the opening of fires** **RIGHT (or left) BY PIECE AT (interval)** is a restrictive command which will cause the howitzer to fire at an announced interval beginning at either end of the gun line. This is used to allow the observer to examine the impacts and determine pieces that are placing rounds outside the sheaf. **DO NOT LOAD (DNL)** is a restrictive fire command that prohibits loading and firing. The section may prepare the projectile, charge, and fuze (if applicable) and lay the howitzer for deflection; and set the quadrant elevation (or loading elevation). This command will be used when a long period of time may elapse before the firing of the mission. This allows other missions to be processed. DNL is announced as a special instruction in the fire commands. **CANCEL DO NOT LOAD (CDNL), QUADRANT (so much)** is the supplementary command of DNL. This command allows the howitzers to load if not otherwise restricted by special instructions. The target number may be used in place of the command QUADRANT to allow loading and firing of preplanned targets and scheduled fires. CANCEL DO NOT LOAD does not apply to the entire mission, it must be announced with each initial or subsequent command. Other restrictive commands may be necessary; for example CANCEL DO NOT LOAD, TARGET NUMBER AC4000 [If applicable], AMC, and QUADRANT 347. **AZIMUTH (AZ)** may be included in the fire order when the FDO examines the plot of the target and finds that the howitzers must shift trails. The command AZIMUTH (four-digit value) is announced as a special instruction in the fire commands. **SPECIAL CORRECTIONS, (LEFT, CENTER, or RIGHT) SECTOR** is announced when terrain gun position corrections for other than the primary sector are being used. If TGPCs are computed, the corrections for primary sector are set on the gunner's aid of all weapons. These corrections are announced administratively and recorded on the DA Form 5212-R (Gunner's Reference Card). To change sectors, the FDC commands (LEFT, CENTER or RIGHT) SECTOR. Upon termination of the mission, the howitzer sections reapply the corrections that were in effect before the mission. **CANCEL TERRAIN GUN POSITION CORRECTIONS (CTGPC)** is announced by the FDO when he/she does not want the howitzer to apply TGPCs previously announced. CTGPC applies only to the mission in which the command is announced. CTGPC is announced as a special instruction in the fire commands. **HIGH ANGLE (HA)** indicated that the mission is to be fired at an angle of elevation greater than 800 mils. Light artillery weapons can be elevated before loading. Medium and heavy artillery weapons normally must be loaded at loading elevation. HA is announced as a special instruction in the fire commands.

Table 5-1. Battery or Platoon Fire Order (continued).

STEP	***ACTION***
5	**SWEEP (so many) MILS, (so many) DEFLECTIONS**, commands a method of fire used when the standard sheaf does not adequately cover the target and more width is required. Sweep fire provides for firing several deflections with one quadrant. The section chief computes the required deflections based on data determined by the FDC, fires initial deflection, and then fires the remaining deflections in any order or as directed by unit SOP. SWEEP fires always include an odd number of deflections to be fire. SWEEP (so many) MILS, (so many) DEFLECTIONS is announced as a special instruction in the fire commands. **ZONE (so many) MILS, (so many) QUADRANTS** commands a method of fire used when the standard sheaf does not adequately cover the target and more depth is required. Zone fire provides for firing one deflection with several quadrants. The section chief computes the required quadrants based on data determined by the FDC , fires the initial quadrant, and then fires the remaining quadrants in any order or as directed by unit SOP. ZONE fires always include an odd number of quadrants to be fire. ZONE (so many) MILS, (so many) QUADRANTS is announced as a special instruction in the fire commands. **SWEEP (so many) MILS, (so many) DEFLECTIONS, ZONE (so many) MILS, (so many) QUADRANTS** commands a method of fire combining sweep fire and zone fire. Sweep and zone fire provides for firing several deflections and quadrants. The chief of section fires the initial commands for deflection and quadrant first and then fires all combinations of computed deflections and quadrants, in any order or as directed by unit SOP. Procedures for determining data for Sweep and/or Zone missions are found in Appendix G. **SPECIAL CORRECTIONS** is announced by the FDO to alert the crew when a separate time, deflection, and/or quadrant will be sent to or fired by one or more howitzer sections. The words SPECIAL CORRECTION(S) should precede any special corrections that apply in the fire command. This command prevents misunderstanding and unnecessary repetition of missed special corrections. If SPECIAL CORRECTIONS is announced alone, it alerts the sections that separate data will be sent to one or more sections. Unit SOP and degree or training dictates how this should be implemented. SPECIAL CORRECTIONS is announced as a special instruction in the fire commands. **USE GUNNER'S QUADRANT** is announced, by the FDO when the FDC desires the gunner's quadrant be used to set or check quadrant elevation. This is more often used when firing danger close, registration or precision fire missions, which require greater accuracy. USE GUNNER'S QUADRANT is announced as a special instruction in the fire commands. Note: When using the Gunner's Quadrant the quadrant elevation is announced to the nearest tenth of a mil.
6	**METHOD OF FIRE FOR EFFECT**. This element indicates the number of rounds in the fire for effect phase of a mission. This element will always be announced by the FDO.
7	**PROJECTILE IN EFFECT**. This element is the projectile to be fired in the fire for effect. Note: See Shell/Fuze SOP in step 9.

Table 5-1. Battery or Platoon Fire Order (continued).

<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td>8</td><td>AMMUNITION LOT AND CHARGE IN EFFECT. This element is the ammunition lot(s) and charge used in fire for effect.
Note: The range-deflection protractor (RDP) can be marked along the range arm to indicate the appropriate charge for a giving range. A guide for marking the RDP is to segment the RDP in the same manner as indicated by the charge selection tables in the introduction of the TFT. The FDO should consider the tactical situation (primary target engagement ranges and counter fire threat), munitions effects (as relate to the angle of fall), probable error, tube wear, and surrounding terrain in selecting the best charge to fire. The announcement of RANGE and CHARGE (such and such) by the HCO significantly speeds mission processing times.</td></tr>
<tr><td>9</td><td>FUZE IN EFFECT. This element is the fuze to be fired in effect.
SHELL/FZ SOP
<table>
<tr><th>SHELL</th><th>With FUZE</th><th>ANNOUNCE</th></tr>
<tr><td>HE</td><td>Q,TI,VT,DLY,CP</td><td>'FUZE' ONLY</td></tr>
<tr><td>BASE EJECTING
(ICM, ILLUM, FASCAM, M825)</td><td>TI</td><td>'SHELL' ONLY</td></tr>
<tr><td>WP or RAP</td><td>Q</td><td>'SHELL' ONLY</td></tr>
<tr><td>WP or RAP</td><td>TI,VT(M732A2 for RAP)</td><td>'SHELL and FUZE'</td></tr>
<tr><td colspan="3">Legend: CP – concrete penetrating DLY – delay FASCAM – family of scatterable mines ICM – improved conventional munition ILLUM – illumination Q – quick RAP – rocket assisted projectile TI – time VT – variable time WP – white phosphorous</td></tr>
</table>
Note: When shell HE is fired in effect, only the fuze needs to be announced. When shells other that HE are fired, the fuze is not announced, except when white phosphorous (WP) or RAP is desired to be fired with Time Fuze or/VT for RAP only.</td></tr>
<tr><td>10</td><td>TARGET NUMBER. This element is the specific target number assigned to a fire mission. The target number consists of six characters comprised of two alphabetic characters followed by four numerical positions. This element allows a target number from the firing unit's target block to be assigned to the mission. The computer assigns the target number and records it on DA Form 4504 (Record of Fire). It is transmitted by the RTO (in the message to observer) to help the observer identify all fire missions-related messages to a particular mission. This facilitates mission processing. All missions must have a target number.</td></tr>
<tr><td colspan="2">Legend: adj – adjustment BTRY – battery CHG - charge FDC – fire direction center FDO – fire diection officer FZ – fuze
GFT – graphical firing table HCO – horizontal control operator HE – high explosive PLT – platoon
RDP – range deflection protractor RTO – radio telephone operator SOP – standard operating procedure
TFT – tabular firing table</td></tr>
</table>

FIRE ORDER STANDARD OPERATING PROCEDURES (SOP)

5-16. In most cases, a particular element of the fire order may remain the same from one mission to the next. On the basis of the tactical situation, type and amount of ammunition available, and commander's guidance, the FDO establishes an SOP for each element, which should be displayed in the FDC. When the FDO does not address an element in his fire order, the standard for that element will apply. The FDO need only announce what has changed from the standard. However, the method of fire for effect must ALWAYS be announced.

5-17. The FDO must ensure that the fire order is clear, concise, and in the proper format. The fire order format is designed to disseminate information clearly and rapidly with minimal discussion. It is impossible to provide a textbook solution for every conceivable situation, but a combination of technical knowledge and common sense should be enough to avoid confusion. It is better, if any confusion exists, to be redundant rather than too brief.

5-18. The use of a good SOP to clarify certain missions is essential. Immediate suppression, immediate smoke, illumination, and mixed shell missions (HE and WP, for instance), can be handled more responsively when governed by an SOP. For example, the FDO need only to say IMMEDIATE SUPPRESSION to mean a platoon will fire two volleys of high explosive (HE)/variable time (VT).

5-19. The following example shows the fire order elements and the fire order SOP for a four-howitzer platoon (see figure 5-3).

FIRE ORDER ELEMENT	***FIRE ORDER SOP***
UNIT TO FIRE	BATTERY/ PLATOON
ADJUSTING ELEMENT AND/OR MOF Projectile in adjustment Lot and charge in adjustment Fuze in adjustment	#3, 1 round HE LOT A/H (FDO or COMPUTER SELECT1) Q
BASIS FOR CORRECTIONS	USE GFT
DISTRIBUTION	PARALLEL
SPECIAL INSTRUCTIONS	
METHOD OF FIRE FOR EFFECT	FDO ANNOUNCE
PROJECTILE IN EFFECT	OBSERVER/FDO SELECT[2]
AMMUNITION LOT AND CHARGE IN EFFECT	FDO or COMPUTER SELECT[1]
FUZE IN EFFECT	OBSERVER/FDO SELECT[2]
TARGET NUMBER	NEXT AVAILABLE
Note: The FDO has the final decision-making authority in the FDC and can override any standard by announcing his choice. He will also make any additional announcement that he/she feels are necessary to avoid confusion and allow him/her to maintain control.	
1 The FDO/ computer must select a charge that will allow the engagement of the majority of the targets within the area of operation. This provides the charge to register and the one to be used in the computations of TGPCs. If the fire for effect lot(s) and charge are the same as the adjustment phase, they will not be addressed in the AMMUNITION LOT AND CHARGE I/E block.	
2The standard OBSERVER/ FDO SELECT allows the FDO to agree with the observer's selection as announced, by making no announcement. This should result in a shorter fire order. In most cases, the FDO should try to fulfill the observer's request. The FDO overrides the observer's request by announcing his choice.	
Legend: FDO – fire direction officer GFT – graphical firing table HE – high explosive Q – quick	

Figure 5-3. FDC Fire Order SOP.

5-20. Figure 5-4 on page 5-11 outlines an example of a fire order.

<table>
<tr><th colspan="4">EXAMPLE</th></tr>
<tr><td colspan="2">Recorded call for fire</td><td colspan="2">K38 de C19, AF k
GRID ND 3645 2393 ALT 350 k
BTR-70, ICM i/e k</td></tr>
<tr><td colspan="4">FDO decision: the FDO decides to attack the target and fire platoon, 1 round, shell HE/fuze VT I/E with a converge sheaf with CHG 4, lot A/H, and adjust with howitzer number 2.</td></tr>
<tr><td colspan="4">(Element in parentheses are SOP and are not announced)</td></tr>
<tr><th colspan="2">ELEMENT</th><th>DECISION</th><th>EXPANATION</th></tr>
<tr><td>1</td><td>UNIT TO FIRE</td><td>(PLT)</td><td>SOP</td></tr>
<tr><td>2</td><td>ADJUSTING ELEMENT AND/OR MOF
Projectile in adj
Lot and charge in adj
Fuze in adj</td><td>#2, 1 ROUND

(HE)
(A/H CHG 4)
(Q)</td><td>Differs from SOP

SOP
Does not differ from SOP
SOP</td></tr>
<tr><td>3</td><td>BASIS FOR CORRECTIONS</td><td>(Use GFT)</td><td>SOP</td></tr>
<tr><td>4</td><td>DISTRIBUTION</td><td>Converged</td><td>Differs from observer’s choice</td></tr>
<tr><td>5</td><td>SPECIAL INSTRUCTIONS</td><td></td><td>No special instruction required</td></tr>
<tr><td>6</td><td>METHOD OF FIRE FOR EFFECT</td><td>1 ROUND</td><td>FDO must announce</td></tr>
<tr><td>7</td><td>PROJECTILE IN EFFECT</td><td>(HE)</td><td>Differs from the observer’s request but is not announced as HE. Since VT will be fired in effect, it is understood it is HE.</td></tr>
<tr><td>8</td><td>AMMUNITION LOT AND CHARGE I/E</td><td>(A/H CHG 4)</td><td>Same as adjustment</td></tr>
<tr><td>9</td><td>FUZE I/E</td><td>VT I/E</td><td>Differs from observer’s request</td></tr>
<tr><td>10</td><td>TARGET NUMBER</td><td>(AA7000)</td><td>Assigned by the computer</td></tr>
<tr><td colspan="4">Thus the fire order is: #2, 1 round, converge sheaf, 1 round VT I/E</td></tr>
<tr><td colspan="4">Legend: AF – adjust fire   adj - adjust   ALT – altitude   CHG – charge   FDO – fire direction officer
HE – high explosive   ICM – improved conventional munition   I/E – in effect
MOF – method of fire   PLT – platoon   Q – quick   SOP – standard operating procedure
VT – variable time</td></tr>
</table>

Figure 5-4. Example Fire Order.

BATTALION FIRE ORDER

5-21. Battalion fire orders must be issued to mass the fires of the battalion on a single target. The battalion fire order differs from the battery or platoon fire order since all the units of the battalion may not be able to receive the call for fire. The battalion fire order must be able to convey all information to cause the units to engage the target. A battalion fire order (figure 5-5 on page 5-12) follows the same basic format as a battery or platoon fire order except for the following:

5-22. **WARNING ORDER**. A warning order is issued to indicate the type of mission (adjust fire [AF] or FFE) to be fired (not standardized).

5-23. **UNIT TO FIRE**. This is the unit to fire for effect. If the fire order originates at the battalion FDC and the FDO decides to fire the entire battalion, the element is announced as BATTALION. To designate less than the entire battalion, the individual elements are announced (for example, ALPHA and CHARLIE). When the designation of the unit to fire is transmitted outside the FDC, the unit call sign should be used.

5-24. **UNIT TO ADJUST or METHOD OF FIRE OF THE ADJUSTING UNIT**. This is the battery that conducts the adjustment. The battalion FDC will not try to direct a specific howitzer to adjust; however, the adjusting battery's base piece should be the adjusting howitzer. When the battalion fire order is transmitted, the unit call sign will be used (can be standardized). The battalion may specify the number of rounds, projectile type, lot, charge, and fuze to use in the adjustment by the adjusting unit.

5-25. **BASIS FOR CORRECTIONS**. This is the same as the battery-or platoon-level fire order (can be standardized).

5-26. **DISTRIBUTION or TARGET LOCATION**. This is the forward observer's (FO) target location, to include target altitude, from the call for fire. If adjustment is necessary, the non adjusting units will follow the adjustment and fire for effect on the adjusted grid. In adjust-fire missions, the battalion FDO may direct the adjusting unit to transmit the replot location and altitude to the battalion FDC after the completion of the adjustment. The battalion FDC may choose to segment the target, sending aimpoints to the units of the battalion, before fire for effect or direct the units to mass on the adjusted grid by sending the adjusted or replot grid (not standardized).

Note. The remaining elements of the battalion fire order are similar to the battery or platoon fire order except for standards

5-27. **SPECIAL INSTRUCTIONS**. This element can be standardized.

5-28. **METHOD OF FIRE FOR EFFECT**. This element is not standardized.

5-29. **PROJECTILE IN EFFECT**. This element can be standardized.

5-30. **AMMUNITION LOT AND CHARGE IN EFFECT**. This element can be standardized; however, normally the battery or platoon FDO will select it.

5-31. **FUZE IN EFFECT**. This element can be standardized.

5-32. **TARGET NUMBER**. This element is not standardized.

FIRE ORDER ELEMENT		***FIRE ORDER SOP***
1	WARNING ORDER	Always Announced (Not Standardized)
2	UNIT TO FIRE	Battalion
3	ADJUSTING ELEMENT AND/OR MOF	"A"
4	BASIS FOR CORRECTIONS	Fastest Method
5	DISTRIBUTION	Location (Grid and Altitude)
6	SPECIAL INSTRUCTION	
7	METHOD OF FIRE FOR EFFECT	Always Announced
8	PROJECTILE I/E	HE
9	AMMUNITION LOT AND CHARGE I/E	Battery/Platoon FDO Selects
10	FUZE I/E	VT
11	TARGET NUMBER	Next Available from the Battalion Target Block Number
Legend: FDO – fire direction officer HE – high explosive I/E – in effect MOF – method of fire SOP – standard operating procedure VT – variable time		

Figure 5-5. Example Battalion Fire Order SOP.

MASSING OF FIRES

5-33. Massing. ***Massing* is the simultaneous execution of two or more firing elements to achieve maximum effects on a critical target**. The 3 x 6 battery bringing its two platoons to bear on a single target, a battalion massing on one point and even a Field Artillery Brigade commander bringing all his battalions onto a single target are all examples of massing. Regardless of the level of command, certain fundamental conditions must be met for two or more units to engage targets effectively together.

5-34. The **first condition** for massing is that all firing units must be on a common location and azimuth system; that is, common survey. This includes all platoons, radars, meteorological stations, and observers. The survey control should extend into the target area as well.

5-35. The **second condition** is accurate MV information for each weapon. Manual corrections for MVVs will occur during concurrent met techniques and subsequent met applications and through determining TGPCs with the Ml7/M19 plotting boards.

5-36. The **third condition** is valid met corrections considered by each of the firing platoons. This includes the met message valid for the firing platoon, propellant temperature, projectile weight, vertical interval, and corrections for earth rotation.

5-37. The **fourth condition** is accurate location. This is the reason the target-locating assets must be on common survey with the firing units. Ensure the target location determined by the observer is the same location plotted by the FDC.

5-38. If the target is accurately located and the first three conditions are satisfied, then you can mass without having to adjust each unit onto the target. However, if it is an adjust-fire mission, the adjusting unit must determine the accurate target location and then announce it to the other units. To determine the accurate target location, the adjusting FDC must perform replot procedures discussed in Appendix D. The FDC must then announce the replot grid. The controlling FDC is responsible for the fire order and control of the mission.

5-39. When massing the fires of more than one battery either firing for effect or adjusting, **AT MY COMMAND, TIME ON TARGET, or WHEN READY** will be used. The most effective technique is **TIME ON TARGET**, which achieves the greatest surprise to the enemy.

5-40. Control of FFE mass missions on stationary targets can best be affected by using TOT techniques. Accurate time coordination is essential to ensure the simultaneous impact of all initial rounds; lengthy countdowns are unnecessary.

- The TOT may be announced as a specific time (for example, TOT 0915). The battalion would announce a time hack to synchronize the units designated to fire. This is performed by using the following procedure:
  - The battalion FDC will announce the time (for example, **AT MY MARK THE TIME WILL BE 0908**).
  - The battalion FDC will give a short countdown starting 5 seconds before the mark (for example, **5, 4, 3, 2, 1, MARK, 1, 2, 3, 4, 5**).
  - Each FDC would start its clock at **MARK**. From that moment, each FDC would control its own firing.
  - Each FDC would respond to the battalion FDC with ROGER OUT if they received a good mark.
  - If a good mark was not received, the unit FDC will request a new time hack and the previous four steps will be done again.
- Another technique to execute a TOT is to specify the amount of time before it is to occur (for example, **TOT 5 MINUTES FROM MY MARK**). Each FDC would start its stopwatch at MARK. From that moment, each FDC would control its own firing.
- The preferred technique is the short countdown TOT (for example, **TOT 40 SECONDS FROM MY MARK**). The short countdown allows the FDO to decrease the amount of time between receiving a call for fire and massing on the target. The FDO will announce as part of the special instructions in his fire order **SHORT COUNT TOT FOLLOWS**. This alerts the firing units

that the mission is **AT MY COMMAND** and that they will report **READY, TOF** to the battalion FDC. The battalion FDO will add 10 seconds (reaction time) to the longest time of flight reported. If the longest time of flight (TOF) is 30 seconds, he will announce **TOT 40 SECONDS FROM MY MARK, 5, 4, 3, 2, 1 MARK.** The firing units will quickly subtract their TOF from the number of seconds the battalion FDO announced. The result is the number of seconds after **MARK** until they command **FIRE**.

5-41. Control of an FFE mass mission on moving targets is best achieved by using **AT MY COMMAND or WHEN READY**. The time consumed during a TOT countdown may result in the rounds missing the target.

- **AT MY COMMAND**. All units will fire at the same time. The battalion FDO will select this technique if he is willing to accept some loss of surprise caused by varying times of flight to get the rounds on the target quickly. This technique is particularly effective when the unit's times of flight as reported by each FDC are similar.
- **WHEN READY**. Unless otherwise specified, each battery will fire when ready. This technique is used more often with adjust-fire missions (particularly those with lengthy adjustment phases) than with fire-for-effect missions. (When surprise has been lost, the difference in reaction times and times of flight between units is less significant.)

5-42. Control of the FFE phase in an adjust-fire mass mission can be achieved by the same means as an FFE mass mission.

- **TIME ON TARGET**. If the observer is able to enter the FFE phase with one correction and he judges that the target has not been warned, a **TIME ON TARGET** may be used to control time of firing in effect. If the battalion FDO decides a TOT is unsuitable (for example, loss of time outweighs simultaneous impacting of all initial FFE rounds), he will direct use of **AT MY COMMAND or WHEN READY**. It is rare, however, that a target would not be warned during adjustment. Therefore, TOT to control time of firing in effect after adjustment is not normally used.
- **AT MY COMMAND**. The considerations for the selection of this technique are the same as in paragraph above. In addition, it is useful if the observer is able to enter the FFE phase with a large correction.
- **WHEN READY**. In most adjust-fire mass missions, no control of time of firing in effect will be used. Since most targets would be warned during adjustment, the battalion FDO would allow units to fire when ready.

5-43. Examples of Battalion Fire Orders. Examples of battalion fire orders are shown (figure 5-6) below.

EXAMPLE 1

The battalion FDC is using voice communications to transmit the fire order to the platoon FDCs. The call signs are as follows:

BN FDC	G6H38
1/A	J3D38
2/A	J3E38
1/B	H5K38
2/B	H5M38

The following call for fire is received by the battalion FDC:

H38 de C19, AF k

Grid 3542 2235 ALT 350 k

Battalion Assembly Area, VT I/E k

The battalion FDO decides to have 2/B adjust and 1/A, 2/A, 1/B and 2/B to fire for effect. The battalion FDO decides to honor the observer's request for variable time.

ELEMENT	***FIRE ORDER WITHOUT STANDARDS***	***FIRE ORDER WITH STANDARDS***
WARNING ORDER	AF	AF
UNIT TO FIRE	H	H
ADJUSTING ELEMENT AND/OR MOF	M	M
BASIS FOR CORRECTIONS	Fastest Method	
DISTRIBUTION	GRID 3542 2235 ALT 350	GRID 3542 2235 ALT 350
SPECIAL INSTRUCTION	TOT 0915	TOT 0915
METHOD OF FIRE FOR EFFECT	10 round I/E	10 round I/E
PROJECTILE I/E	HE I/E	
AMMUNITION LOT AND CHARGE I/E	PLT FDO SELECT	
FUZE I/E	VT I/E	
TARGET NUMBER	AB7022	AB7022

Legend: AF – adjust fire ALT - altitude BN – battalion FDC – fire direction center FDO – fire direction officer HE – high explosive I/E – in effect MOF – method of fire PLT – platoon TOT – time on target VT – variable time

Figure 5-6. Example Battalion Fire Order.

SECTION II: MESSAGE TO OBSERVER

5-44. After the FDC receives the call for fire, the FDO analyzes the target. If the target is to be attacked the FDO issues the fire order as his decision on how the target will be attacked. The observer is informed of this decision through the message to observer.

DESCRIPTION

5-45. The message to observer consists of four elements and is composed by the RTO.

5-46. **Units to Fire**. The first element is the unit(s) that will fire the mission. It is **always announced**. If a battalion is firing in effect with one battery or platoon adjusting, the MTO will designate the FFE unit (battalion) and the adjusting unit (battery or platoon). The units to fire are identified by their radio call signs, using long call signs, short call signs, or the first letter of the short call sign. Some examples are listed below (see figure 5-7).

EXAMPLES

The mission is an adjust-fire mission with the battalion firing for effect. The battalion FDC call sign is G6H38. Battery B, 1st Platoon FDC call sign is H5K38. 1st Platoon, Bravo Battery, will adjust, and the battalion will fire for effect. The RTO would announce **MTO H, K**
Note: The RTO would use the phonetic alphabet to announce units to fire. For example, the announcement in the paragraph above would be given as **MIKE, TANGO, OSCAR, HOTEL KILO**
The mission is a battalion FFE mission, The battalion FDC call sign is G8H38. The RTO would announce **H**. In autonomous operation, 1st Platoon Bravo Battery receives a call for fire for an adjust-fire mission. The RTO would announce **K**.

Figure 5-7. Example Units to Fire.

5-47. Changes or Additions to the Call for Fire. The second element of the MTO allows the FDC to inform the observer of changes and/or additions made by the FDO to the call for fire. If high-angle fire is to be used, HIGH ANGLE must be included in the MTO if the observer did not request it. The following examples (figure 5-8) use the previously stated call signs.

NOTE: HE/Quick (Q) is not a standard shell fuze combination in effect and must be announced in accordance with the Shell/Fuze SOP discussed in table 5-1 on page 5-5 if the observer neglects to recommend a shell fuze combination in their CFF.

EXAMPLES

The observer requests VT in effect, and the FDO decides to fire fuze time in effect. The RTO for battalion would announce **MTO H, K, TIME IN EFFECT**. For the battery or platoon, it would be announced as **MTO K, TIME IN EFFECT**.
The observer requests time in effect and the FDO decides to fire high-angle using fuze VT in effect. The RTO for battalion would announce **MTO H, K, HA, VT IN EFFECT**. For the battery or platoon, it would be announced as **MTO K, HA, VT IN EFFECT**.

Figure 5-8. Example Changes or additions to the CFF.

5-48. Number of Rounds. The third element is the number of volleys in fire for effect. The number of rounds to be fired in effect is always announced. The following example (figure 5-9 on page 5-17) uses the previously stated call signs and change to the call for fire.

EXAMPLES

The battalion FDO decides to fire three rounds in effect. The RTO would announce **MTO, H, K, TIME IN EFFECT, 3 ROUNDS.** For the battery or platoon, it would be announced as **MTO K, TIME IN EFFECT, 3 ROUNDS.**

Figure 5-9. Example Number of Rounds.

5-49. Target Number. The last element is the target number assigned to the mission for reference purposes, it is always announced. This is done to avoid confusion if multiple missions are being fired or if more than one observer is operating on the radio net. Target numbers are used in sequential order based on the units target block. The following example (figure 5-10) uses the previously stated call signs, change(s) to the call for fire, and number of rounds.

EXAMPLES

The next available target number for the battalion FDC is AA7000. The RTO would announce, **MTO H, K, TIME IN EFFECT, 3 ROUNDS, TARGET NUMBER AA7000**. The next available target number for the battery of platoon is AA7300. The RTO would announce **MTO K, TIME IN EFFECT, 3 ROUNDS, TARGET NUMBER AA7300.**

Figure 5-10. Example Target Number.

ADDITIONAL INFORMATION

5-50. The following additional information may be announced with or after the message to observer.

5-51. Probable Error in Range. If the probable error in range for an area fire mission is equal to or greater than 38 meters, the FDC will inform the observer. For precision fire, the FDC will inform the observer if the probable error in range is equal to or greater than 25 meters. The actual value is not announced. For example, the RTO would announce **PROBABLE ERROR IN RANGE GREATER THAN 38 METERS.**

5-52. **Angle T**. Angle T is announced to the observer when it is equal to or greater than 500 mils or if the observer requests it. It is announced to the nearest 100 mils. For example, if angle T is 580 mils, it is expressed and announced as **ANGLE T 600**.

5-53. **Pulse Repetition Frequency Code**. The pulse repetition frequency (PRF) code for a mission is transmitted in voice operations; for example, the RTO will announce **PRF CODE 241**. The range and direction of approach (left or right of the observer-target line) are needed to orient the footprint.

5-54. **Time of Flight**. Time of flight (TOF) is announced to the nearest whole second. It is announced to observers when targets are engaged with:

- When moving targets are engaged
- When conducting high-angle missions
- When using an aerial observer
- When requested by the observer.

For example, the RTO would announce **TIME OF FLIGHT 34 SECONDS**.

5-55. **Splash**. Splash informs the observer that the round(s) fired will impact in 5 seconds. It must be sent to aerial observers and during high-angle fire missions. It can also be sent at the observer's request.

Note: Burst Illumination. Burst illumination informs the observer that the illumination round will function in 5 seconds.

5-56. **Shot and Rounds Complete**. SHOT is announced to the observer to report when a round has been fired. Rounds complete is announced to the observer when all rounds for a particular mission have been fired. During an adjust-fire mission SHOT is announced after each round. Once the FFE phase is initiated, SHOT is announced only on the initial round. Once all rounds have been fired, rounds complete is announced to the observer. For an FFE mission, SHOT is announced only on the initial round; once all rounds have been fired, rounds complete is announced to the observer.

SECTION III: FIRE COMMANDS

5-57. Fire commands are used by the FDC to give the howitzer sections all the information needed to conduct a fire mission. Initial fire commands include all elements needed for orienting, loading, and firing the howitzer. Subsequent fire commands include only those elements that have changed from the previous command(s), except quadrant elevation. **Quadrant elevation is announced in every set of fire commands and allows the howitzer section to fire if in a when ready (WR) status.**

FIRE COMMAND ELEMENTS

5-58. The elements of fire commands are always announced in the same sequence (table 5-2). This saves time and eliminates confusion; each member of the howitzer section knows the sequence and should be ready for the next command.

5-59. Certain elements of the fire commands may be standardized. Once the standards are established and announced to the howitzer sections, the standard elements will not be announced. Quadrant elevation may never be standardized. It is announced in-each set of fire commands.

Table 5-2. Fire Commands Sequence.

ELEMENT		***WHEN ANNOUNCE***	***WHEN ANNOUNCE***
Commands		Initial Fire Commands	Subsequent Fire Commands
1	WARNING ORDER	Always	Never
2	PIECES TO FOLLOW	When applicable	When Changed
	PIECES TO FIRE	When other than standard	When Changed
	METHOD OF FIRE	When other than standard	When Changed
3	SPECIAL INSTRUCTIONS DO NOT LOAD AMC (BPAMC, BRAMC, BPBRAMC) HIGH ANGLE USE GUNNER'S QUADRANT AZIMUTH SPECIAL CORECTIONS SWEEP AND/OR ZONE FIRE	When applicable	When Changed
4	PROJECTILE[1]	When other than standard	When Changed
5	AMMUNITION LOT[1]	When other than standard	When Changed
6	CHARGE	Always	When Changed
7	FUZE[1]	When other than standard	When Changed
8	FUZE SETTING	When applicable	When Changed
9	DEFLECTION	Always	When Changed
10	QUADRANT	Always	Always
11	METHOD OF FFE	When applicable	When Changed
1These element may be standardized. Elements that are standardized will be announced only when something other than standard is to be fire.			
Legend: BPAMC – by piece at my command BPBRAMC – by piece by round at my command		BRAMC – by round at my command FFE – fire for effect	

BATTERY OR PLATOON FIRE COMMANDS

5-60. The procedures and sequence for announcing fire commands are in table 5-3; all other fire commands are in table 5-4 on page 5-23.

Table 5-3. Battery or Platoon Fire Commands.

STEP	***ACTION***
1	**WARNING ORDER** A warning order is always announced to alert the firing unit to the mission. When a firing battery is using voice commands, a warning order of "**FIRE MISSION**" is announced. The warning order is not announce in subsequent commands.
2	**PIECES TO FOLLOW, PIECES TO FIRE, AND METHOD OF FIRE** This element designates the howitzer(s) that will follow the mission, the howitzer (s) that will fire initially, and how they will engage the target. ● **PIECES TO FOLLOW** tell the platoon who will follow the commands given for an adjust-fire mission. **BATTERY ADJUST or PLATOON ADJUST** indicates that the mission will be an adjust-fire mission and that all howitzers will copy the commands, follow the mission, and participate in the FFE phase. Any howitzer or number of howitzers may be announced in this element; for example, **PLATOON ADJUST or NUMBER 1 AND NUMBER 3 ADJUST**. If the mission is an FFE mission, pieces to follow is not given. ● **PIECES TO FIRE** indicate which howitzer(s) will fire the data given in the initial fire command. For example **PLATOON ADJUST, NUMBER 3, 1 ROUND** indicates that during this adjust-fire mission Number 3 will fire one round at the data given in the initial fire command. **PLATOON 1 ROUND** indicates a FFE mission with all weapons firing one round at the data given in the initial fire command. ● **METHOD OF FIRE** tells the howitzer(s) how many rounds to fire. **PLATOON ADJUST, NUMBER 3, 1 ROUND** indicates that during this adjust-fire mission Number 3 will fire one round at the data given in the initial fire command. **PLATOON 1 ROUND** indicates a FFE mission with all howitzers firing one round at the data given in the initial fire command.
3	**SPECIAL INSTRUCTIONS** Special instructions are used when actions that are different from normal are required. The FDC must announce the words **SPECIAL INSTRUCTIONS** followed by the special instruction. When more than one special instruction applies, restrictive commands should be announce first. • **DO NOT LOAD** is a restrictive fire command that prohibits loading and firing. The section may prepare the projectile, charge, and fuze (if applicable) and lay the howitzer for deflection; and set the quadrant elevation (or loading elevation). The command from the FDC would be **(so many) ROUNDS, SPECIAL INSTRUTIONS DO NOT LOAD.** To fire the rounds, the FDC commands **CANCEL DO NOT LOAD, QUADRANT (so much).** This command allows the howitzers to load if not otherwise restricted by special instructions. The target number may be used in place of the command **QUADRANT** to allow loading and firing of preplanned targets and scheduled fires. **CANCEL DO NOT LOAD** does not apply to the entire mission, it must be announced with each initial or subsequent command. • **AT MY COMMAND (or BY PIECE BY ROUND AT MY COMMAND)** is a restrictive command that prohibits the battery from firing until directed to

Table 5-3. Battery or Platoon Fire Commands (continued).

STEP	ACTION
3	do so by the FDC. The command from the FDC would be (so many) **ROUNDS, SPECIAL INSTRUCTIONS AT MY COMMAND**. When directed to fire the rounds, the section(s) would fire all the rounds specified in the method of fire. The command **BY PIECE AT MY COMMAND** would direct the sections to fire all the rounds specified in the method of fire by section(s) as announced by the FDC. The command **BY ROUND, AT MY COMMAND** would direct the section(s) to fire each of the rounds in the method of fire by volley as commanded by the FDC. The command **BY PIECE, BY ROUND, AT MY COMMAND** combines the control of both commands explained above. **AT MY COMMAND** remains in effect until the FDC commands • **CANCEL AT MY COMMAND (or BY PIECE or BY ROUND AT MY COMMAND). AT MY COMMAND** may be cancelled at any time. If the FDC has announced QUADRANT, the command would be **CANCEL AT MY COMMAND, QUADRANT (so much).** • **HIGH ANGLE** is announced, to alert the section that the mission is to be fired at an angle of elevation greater than 800 mils. Light artillery weapons can be elevated before loading. Medium and heavy artillery weapons normally must be loaded at loading elevation. • **USE GUNNER’S QUADRANT** is announced, when the FDC desires the gunner's quadrant be used to set or check quadrant elevation. This is more often used when firing danger close or precision fire missions, which require greater accuracy. • **AZIMUTH** is announced, to alert the sections to a large shift in the direction of fire. The command **AZIMUTH** will be followed by the azimuth in mils. • **SWEEP (so many) MILS, (so many) DEFLECTIONS** commands a method of fire used when the standard sheaf does not adequately cover the target and more width is required. Sweep fire provides for firing several deflections with one quadrant. For example, **SWEEP 10 MILS, 5 DEFLECTIONS**. The section chief computes the required deflections and, fires the initial deflection, and then fires the remaining deflections in any order or as directed by unit SOP. • **ZONE (so many) MILS, (so many) QUADRANTS** commands a method of fire used when the standard sheaf does not adequately cover the target and more depth is required. Zone fire provides for firing one deflection with several quadrants. For example **ZONE, 5 MILS, 3 QUADRANTS**. The section chief computes the required quadrant, fires the initial quadrant, and then fires the remaining quadrants in any order or as directed by unit SOP. **SWEEP (so many) MILS, (so many) DEFLECTIONS, ZONE (so many) MILS, (so many) QUADRANTS** commands a method of fire combining sweep fire and zone fire. Sweep and zone fire provides for firing several deflections and quadrants. The chief of section fires the displayed commands for deflection and quadrant first and then fires all combinations of computed deflections and quadrants, in any order or as directed by unit SOP. Procedures for determining data for Sweep and/or Zone missions are found in Appendix G.

Table 5-3. Battery or Platoon Fire Commands (continued).

STEP	***ACTION***
3	• **SPECIAL CORRECTIONS** is announced to alert the crew when a separate time, deflection, and/or quadrant will be sent to or fired by one or more gun sections. The words **SPECIAL CORRECTION(S)** should precede any special corrections that apply in the fire command. This command prevents misunderstanding and unnecessary repetition of missed special corrections. If **SPECIAL CORRECTIONS** is announced alone, it alerts the sections that separate data will be sent to one or more sections. Unit SOP and degree or training dictates how to implement. • **SPECIAL CORRECTION, NUMBER (so-and-so) LEFT or RIGHT (so many mils)** may be announced. These corrections are applied by the specified piece to the announced deflection and remain in effect until changed (within a fire mission) or until the command **END OF MISSION** is given. This command may be given administratively, apart from fire commands; or it may be announced in the special instructions element of a fire command. These corrections are in addition to any corrections currently on the gunner's aid. • **SPECIAL CORRECTION ON NUMBER (so-and-so), OPEN or CLOSE (so many mils)** may be announced. Each piece (other than the piece specified) applies aid. Each section chief determines his correction by multiplying the number of mils announced by the number of pieces his piece is removed from the piece announced. For example, the command **ON NUMBER 3, CLOSE 4** is given. Number 3 applies no correction. Number 1 applies left 8. Number 2 applies left 4. Number 4 applies right 4. All guns fire the announced deflection after applying their corrections to the gunner's aid. These corrections are applied to any corrections already on the gunner's aid and remain in effect until changed (within a fire mission) or until the command **END OF MISSION** is given. • **SPECIAL CORRECTIONS, (LEFT, CENTER, or RIGHT) SECTOR** is announced when terrain gun position corrections for other than the primary sector are being used. If TGPCs are computed, the corrections for primary sector are set on the gunner's aid of all weapons. These corrections are announced administratively and recorded on the DA Form 5212-R. To change sectors, the FDC commands (**LEFT, CENTER or RIGHT) SECTOR**. Upon termination of the mission, the howitzer sections reapply the corrections that were in effect before the mission. • **CANCEL TERRAIN GUN POSSITION CORRECTIONS** indicates that all howitzer sections are to set their gunner's aid counters to zero. At the end of the mission, the TGPCs that were in effect before the mission (usually the primary sector) will be reapplied unless the FDC directs otherwise.
4	**PROJECTILE** This element designates the type of projectile to be used in the fire mission. When voice fire commands are being used, the projectile must be announced when it differs from standard.
5	**AMMUNITION LOT**. Ammunition lot numbers should be coded for simplicity. Separate-loading ammunition has two designators-the first letter represents the projectile and the second letter represents the propellant. Semi-fixed ammunition has only a one letter designation. The lots designators are established by unit SOP. When voice fire commands are used, the lot designators must be announced when they differ from standard.
6	**CHARGE**. The charge indicates the amount of propellant to be used and grants permission for the crew to cut the propellant. Charge is always announced by the FDC. It is never standardized.
7	**FUZE** This element designated the fuze type to be use in the fire mission. If fuze quick is to be fired in the delay mode, the FDC would announce **FUZE DELAY**. Fuze is only announced if differs from standard. In subsequent for commands, it is only announced when a change in type is desired.

Table 5-3. Battery or Platoon Fire Commands (continued).

STEP	*ACTION*
8	**FUZE SETTING** This element designated the fuze setting for a mechanical time (MT), mechanical time super quick (MTSQ), or proximity (VT) fuze. For example, **FUZE TIME, TIME 17.6 or FUZE VT, TIME 17.0.**
	Note: If shell DPICM is to be fired in the self-registration (SR) mode, fuze setting back triangle 98.0 must be announce. For example, the FDC would announce **SHELL DPICM-SR, LOT F/H, CHARGE 4, FUZE TIME, TIME BLACK TRIANGLE 98.0.**
9	**DEFLECTION** This element tells the howitzer section what direction (left or right) to traverse the tube. With voice commands, deflection is always announced as four digits; for example, **DEFLECTION 3021** (three zero two one) and **DEFLECTION 3300** (three three hundred). The section chief announces deflection using four numbers. The gunner sets the announced, or displayed, deflection on the panoramic telescope and traverses the tube until he has a correct sight picture on the proper aiming point (two step deflection method). When the section chief announces deflection, the gunner reads back the deflection. After the assistant gunner (AG) has reported DEFLECTION, the gunner will verify his sight picture, ensure that his bubbles are centered, and reports DEFLECTION (so much), READY.
10	**QUADRANT ELEVATION** Quadrant elevation gives the section chief permission to load and fire the round unless otherwise restricted by DA Form 4513-R (Record of Missions Fired) special instructions or unsafe conditions. The AG sets off the quadrant elevation announced by the FDC, for example, **QUADRANT 318.** AG elevates the tube to that quadrant elevation after the projectile has been loaded. When the section chief announces quadrant, the AG reads back the quadrant that is set on the range quadrant. After the AG has centered the bubbles on the range quadrant, he reports QUADRANT (so much), SET.
11	**METHOD OF FIRE FOR EFFECT** This element indicates the number of rounds and type of ammunition to be used in effect. When applicable, it is announced in the initial fire commands after the quadrant and must be announced before the last subsequent command in an adjust fire mission. With voice commands, it is announced after quadrant elevation; for example, **2 ROUNDS, VT IN EFFECT**.
Legend: AG – assistant gunner DPICM – dual-purpose improved conventional munition FDC – fire direction center FFE – fire for effect MT – mechanical time MTSQ – mechanical time super quick SOP – standard operating procedure SR – self-registration TGPCs – terrain gun position corrections VT – variable time	

Table 5-4. Other Fire Commands.

STEP	ACTION
	SPECIAL METHODS OF FIRE include those listed below:
1	**CONTINUOUS FIRE** is announced when it is desired that the howitzer crews continue to fire within the prescribed rates of fire for their howitzer until the command **CHECK FIRING or CEASE LOADING** is announced. **FIRE AT WILL** is used in a direct fire role, primarily for perimeter defense. The command is **TARGET (so-and-so), FIRE AT WILL**. Howitzer crews fire under the control of their section chief.
2	**CHECK FIRING**. The command **CHECK FIRING** can be given by anyone, but it should be used only in emergencies or if a safety violation is noted. All firing ceases immediately. The command may be given by voice, and/or given by hand signals all at the same time. Immediate action must be taken to determine the nature of the check fire and to correct the situation. Note: To give the hand signal, raise your hand in front of your forehead, palm to the front, and swing your hand and forearm up and down several times in front of your face.
3	**CANCEL CHECK FIRING**. The command **CANCEL CHECK FIRING** will be announced once the situation requiring check firing has been corrected. The command will be giving by the FDC. Once the check firing is imposed during a fire mission is canceled, all firing data not announced will be announced. At minimum, the quadrant elevation will be announced again. For example, the FDC would announce **CANCEL CHECK FIRING, QUADRANT 422.**
4	**CEASE LOADING**. The command **CEASE LOADING** allows the section chief to fire rounds that have already been loaded, but no additional rounds may be loaded.
5	**END OF MISSION**. The command **END OF MISSION (EOM)** means that the fire mission has been terminated. The howitzer sections should return to the azimuth of lay or priority target data. For example, GUN (number so-and-so) EOM.
6	**PLANNED TARGETS**. The battery may be assigned planned targets for which current firing data must be maintained. Each target is assigned a number and each weapon is laid on its assigned priority target. In such cases, unit SOP usually designates a command or a prearranged signal to fire on the priority target, by passing the usual sequence of fire commands. EXAMPLE: Target #AC7343 has been designated as a priority target. Firing data has been computed and has been transmitted to one of the firing platoons. On the command RIGHT, **SUPPRESS AC7343**, the right platoon engages Target #AC7343 with the previously arranged method of fire. In defensive operations, the command **FIRE THE FPF** causes the firing battery to fire the final protective fires (FPF) on which it is laid.
7	**REPETITION AND CORRECTION OF FIRE COMMANDS.** One section (normally the adjusting piece) of the firing unit should be designated to read back all voice fire commands to ensure that the howitzer sections have received the fire commands correctly. When a command has not been heard or has been misunderstood, the request for repetition is stated as a question; for example, **DEFLECTION NUMBER 2?** When the FDC replies, the repetition of a command is always preceded by **NUMBER (so-and-so), THE COMMAND WAS**; for example, **NUMBER 2, THE COMMAND WAS DEFLECTION 2768.** If an incorrect command has been given, but the command **QUADRANT** has not been announced, the FDC commands **CORRECTION** followed by the correct command and all subsequent elements. If **QUADRANT** has been announced, the FDC commands **CHECK FIRING, CANCEL CHECK FIRING** is announced followed by the corrected element and all subsequent elements.

Table 5-4. Other Fire Commands (continued).

8	**FIRING REPORTS**. The section chief reports to the FDC all actions that affect the firing of his weapon in support of the battery mission. During firing, the following specific reports are made: ● When the special instruction **DO NOT LOAD** has been commanded by the FDC the section chief reports LAID, NUMBER (so-and-so). This report is sent when the projectile, charge, and fuze (if applicable) have been prepared; the howitzer has been laid for deflection; and the quadrant (or loading elevation) has been set. ● When the special instruction **AT MY COMMAND or BY PIECE (or BY ROUND) AT MY COMMAND** has been commanded by the FDC, the section chief reports by voice **READY, NUMBER (so-and-so).** This report is sent when the section is ready to fire (in compliance with the fire command). ● In voice operations, **SHOT NUMBER (so-and-so)** is reported after each round has been fired. However, if the method of fire is more than one round, SHOT is announced only after the initial round. ● **ROUNDS COMPLETE NUMBER (so-and-so)** is announced when the final round designated in the method of fire has been fired. However, if only one round is to be fired, ROUNDS COMPLETE will not be reported after SHOT. ● **MISFIRE NUMBER (so-and-so)** is announced when a misfire has occurred (voice only). Normally followed with the FDC requesting the nature of the misfire. ● Ammunition status is reported. The number of rounds expended, by type and lot number, is reported when requested by the FDC (voice or per unit SOP). ● Data fired in error are reported. The chief of section reports to FDC the actual data fired in error; for example, **NUMBER 2 FIRED DEFLECTION (so much).**
Legend: EOM – end of mission FDC – fire direction center FPF – final protective fires SOP – standard operating procedures	

EXAMPLE OF FIRE COMMANDS

5-61. Figure 5-11 is an example of an adjust-fire mission without fire command standards applied for a four-howitzer platoon.

EXAMPLE

FIRE MISSION, PLATOON ADJUST, NUMBER 3, 1 ROUND, SHELL HE (HIGH EXPLOSIVE), LOT A/H, CHARGE 4, FUZE QUICK, DEFLECTION 3024, QUADRANT 347, 2 ROUNDS IN EFFECT.

Number 3 is announced as the adjusting weapon. It fired one round (shell HE, Lot A/H, fuze quick) with the announced charge and the announced deflection and quadrant. Non-adjusting pieces prepare two rounds of HE with fuze quick and follow the mission.

The first subsequent fire command is a follow: **DEFLECTION 2978, QUADRANT 318**. Number 3 fires one round (shell HE, lot A/H, charge 4, fuze quick) at the new deflection and quadrant.

The second sub-sequent fire command is as follows: **PLATOON 2 ROUNDS, DEFLECTION 2950, and QUADRANT 310**. The entire platoon fires two rounds at the announced deflection and quadrant. **END OF MISSION** is announced as appropriate and ammunition expended is updated.

Figure 5-11. Fire Command Example Adjust Fire.

5-62. Figure 5-12 is an example of an FFE mission without fire command standards applied.

EXAMPLE

FIRE MISSION, NUMBER 3 AND NUMBER 4, 3 ROUND, SHELL WP (WHITE PHOSPHOROUS), LOT W/H, CHARGE 4, FUZE QUICK, DEFLECTION 2870, QUADRANT 320.

Number 3 and Number 4 each fire three rounds as commanded. END OF MISSION is announced as appropriate, and ammunition expended is updated.

Figure 5-12. Fire Command Example Fire for Effect.

STANDARDIZING ELEMENTS OF THE FIRE COMMAND

5-63. Certain elements of fire commands may be standardized after the tactical situation, weapon, and personnel capabilities, ammunition status, and enemy counterfire threat have been considered. As shown in table 5-2 on page 5-18, the following elements of the fire commands may be designated as standard: pieces to follow, pieces to fire, method of fire, projectile, ammunition lot, and fuze. If the FDO decides to vary from fire command standard data, he must administratively cancel the existing standard and issue the replacement standard data. Only one set of standard data can be in effect at any particular time. Once standard data are placed in effect, the platoon will fire the standard data unless the fire command specifies something different (see example in figure 5-13).

EXAMPLE

The FDO or platoon leader considers the tactical situation and the other factors mentioned above and determines that the fire command elements designated as standard should be as follows:

Projectile: HE (high explosive)

Ammunition Lot : A/H

Fuze: Quick

These standards tell the howitzer section that if not stated in the fire commands, the projectile, lot, and fuze will be shell HE, lot A/H and fuze quick.

Adjust-Fire Mission With Fire Commands Standards Applied

Elements designated as standards in this example are shell HE, lot A/H, and fuze quick.

FIRE MISSION, PLATOON ADJUST, NUMBER 3, 1 ROUND, CHARGE 4, DEFLECTION 2938, QUADRANT 300, 2 ROUNDS SHELL WP (WHITE PHOSPHOROUS), LOT W/H TIME IN EFFECT.

Number 3 fires one round (shell HE, lot A/H, fuze quick) with the announced charge and at the announced deflection and quadrant. Non-adjusting pieces prepare two rounds of white phosphorous and follow the mission. Adjustment continues.

When the fire for effect is entered, the commands are as follows:

PLATOON 2 ROUNDS, SHELL WP (WHITE PHOSPHOROUS), LOT W/H, FUZE TIME, TIME 25.2, DEFLECTION 3008, QUADRANT 325.

All howitzer fire two rounds of shell WP with the announced deflection and quadrant. END OF MISSION is announced as appropriate.

FFE Mission With Fire Commands Standards Applied

Elements designated as standard in this example are HE, lot A/H, fuze quick.

FIRE MISSION, PLATOON 3 ROUNDS, CHARGE 4, DEFLECTION 3111, QUADRANT 400.

Each howitzer fires three rounds (Shell HE, lot A/H, fuze quick) with the announced charge and at the announced deflection and quadrant. **END OF MISSION** is announced as appropriate.

Figure 5-13. Fire Command SOP Example.

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Chapter 6
Firing Charts

One of the elements to the solution of the gunnery problem is the determination of chart data. Chart data consists of chart range, chart deflection, and angle T. The determination of chart data requires the construction and operation of a firing chart.

SECTION I: EXPLANATION OF TERMS

DIRECTION

6-1. Determining direction is an essential skill for the FDC. Direction is an integral part of terrain map association, target location, and the adjustment of fires. ***Direction* is a horizontal clockwise angle measured from a fixed reference.** There are two different units of measurement used for direction, mils and degrees. Using mils is preferred, because it is a more precise unit of measurement.

MILS

6-2. A ***mil* is a unit of measure for angles that is based on the angle subtended by l/6400 of the circumference of a circle.** The mil is used because of its accuracy and the mil relation formula, which is based on the assumption that an angle of one mil will subtend an arc of one meter at a distance of 1,000 meters. The graphic representation of a mil is a lower case letter "m" with a virgule (/) through it (m̸).

DEGREES

6-3. A degree is a unit of horizontal clockwise angular measurement that is equal to 1/360 of a circle. Degrees may be converted to mils by multiplying the number of degrees by 17.7778 (mils = number of degrees X 6,400 ÷ 360).

CARDINAL DIRECTIONS

6-4. Cardinal directions are expressed in terms of north (N), east (E), south (S), and west (W). Figure 6-1 illustrates the relationship between cardinal directions, mils, and degrees.

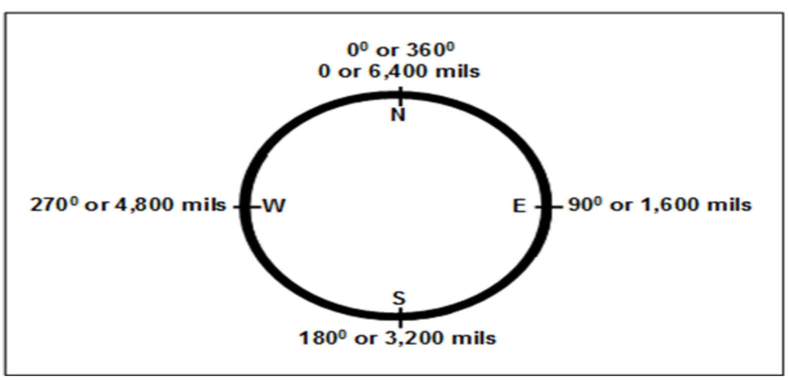


Figure 6-1. Cardinal directions.

AZIMUTH

6-5. An ***azimuth*** **is the horizontal angle, measured clockwise by degrees or mils between a reference direction and the line to an observed or designated point**. There are three base (reference) directions or azimuths: true, grid, and magnetic azimuth (TC 3-25.26).

RIGHT ADD, LEFT SUBTRACT RULE (RALS) (FOR DETERMINATION OF AZIMUTH)

6-6. Compute the direction to a target by determining the difference (horizontal angular deviation) in mils between a reference point of known direction and the target, then adding or subtracting the measured difference to the known direction. Direction increases to the right and decreases to the left. Therefore, to determine the direction to the target, apply the number of mils measured right or left of the reference point known direction by use of the right add, left subtract (RALS) rule. For example, the azimuth to the reference point is 2,100 mils. The target is 40 mils to the left of the reference point. The direction to the target is 2,060 mils (2,100 - 40). If the target is 60 mils to the right of the reference point, the direction to the target is 2,160 mils (2,100 + 60).

DEFLECTION

6-7. ***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 a designated aiming point with the vertex of the angle at the sight**. In addition to the deflection as a fire command, the firing battery is concerned with common deflection. Currently, all U.S. Howitzers use a common deflection of 3200 (ATP 3-09.50).

LEFT ADD, RIGHT SUBTRACT RULE (LARS) (FOR DETERMINATION OF DEFLECTION)

6-8. Compute the direction to a target by determining the difference (horizontal angular deviation) in mils between a reference point of known direction and the target, then adding or subtracting the measured difference to the known direction. Deflection increases to the left and decreases to the right. Therefore, to determine the deflection to the target, apply the number of mils measured right or left of the reference point known direction by use of the left add, right subtract (LARS) rule. For example, the common deflection 3200 mils. The target is 40 mils to the left of the reference point. The deflection to the target is 3240 mils (3200 + 40). If the target is 60 mils to the right of the common deflection the deflection to the target is 3140 mils (3200 - 60).

OBSERVER-TARGET LINE

6-9. The ***observer-target line*** **(OTL) is an imaginary straight line from the observer/spotter to the target**. It is the most commonly used direction for locating targets and conducting adjustments.

GUN-TARGET LINE

6-10. The ***gun-target line*** **(GTL) is an imaginary straight line from gun to target.**

ANGLE T

6-11. ***Angle T*** **is the interior angle formed at the target by the intersection of the observer-target and the gun-target lines.** Angle T is transmitted to the observer when it is 500 mils or greater, or if requested by the observer. Angle T is announced to the nearest 100 mils. For example, if angle T is 580 mils, express and announce angle T as **Angle T 600.**

RANGE/DISTANCE

6-12. Once a direction to the target is determined, the FDC must determine range to the target. ***Chart range* is the horizontal space between the firing unit and the target**. ***Distance* is the horizontal space between the observer and the target.** The meter is the standard unit of measurement for range and distance.

SECTION II: TYPES OF FIRING CHARTS

6-13. Three types of firing charts may be constructed in the FDC. They are surveyed firing charts, observed firing charts, and emergency firing charts (discussed in Chapter 14). Regardless of the type constructed, two firing charts are maintained in a manual FDC. The horizontal control operator (HCO) maintains the primary firing chart. The vertical control operator (VCO) maintains a secondary chart in order to check the HCO's chart data.

DESCRIPTION

6-14. A ***firing chart* is a graphic representation of a portion of the earth's surface used for determining distance (or range) and direction (azimuth or deflection).** The chart may be constructed by using a map, a photomap, a grid sheet, or other material on which the relative locations of batteries, known points, targets, and observers can be plotted. Additional positions, fire support coordinating measures, and other data needed for the safe and accurate conduct of fire may also be recorded.

FIRING CHART CONSTRUCTION

6-15. **Grid Sheet**. A ***grid sheet* is a plain sheet of paper or plastic (Mylar) on which equally spaced horizontal and vertical lines, called grid lines, are printed**. The intervals between these grid lines will create 1,000-meter grid squares on a scale of 1:25,000. This scale provides the best compromise between accuracy and convenience and is therefore the scale for which standard plotting equipment is graduated. The locations of all points plotted on the grid sheet must be determined either by survey data, map inspection, or firing. The grid sheet is numbered to correspond to the map area of the zone of operation of the supported force. The FDO assigns the lower left-hand corner casting and northing coordinates, and the direction of the long axis (east-west or north-south) also is specified. The rightmost and topmost grid lines are not labeled because data are not determined from these grid lines.

6-16. **Map**. A ***map* is a graphic representation, drawn to scale, of a portion of the earth's surface** (TC 3-25.26). Only maps based on accurate ground survey should be used for constructing firing charts. If the map scale is other than 1:25,000, the range readings obtained from plotting equipment must be adjusted. For example, if a 1:50,000-scale map is used, the ranges determined with the Range-Deflection Protractor (RDP) must be doubled. Deflections and azimuths are not affected. If a map is not based on accurate and adequate ground survey control, it should be used only to obtain approximate locations and vertical control to supplement a grid sheet firing chart.

6-17. **Photomap**. A ***photomap* is a reproduction of an aerial photograph or a mosaic of aerial photographs on which grid lines, marginal information, and place names are superimposed** (TC 3-25.26). A photomap must not be considered exact until its accuracy has been verified. Photomaps may include errors caused by tilt, distortion caused by relief, and errors caused by poor assembly, If points cannot be located on the photomap by inspection, the photomap scale must be determined before points can be located on the photomap survey. Normally, vertical control can be established by estimation only. Determination of the scale of vertical control of photographs is discussed in TC 3-25.26 Map Reading and Land Navigation. Some photomaps have spot altitudes, but interpolation for altitude is difficult and inaccurate.

SECTION III: PLOTTING EQUIPMENT AND FIRING CHART PREPARATION

6-18. To ensure the accuracy of the data shown on the firing chart, FDC personnel should construct and plot from a standing position directly above the chart. Plotting pins must be kept perpendicular to the firing chart. Personnel, equipment and the firing chart should be kept as clean as possible at all times. If two charts are present in the FDC, they must be checked against each other for accuracy. If one chart is a backup for another system, it should be verified against that system for accuracy. (Refer to Appendix E for automated FDC procedures.)

PENCILS

6-19. **6H Pencil**. The 6H (hard lead) pencil is sharpened to a wedge point and is used to draw fine index lines from which measurements are made. If a 6H pencil is not available, a 5H pencil is an acceptable substitute. (See figure 6-2.) Place a 1-inch piece of tape on the end to differentiate between a 4H pencil.

Figure 6-2. The 6H Pencil (Wedge Point).

6-20. **4H Pencil**. The 4H pencil is sharpened to a conical point and is used to label and construct tick marks and to label azimuth and deflection indexes. If a 4H pencil is not available, a 3H pencil is an acceptable substitute. (See figure 6-3.)

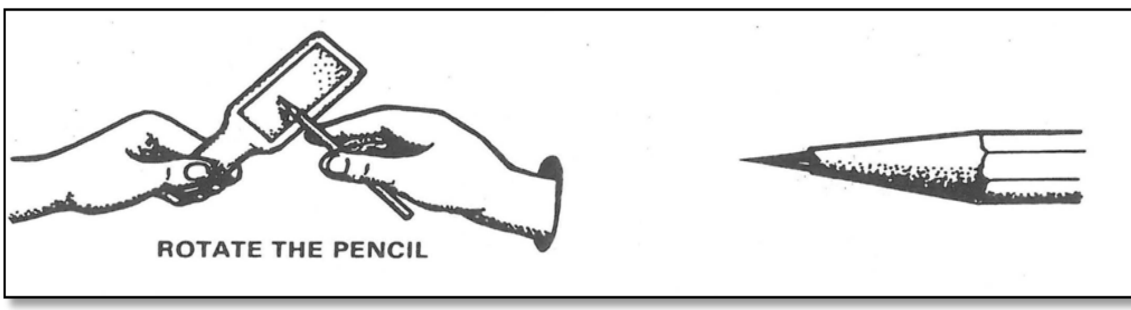


Figure 6-3. The 4H Pencil (Conical Point).

6-21. **Colored Pencils**. All colored pencils are sharpened to a conical point. Red, blue, and orange pencils are used to label and construct tick marks and label deflection indexes as required by the color code. The green pencil is used to label tick marks for radars. (See table 6-4, step 7 on page 6-37).

6-22. **Eraser.** An eraser will be used to remove unwanted markings on the firing chart. The preferred eraser is the art gum eraser.

PLOTTING PINS

6-23. Plotting pins are used to mark indexes and temporary positions on the firing chart. On a 1:25,000-scale chart, the thickness of the plotting pin shaft equals 20 meters.

PLOTTING SCALE

6-24. The plotting scale is a square-shaped scale used to plot or determine grid coordinates. The scale is graduated in meters and yards at scales of 1:25,000 and 1:50,000. Using the four-step plotting method, locations are plotted to an accuracy of 10 meters with the plotting scale. Personnel must be careful not to confuse the meter and yard scales on this instrument (newer plotting scales only have meter scales on them). (See figure 6-4). If there is a yard scale, tape over it so this scale is not accidentally used.

Note: 10-digit grid coordinates are expressed to 8-digit grid coordinates when plotting because of the limitations of the plotting scale.

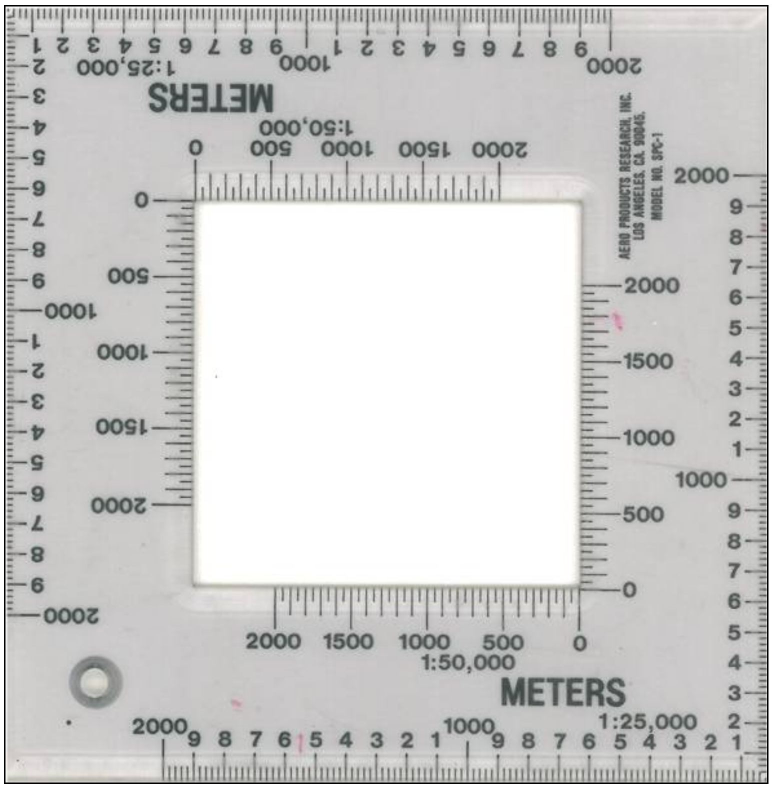


Figure 6-4. Plotting Scale.

RANGE-DEFLECTION PROTRACTOR

6-25. The Range-Deflection Protractor (RDP) is used to measure angles in mils and distances in meters. Range and deflection are measured from a firing unit to a target. Direction and distance are measured from an observer to a target. (See figure 6-5 on page 6-6).

- The left edge of the instrument is the arm and is used to measure range or distance. It is graduated in 50-meter increments and labeled every 500 meters on a scale of 1:25,000. Ranges and distances are visually interpolated to an accuracy of **10 meters**. The arm can be labeled to represent charge or range spans and other pertinent data to aid the FDO.
- The 1,000-mil arc of the RDP is graduated in 5-mil increments. The 50-mil increments are indicated by longer graduations and are permanently numbered. The arc is visually interpolated to an accuracy of 1 mil.
- The vertex, the slotted portion of the RDP, is placed against a plotting pin to properly position the RDP for determining data.

- There are four different RDP models. They differ by the maximum range of the arm (12,000, 15,000, 25,000, and 30,000 meters).
- RDPs are also available on a 1:50,000 scale.

Note: When labeling the RDP, label azimuth values in blue and deflection values in red. Additionally, the 2 on the deflection scale will be circled in red. (See figure 6-5).

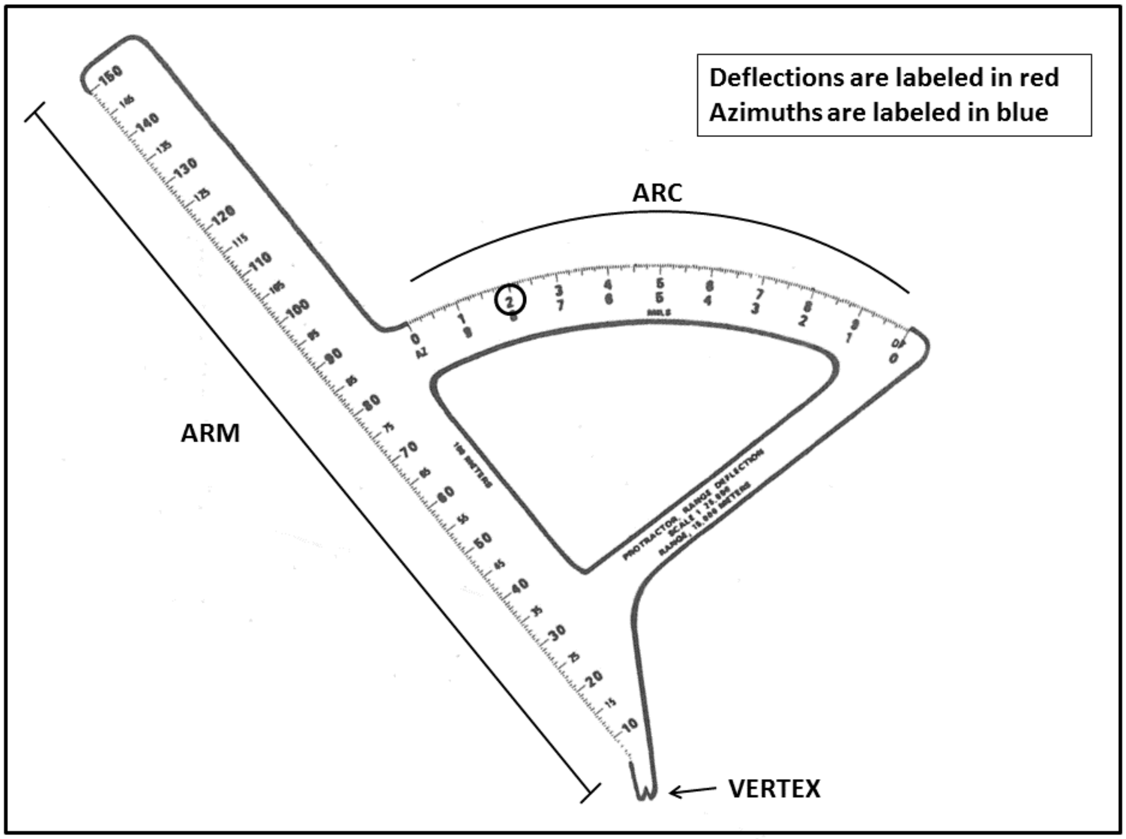


Figure 6-5. Range-Deflection Protractor.

TARGET GRID

6-26. The ***target grid*** **is a circular paper device on which grid lines are printed**. Normally, the target grid used is DA Form 4176 (Target Plotting Grid Field Artillery Graduated in Mils and Meters Scale). Grid lines on the target grid match the scale of the 1:25,000 firing chart, dividing a 1,000-meter grid square into 100-meter squares. An azimuth scale is printed around the outer edge of the target grid. It is graduated in 10-mil increments and is numbered every 100 mils. An arrow extends across the center of the target grid and is used to indicate the observer-target line (or other line of known direction). The target grid should be labeled as shown in figure 6-6 on page 6-7. (**The L and - are recorded in blue pencil; the R and + are recorded in red.)** Transparent tape should be applied to the reverse side of the target grid to prevent the center hole from becoming enlarged. The target grid is used for three distinct operations:

- Plotting the position of targets located by a shift from a known point.
- Plotting observer subsequent corrections.
- Determining angle T.

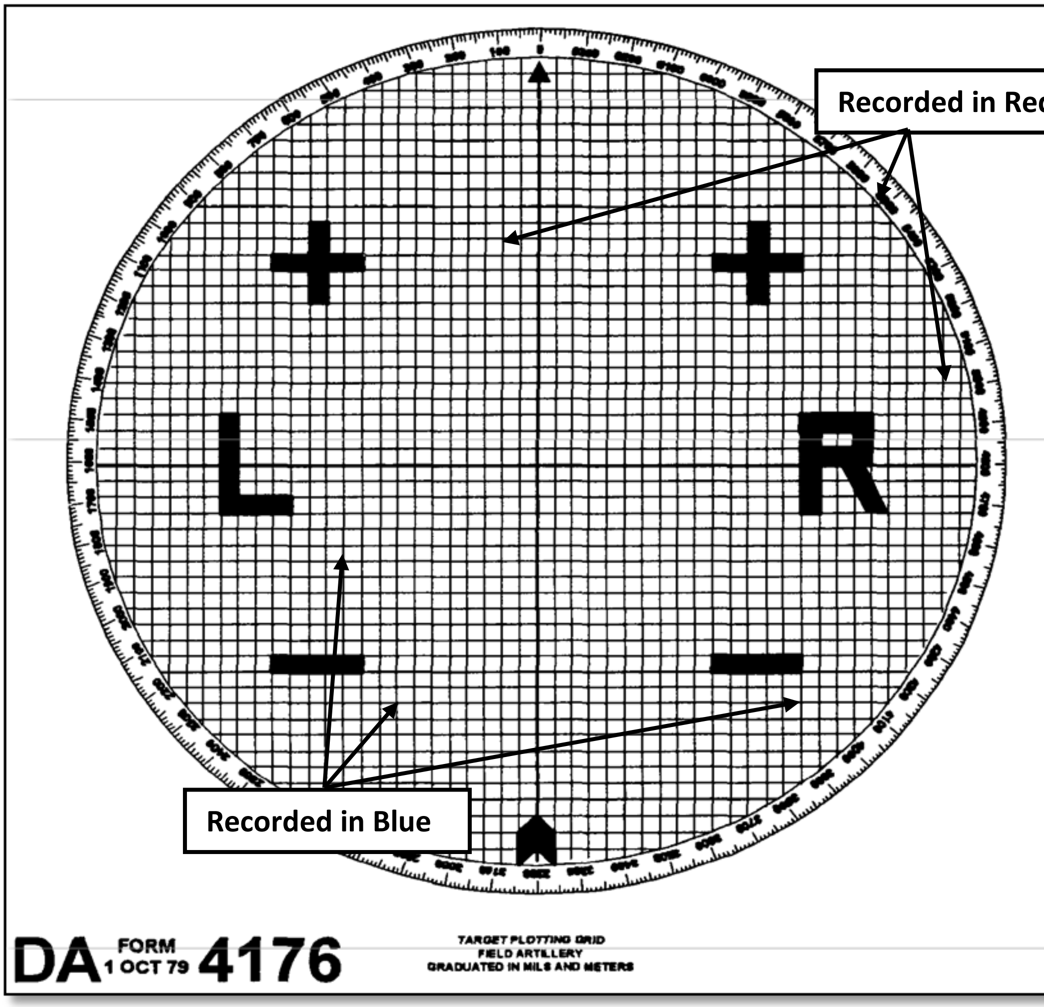


Figure 6-6. Labeling the Target Grid.

SECTION IV: SURVEYED FIRING CHART

6-27. **A *surveyed firing chart* is a chart on which the location of all required points (battery or platoon positions, known points, and observation points) are plotted.** These locations can be based on survey or map inspection. All plotted points are in correct relation to one another and reflect actual map coordinates.

SELECTION OF LOWER LEFT-HAND CORNER AND AZIMUTH OF LAY

6-28. For the chart operator to construct a firing chart correctly, he needs to be provided guidance on what coordinates to assign to the lower left-hand corner (LLHC) of the grid sheet and the azimuth of lay. The FDO is responsible for providing this information. The azimuth of lay can be determined on the basis of the zone of operations or the guidance from the battery commander or higher HQ. After the azimuth of lay is determined, the LLHC coordinates need to be carefully selected. The selected LLHC coordinates should include all critical points on the firing chart and allow full use of the RDP. The steps in table 6-1 on page 6-8 will help to serve as a guide in determining the LLHC and azimuth of lay.

Table 6-1. Selection of LLHC and Azimuth of Lay.

STEP	*ACTION*
1	Plot the unit location on the map.
2	Plot the center of the zone of operations. This can be performed by visual inspection of the map.
3	Determine the azimuth from the unit location to the center of the zone of operations. This can be performed by using a protractor or other instrument. For ease of mathematical computations, the determined value can be expressed to the nearest 100 mils.
4	Before selecting the LLHC coordinates, approximate the unit location on the grid sheet in the general area of the firing chart where it will be located. The FDO or chief should verify that the RDP can be used effectively from this location. The LLHC coordinates are selected so that all critical points in the zone of operations can be plotted.
5	Once the values are determined, give them to the HCO or VCO so they can begin to construct the firing charts.
	Note: If the chart table is not permanently affixed in the FDC, the FDO will also need to provide guidance on the orientation of the long axis of the firing chart. The long axis of the firing chart should be oriented to allow maximum coverage of the zone of operations. If the general direction to the zone of operations is East or West, the long axis should be oriented East-West. If the general direction to the zone of operations is north-south, the long axis should be oriented north-south.
Legend: FDC – fire direction center FDO – fire direction officer HCO – horizontal control operator LLHC – lower left hand corner RDP – range deflection protractor VCO – vertical control operator	

FIRING CHART PREPARATION

6-29. The steps in table 6-2 are the procedures for the preparation of a firing chart.

Table 6-2. Firing Chart Preparation.

STEP	*ACTION*
1	Choose a suitable smooth surface on which the firing chart will be constructed. Place the grid sheet on this surface.
2	Tape one corner of the grid sheet down. Be sure that the tape does not cover any grid lines.
3	Smooth out the grid sheet and tape down the corner opposite of the first corner that was taped down.
4	Repeat steps 2 and 3 for the remaining two corners.
5	Orient the long axis of the firing chart north-south or east-west according to the FDO's guidance. (Disregard this step if using a permanently mounted chart table.)
6	Using a 4H pencil, label the leftmost vertical grid line with the easting of the LLHC as specified by the FDO. The numbers should be beneath and divided by the vertical grid lines, but they will not touch them. Number the remaining vertical grid lines so that the value Increases from left to right. The last vertical grid line is not labeled because measurements will not be made from it. (See figure 6-7 on page 6-9.)
7	Using a 4H pencil, label the bottommost horizontal grid line with the northing of the LLHC as specified by the FDO. The numbers should be to the left and centered on the horizontal grid lines, but they will not touch them. Number the remaining horizontal grid lines so that the value increases from bottom to top. The last horizontal grid line is not labeled because measurements will not be made from it. (See figure 6-7 on page 6-9.)
Legend: FDO – fire direction officer LLHC – lower left hand corner	

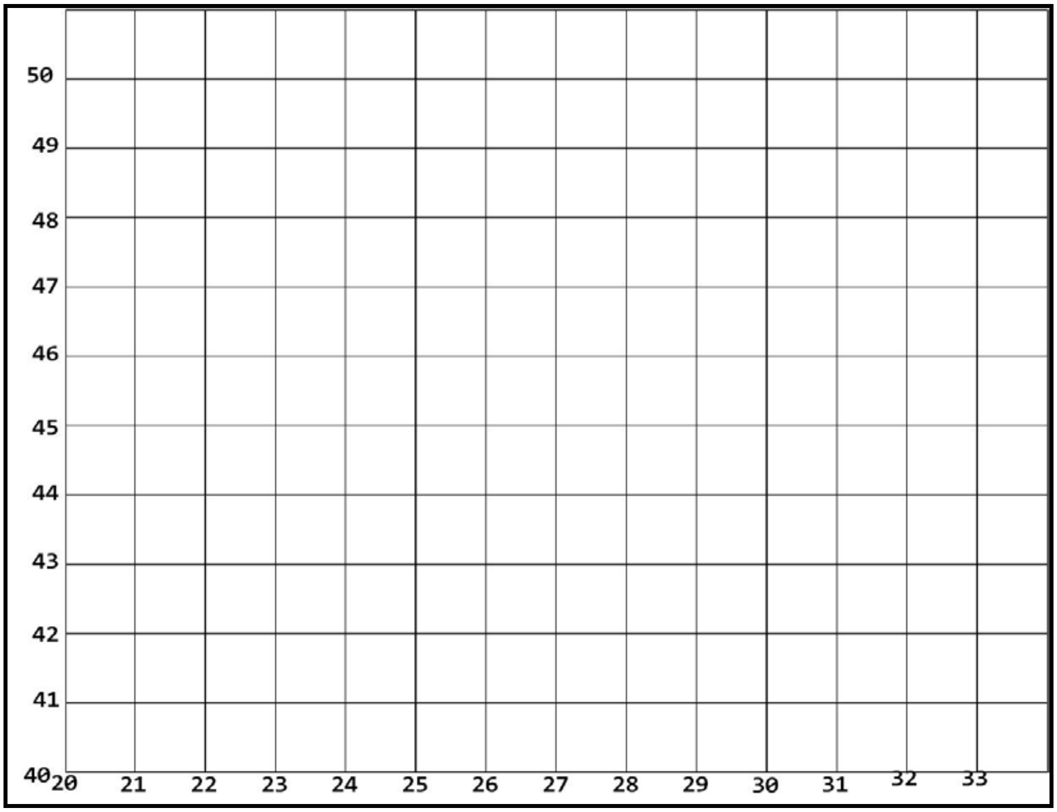


Figure 6-7. LLHC 2040, With the Long Axis Oriented East-West.

FOUR-STEP PLOTTING METHOD

6-30. Points commonly plotted on a firing chart include battery or platoon base piece locations, known points, targets, observer locations, and maneuver checkpoints. Base piece locations can be determined by using the M17 plotting board and protractor. To plot points located by grid coordinates, use the steps in Table 6-3.

Table 6-3. Four-Step Plotting Method.

STEP	*ACTION*
1	Place a plotting pin in the upper right-hand corner of the grid square where the point is to be plotted. This point will prevent the incorrect plotting of the point in the wrong grid square. (See Figure 6-8 on page 6-10.)

Table 6-3. Four-Step Plotting Method (continued).

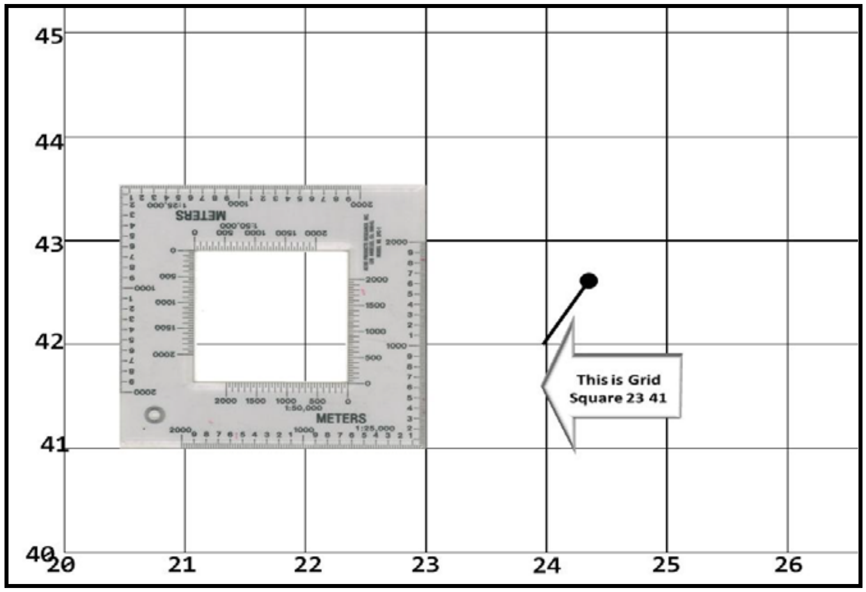
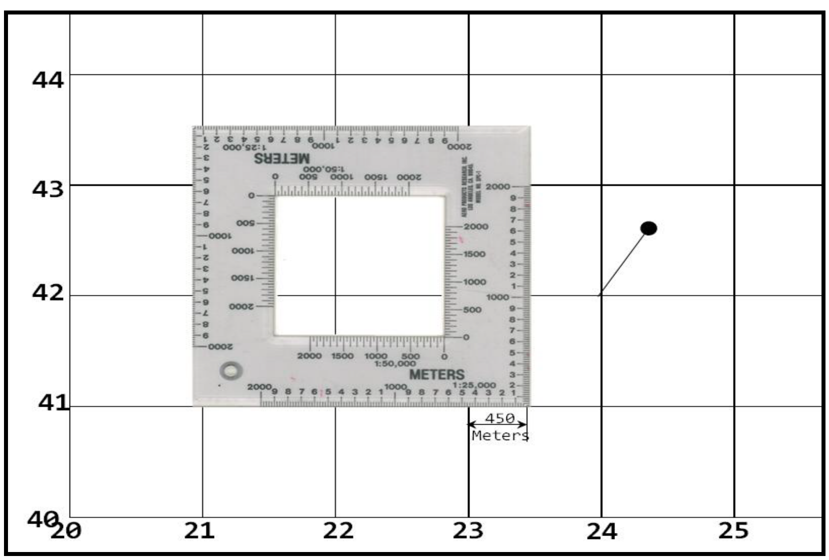
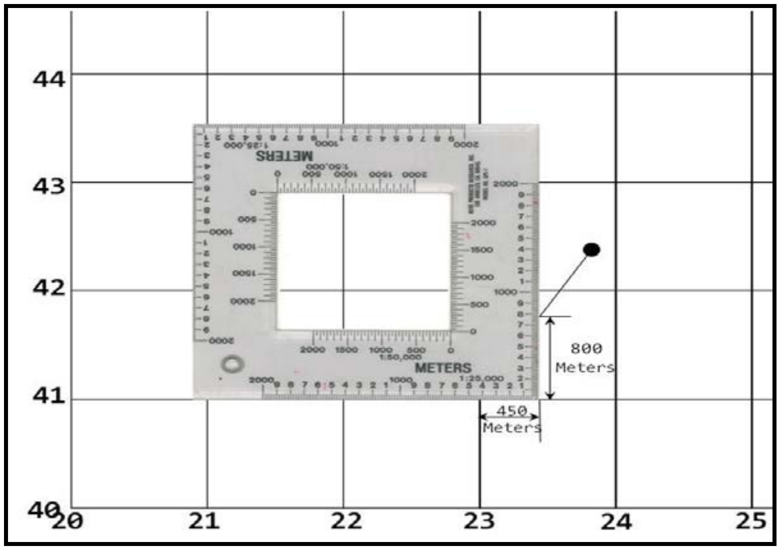
STEP	***ACTION***
2	Place the plotting scale along the left edge of the grid square so that the 0 on the bottom scale is at the lower left-hand corner of the grid square. (See figure 6-8.)  **Figure 6-8. Position Plotted in Grid Square 2341.**
3	Slide the plotting scale to the right and read the easting on the plotting scale by using the north-south (vertical) grid line as an index. Below, easting 23448 is expressed to 2345. (See figure 6-9.)  **Figure 6-9. Easting 2345.**

Table 6-3. Four-Step Plotting Method (continued).

STEP	***ACTION***
4	With the bottom edge of the plotting scale aligned precisely on the east-west (horizontal) grid line, remove the pin from the upper right-hand corner and plot the northing on the vertical scale with a plotting pin. Set the pin at a 45° slant and slide the plotting scale away. Rotate the head of the pin to vertical and push the pin into place. Below, 41795 is the plotted location. (See figure 6-10.) Northing 41795 is expressed to 4180.  **Figure 6-10. Northing 4184.**

TICK MARKS

6-31. The ***tick mark*** **is the symbol used to mark and identify the location of a point plotted on a firing chart.** The tick mark is constructed in the form of a cross with each arm beginning 40 meters from the pinhole on the chart and extending 160 meters in length (1:25,000 scale).

Note: Tick marks will be constructed with a 4H pencil with the following exception: To construct a tick mark for a target that has been located through firing, use a red pencil. Table 6-4 uses the 3-5-7 Method to construct a tick mark.

Table 6-4. Constructing a Tick Mark (3-5-7 Method).

STEP	***ACTION***
1	Align the right-hand edge of the plotting scale so that 5 on the METERS scale is next to the pinhole and the edges of the plotting scale are parallel to the grid lines.
2	Using the appropriate color of pencil for the type of position that is being potted, construct a line beginning 40 meters above the pinhole and extend it to the closest 7 on the meters scale.
3	Using the same color of pencil as in step 2 above, construct a line beginning 40 meters below the pinhole and extend it to the closest 3 on the METERS scale.
4	Move the plotting scale so that the 5 on the bottom METERS scale is aligned above the pinhole and the edges of the scale are paralleled to the grid lines.

Table 6-4. Constructing a Tick Mark (3-5-7 Method) continued.

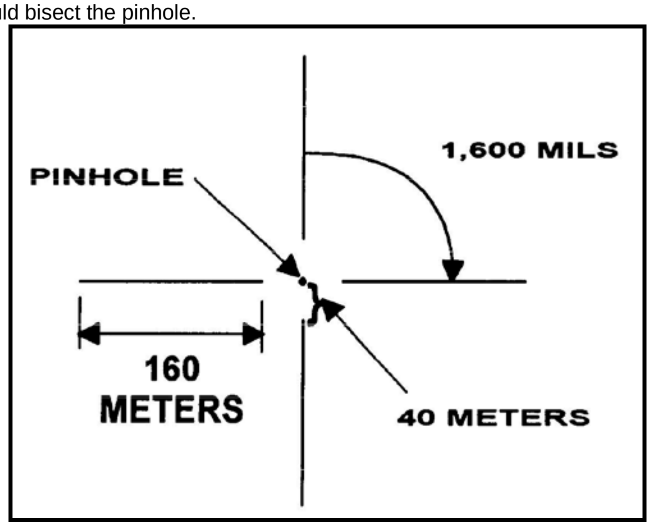
<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td>5</td><td>Using the same color of pencil as in step 2 above, construct a line beginning 40 meters right of the pinhole and extend it to the closest 3 on the METERS scale.</td></tr>
<tr><td>6</td><td>Using the same color of pencil as in step 2 above, construct a line beginning 40 meters left of the pinhole to the closest 7 on the METERS scale. (See figure 6-11)</td></tr>
<tr><td></td><td>Note: The tick mark should bisect the pinhole.


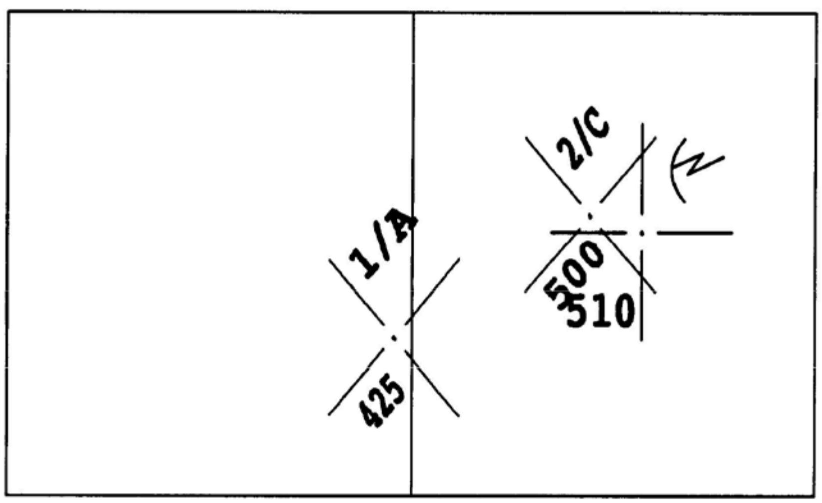
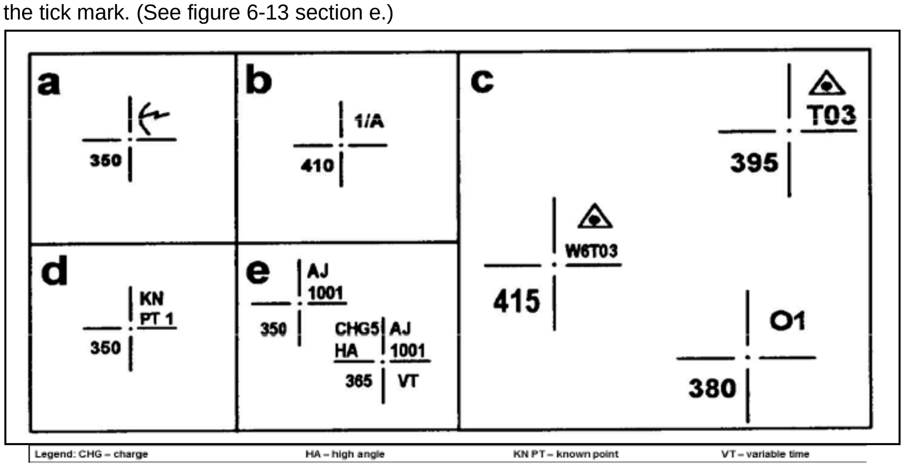
Figure 6-11. Dimensions of a Completed Tick Mark.</td></tr>
<tr><td></td><td>Note: If the plotted position is within 80 meters of a grid line (on a scale of 1:25,000) or the tick mark that is to be constructed interferes with a previously constructed tick mark, the new tick mark should be canted 800 mils counterclockwise to avoid confusion. (See figure 6-12).


Figure 6-12. Canted Tick Marks.</td></tr>
</table>

Table 6-4. Constructing a Tick Mark (3-5-7 Method) continued.

STEP	*ACTION*
7	Using a 4H pencil, label the tick mark by centering the identification of the point in the upper right-hand quadrant and by centering the altitude in the lower left-hand quadrant of the tick mark. Examples of each type are in figure 6-13. Use the following rules: **Note**: Labeling of tick marks will not extend outside the length of the radial arms. At a minimum, the identification and the altitude are required on all tick marks. **Radar**. The military symbol for radar is labeled in green. (See figure 6-13 section a.) **Battery or Platoon**. The battery or platoon identification is labeled by using the following color code: ● Alpha is red. ● Bravo is black. (a 4H pencil may also be used) ● Charlie is blue. ● Delta is orange. **Note**: If more than four batteries are shown on the firing chart, the color coding starts over again with red. In 2x8 operations, platoon identifications (for example, 1/A) are recorded by using the same color code. (See figure 6-13 section b.) **Observation Posts**. Observation posts can be represented by using one of the following methods: ● Label the tick marks by using the military symbol for an observation post (a triangle with a dot in the middle) and the long or short call sign that the observer uses to identify himself (for example, W6T03 or T03; figure 6-13 section c.) ● Label the tick marks with an "O" for observer, followed by the observer's assigned number (for example, O1; See figure 6-13 section c.)
	Known Points. Use a 4H pencil to record in the upper right-hand quadrant the number assigned to the known point. Also, use a 4H pencil to record the altitude in the lower left-hand quadrant. (See figure 6-13 section d.) **Targets**. Use a 4H pencil to record in the upper right-hand quadrant the assigned target number. Also, use a 4H pencil to record the altitude in the lower left-hand quadrant. (See figure 6-13 section e.) Note**:** If plotted positions is a target that has been located thru firing, the **fuze used In the fire for effect** may be recorded by centering the fuze in the lower right-hand quadrant of the tick mark. The **charge used in the mission and/or high-angle** (if mission was an high-angle mission) may be recorded and centered in the upper left-hand quadrant of the tick mark. (See figure 6-13 section e.)  **Figure 6-13. Examples of Different Tick Marks.**
8	Perform Steps 1 through 7 for all plotted locations.

CONSTRUCT NORTH INDEXES

6-32. Construct north indexes for all known points plotted on the firing chart. This index will assist the chart operator when processing shift from known point fire missions. (See table 6-5.)

Table 6-5. Constructing North Indexes.

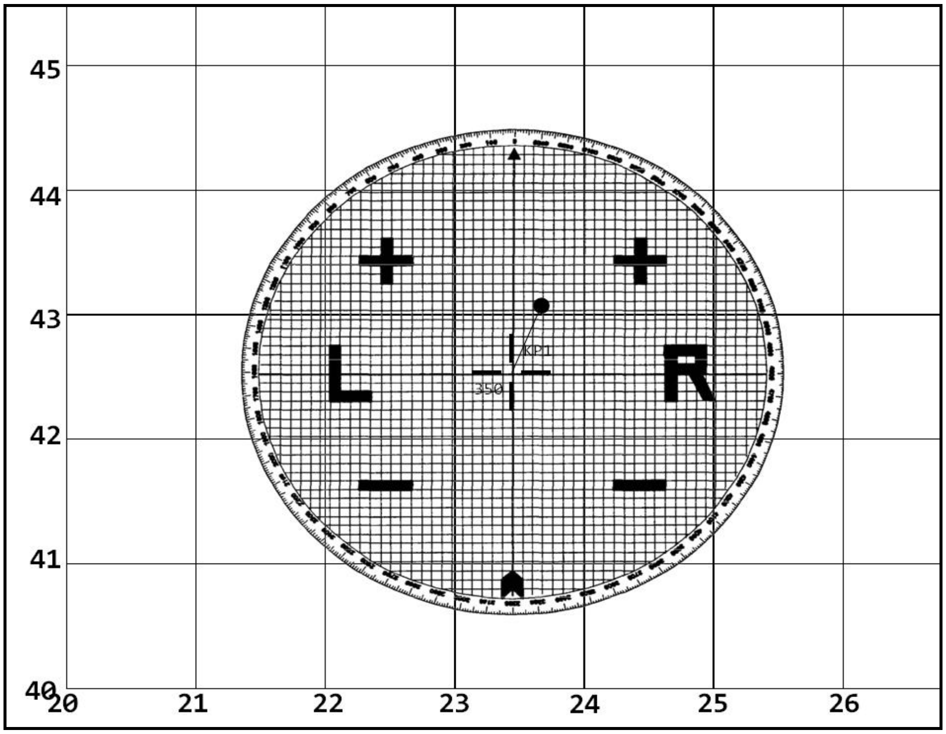
STEP	*ACTION*
1	Insert the pin through the center of the target grid, and then insert the pin in the known point (see figure 6-14).  **Figure 6-14. Constructing North Index Step1.**
2	Orient the target grid until the lines on the target grid are parallel to the grid lines. The arrow on the target grid should be oriented to the north.

Table 6-5. Constructing North Indexes (continued).

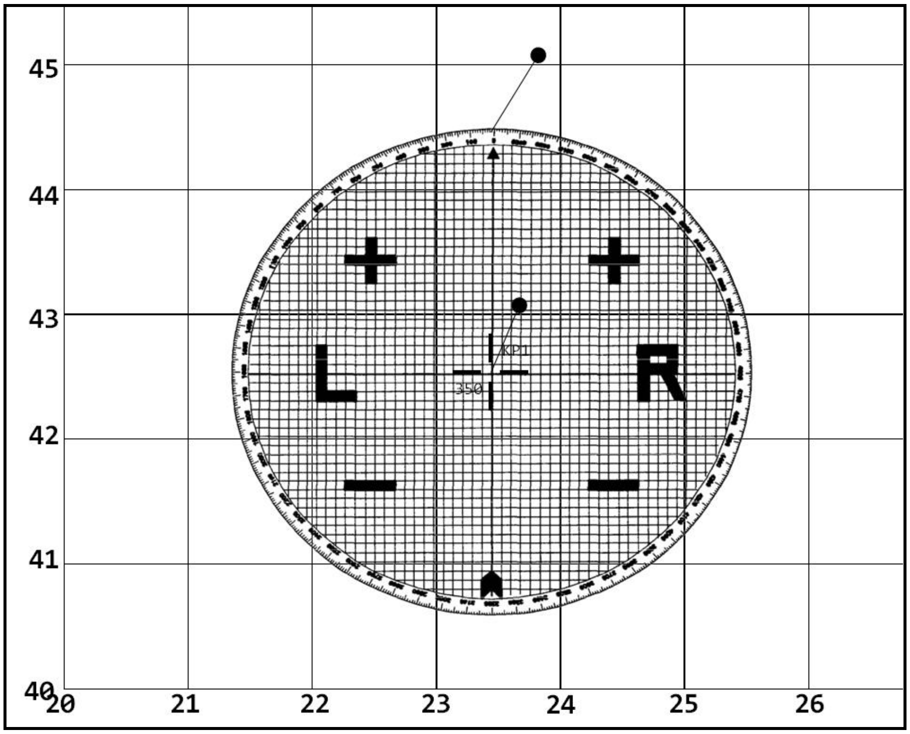
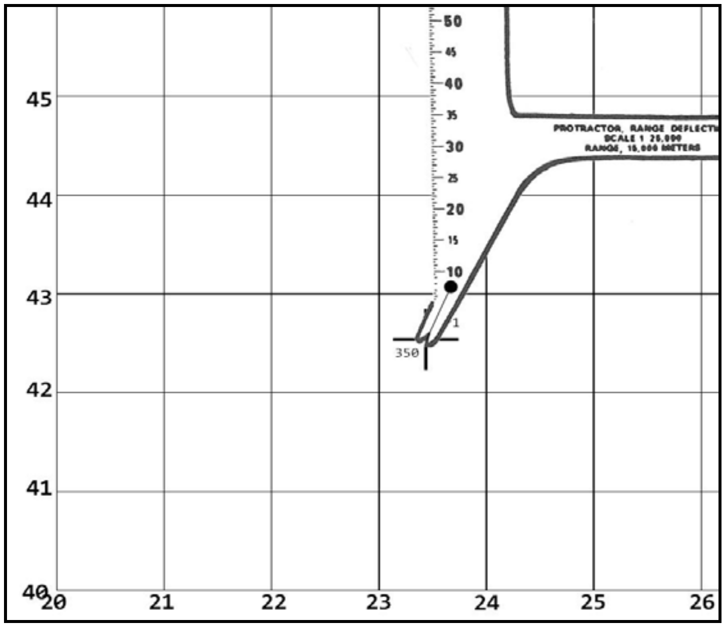
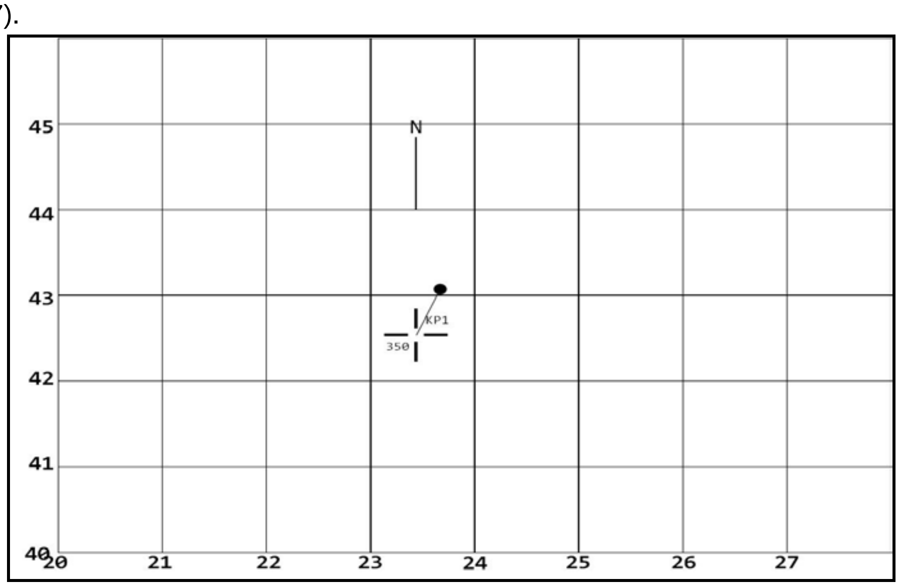
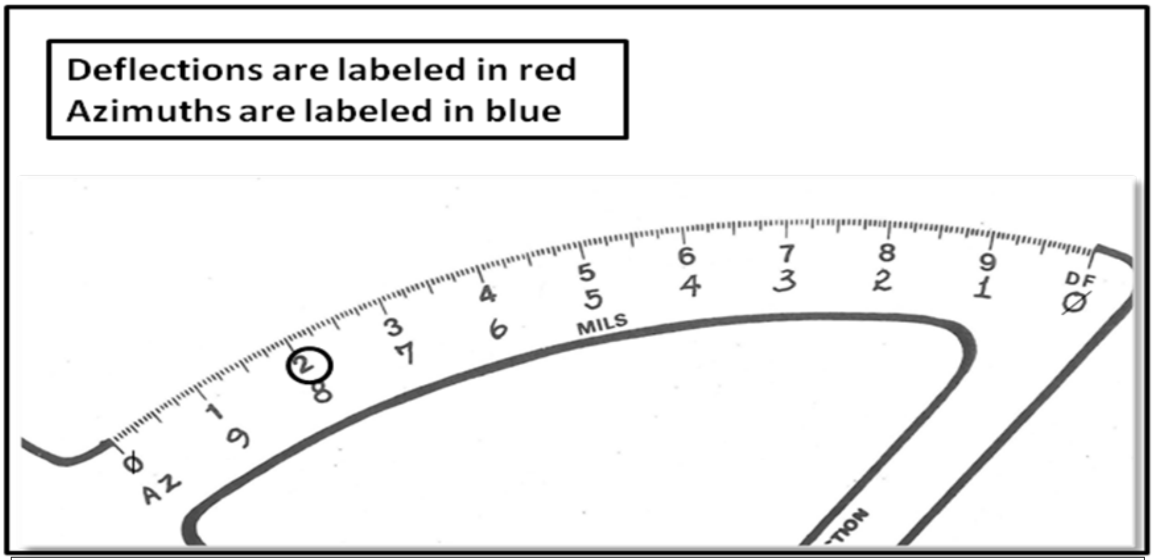
STEP	***ACTION***
3	Insert a pin at the target grid graduation corresponding to azimuth 0. This is a **temporary north index** for the known point (see figure 6-15).  **Figure 6-15. Constructing North Index Step 2.**
4	Remove the target grid and reinsert a pin into the known point location.
5	With the vertex of the range deflection protractor on the known point location, align the arm of the range deflection protractor with the pin in the north index.
6	Remove the north index pin.

Table 6-5. Constructing North Indexes (continued).

STEP	***ACTION***
7	With a 6H pencil, construct a line along the arm of the range deflection protractor (figure 6-16) beginning at range 2050, through the north index pinhole, out to range 3300.  **Figure 6-16. Constructing North Index Step 3.**
8	Using a 4H pencil, label the line with an **"N",** placed immediately above the end of the line (see figure 6-17).  **Figure 6-17. Constructing North Index Step 4.**

CONSTRUCTION OF AZIMUTH INDEXES

6-33. Azimuth indexes are constructed for points located on the firing chart from which the polar method of target location may be expected. The RDP is prepared by numbering the 100-mil azimuth graduations in blue as shown in figure 6-18.



Legend: AZ - azimuth DF - deflection

Figure 6-18. Labeling the RDP.

6-34. Azimuths are always read as four digits. The first digit (thousands of mils) is read from an index or pin that is constructed on the firing chart. The last three digits are read from the arc of the RDP. Azimuth indexes are constructed on the firing chart in 1,000-mil intervals throughout the target area, except the 6000 and 0 indexes, which are 400 mils apart. The steps for constructing azimuth indexes can be found in table 6-6.

Note: To help determine the four digits of a deflection or azimuth, use the memory aid CLUE.

C - Chart index/pin is first digit.

L - Label on RDP arc is second digit.

U - Unit graduation is third digit.

E - Estimate (visually) to nearest mil is fourth digit.

Table 6-6. Constructing Azimuth Indexes.

STEP	*ACTION*
1	Place a plotting pin in the observer location.
2	Place the vertex of the RDP against the pin

Table 6-6. Constructing Azimuth Indexes (continued).

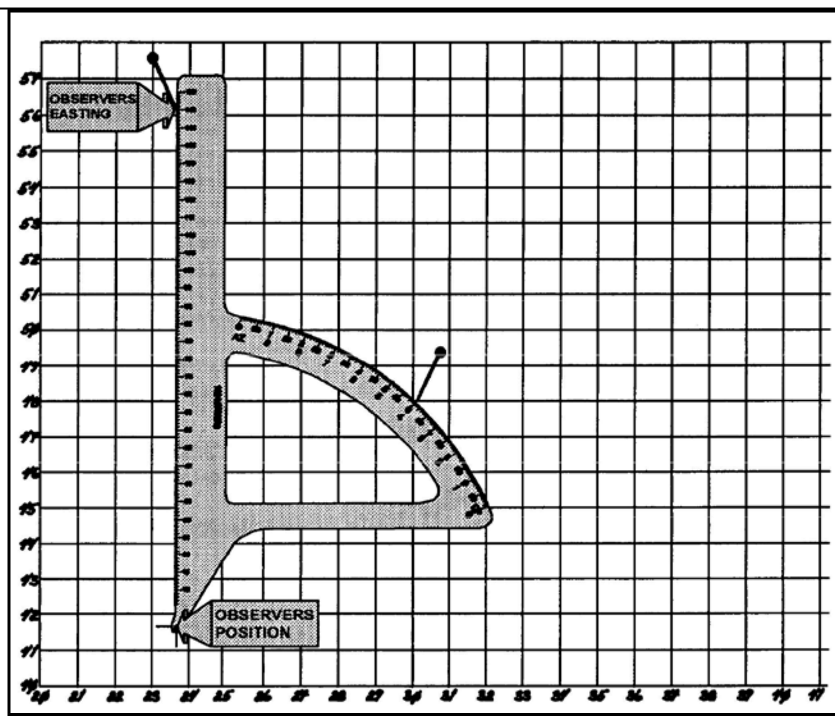
STEP	***ACTION***
3	Align the arm of the RDP so that it's parallel with a convenient grid line. To ensure the arm of the RDP is parallel to the grid line, use the following steps: When using a **north-south** grid line, plot the observer's **easting** from the grid line with a plotting pin and move the RDP until the arm is against the pin. When using an **east-west** grid line, plot the observer's **northing** from the grid line with a plotting pin and move the RDP until the arm is against the pin.
	Note: Easting and nothings should be plotted as far from the plotted location as the range arm of the RDP will allow. This improves the accuracy of the orientation.
4	Place a plotting pin opposite the number on the azimuth scale (blue numbers) on the arc of the RDP corresponding to the last three digits of the azimuth in which the arm of the RDP is oriented. Use the following guide: If the RDP is oriented **north** (6400 mils or 0 mils)- Place a pin opposite the blue 4 on the arc; this represents the 6,000-mil azimuth index. Place a pin opposite the blue 0 on the arc; this represents the 0-mil azimuth index. If the RDP is oriented **east** (1,600 mils), place a pin opposite the blue 6 on the arc this represents the 1,000-mil azimuth index. If the RDP is oriented **south** (3,200 mils), place a pin opposite the blue 2 on the arc; this represents the 3,000-mil azimuth index If the RDP is oriented **west** (4,800 mils), place a pin opposite the blue 8 on the arc; this represents the 4,000-mil azimuth index
	Note: The pin represents a **temporary index**. Its value is the value of the first digit of the azimuth in which the arm of the RDP is oriented. See figure 6-19. The RDP is oriented north (0 or 6,400 mils), so a pin was inserted at the 4 on the azimuth scale. The pin represents the 6,000-mil azimuth index.
	 **Figure 6-19. Orienting the RDP.**
5	Remove the plotting pin that is along the arm of the RDP.
6	Place the arm of the RDP against the plotting pin representing the azimuth index.

Table 6-6. Constructing Azimuth Indexes (continued).

STEP	*ACTION*
7	Remove the plotting pin.
8	Using a 6H pencil, construct a single fine line along the arm of the RDP from Range 8500 to range 9500. Ensure that the line goes through the center of the pinhole. The distance between these two ranges is approximately 2 inches.
9	Move the RDP away from the azimuth index.
10	Label the azimuth index with its identification and azimuth value beginning one-eight inch beyond the pinhole (above the index). Label with the same colors and symbols that were used to label the tick marks. For azimuth values, first record the observer's identification as it is in the observer tick mark. Then record the letters "AZ" followed by the actual value for the azimuth index (0, 1,000, 2,000…6,000). Figure 6-20 shows a completed 0 azimuth index for Observer 1.

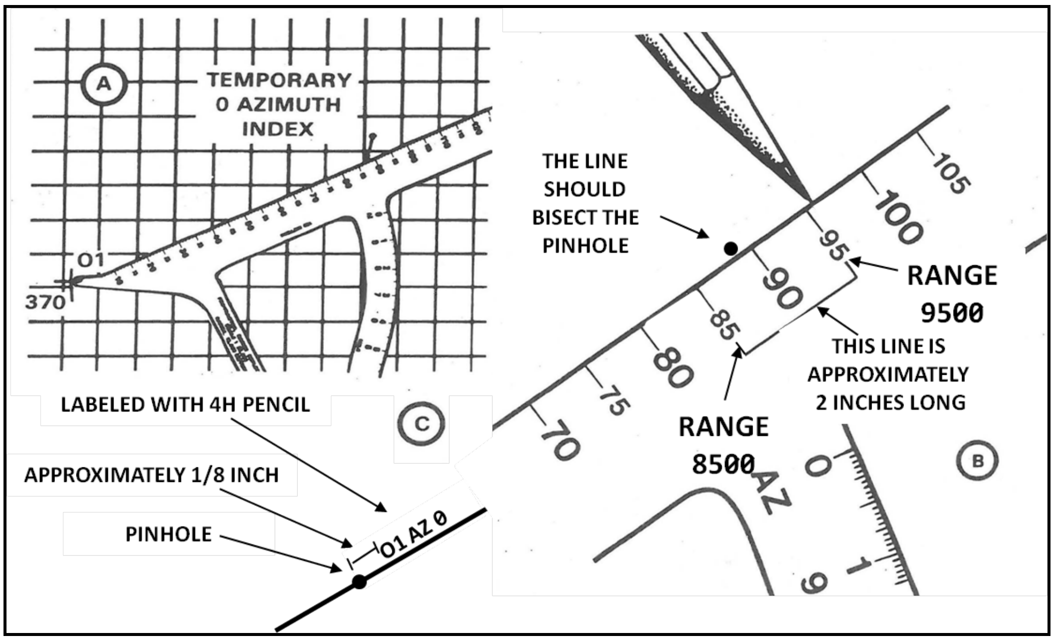


Figure 6-20. Constructing an Azimuth Index.

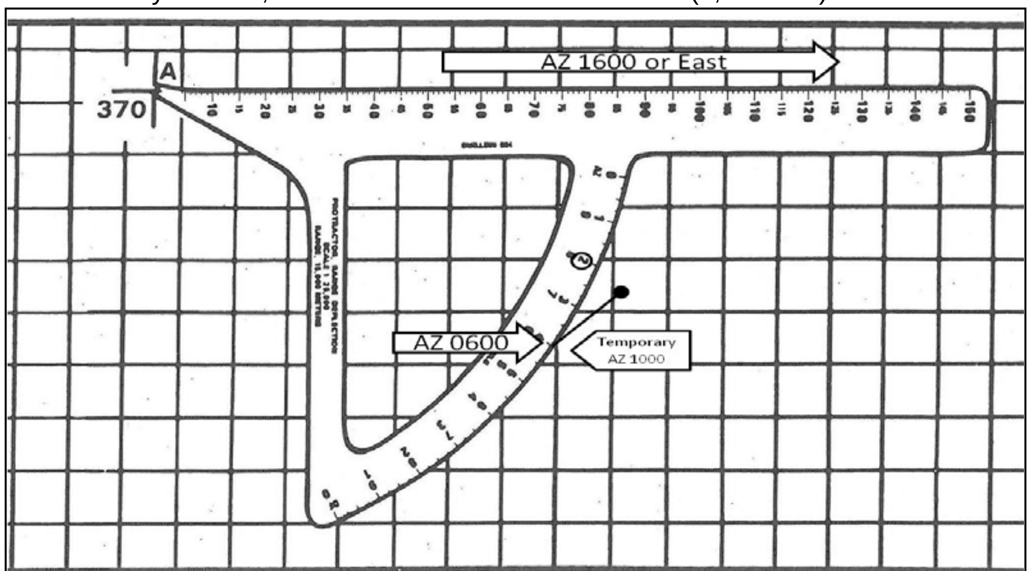
	Note: Other azimuth indexes can be constructed by measuring successive 1,000-mil increments to the left and right of the initial index. These indexes should have the same labeling as the initial index except the azimuth value should reflect the 1,000-mil change in azimuth. If the index is to the right of the initial index, the azimuth value will reflect an increase in azimuth. If the index is to the left of the initial index, the azimuth will reflect a decrease in azimuth. This is because azimuth increases to the right and decreases to the left. An easy rule to remember is the **RALS rule (right, add; left, subtract).** Construct as many azimuth indexes for each observer as will fit on the firing chart or as instructed by the FDO.
11	Complete steps 1 through 10 for each observer location.
Legend: AZ – azimuth FDO – fire direction officer RALS – right add left subtract RDP – range deflection protractor	

CONSTRUCTION OF DEFLECTION INDEXES

6-35. Direction from a battery or platoon to a target normally is measured and announced in terms of deflection. The RDP will be used to measure deflection, so it must be prepared by numbering the graduations of the arc in red as shown in Figure 6-18. Orient the RDP on the azimuth of fire, and place a pin opposite the common deflection for that weapon system. Table 6-7 (on page 6-20) contains the steps required for constructing deflection indexes.

Table 6-7. Constructing Deflection Indexes.

STEP	*ACTION*
1	Place a plotting pin in the base piece location
2	Place the vertex of the RDP against the pin at the base piece location
3	Orient the RDP in the cardinal direction closest to the azimuth of lay.
4	Align the arm of the RDP parallel to a convenient grid line. To ensure the arm of the RDP is parallel to the grid line, use one of the following procedures: ● If using a **north-south** grid line, plot the base piece easting with a plotting pin and move the RDP until the arm is against the pin ● If using an **east-west** grid line, plot the base piece northing with a plotting pin and move the RDP until the arm is against the pin Note: Easting and nothings should be plotted as far from the plotted location as possible. This improves the accuracy of the orientation.
5	Place a plotting pin opposite the number on the azimuth scale (blue numbers) on the arc of the RDP corresponding to the last three digits of the azimuth in which the arm of the RDP is oriented. The location of the pin represents a **temporary index** and will **not be replaced** with a permanent index. The value of the pin is the value of the first digit of the azimuth in which the arm of the RDP is oriented. Use the rules outlined in step 4 of Table 6-6 to determine where the pin should be placed. In figure 6-21, the azimuth of lay is 1900, so the RDP has been oriented east (1,600 mils)



Legend: AZ - azimuth DF - deflection

Figure 6-21. Range-deflection Protractor Oriented East.

Table 6-7. Constructing Deflection Indexes (continued).

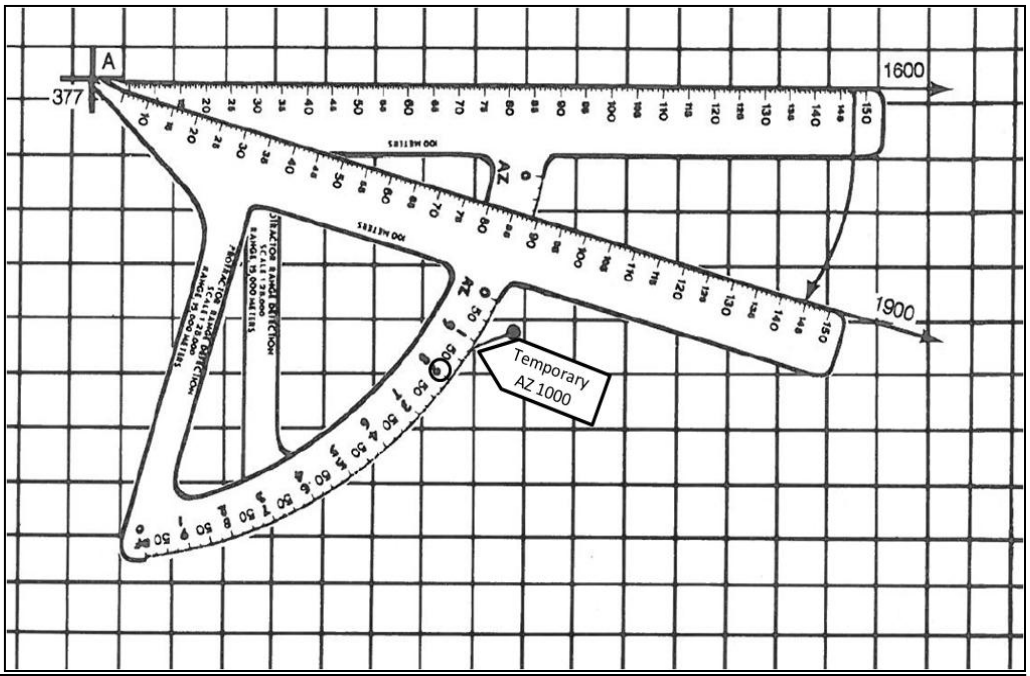
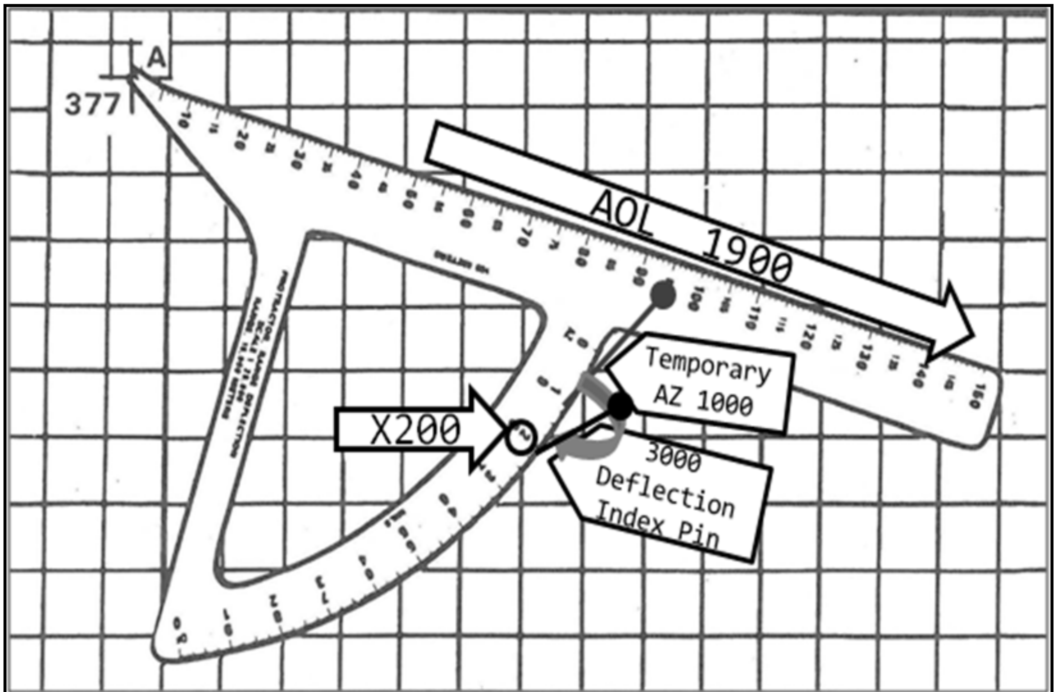
STEP	***ACTION***
6	Move the RDP until the last three digits of the azimuth of lay (read on the azimuth scale of the RDP) are opposite the temporary pin. The arm of the RDP is now oriented on the azimuth of lay. If the RDP cannot be moved to the azimuth of lay, measure 1,000 mils from the initial pin to establish a temporary index appropriate to the azimuth of lay. Continue to follow the procedures as listed in this step until the RDP is oriented on the azimuth of lay. An example is shown in figure 6-22.  Legend: AZ - azimuth DF - deflection **Figure 6-22. Range-deflection Protractor Oriented on Azimuth of Lay.** Note**:** To help determine the four digits of a deflection or azimuth, use the memory aid CLUE. **C** - Chart index/pin is first digit. **L** - Label on RDP arc is second digit. **U** - Unit graduation is third digit. **E** - Estimate (visually) to nearest mil is fourth digit.
7	Remove the pin that was against the arm of the RDP.
8	Once the RDP is oriented on the azimuth of lay, remove the plotting pin that represented the temporary azimuth index and place it opposite the circled, red 2 on the deflection scale. Currently, all US howitzers use 3200 for common deflection, and now the plotting pin represents a temporary deflection index of 3000.

Table 6-7. Constructing Deflection Indexes (continued).

STEP	***ACTION***
	Note: When a howitzer is oriented on the azimuth of lay, it is on its common deflection of 3200. Figure 6-23 shows a common deflection of 3200.



Legend: AOL - azimuth of lay AZ - azimuth DF - deflection

Figure 6-23. Range-Deflection Protractor Oriented on Common Deflection.

STEP	***ACTION***
9	Place the arm of the RDP against the plotting pin representing the temporary deflection index.
10	Remove the pin.
11	Using a 6H pencil, construct a fine line along the arm of the RDP from range 8500 to 9500. Ensure the line bisects the center of the pinhole. The distance between these two ranges is approximately 2 inches. This is the primary deflection index.
12	Move the RDP away from the deflection index Note: The same color code used for tick marks is used when labeling deflection indexes. (See table 6-4, step 7 on page 6-13.)
13	Using the appropriate color of pencil, construct an arrowhead 1/8 of an inch above the pinhole. The arrowhead points toward the base piece location. (See figure 6-24 page 6-23.)

Table 6-7. Constructing Deflection Indexes (continued).

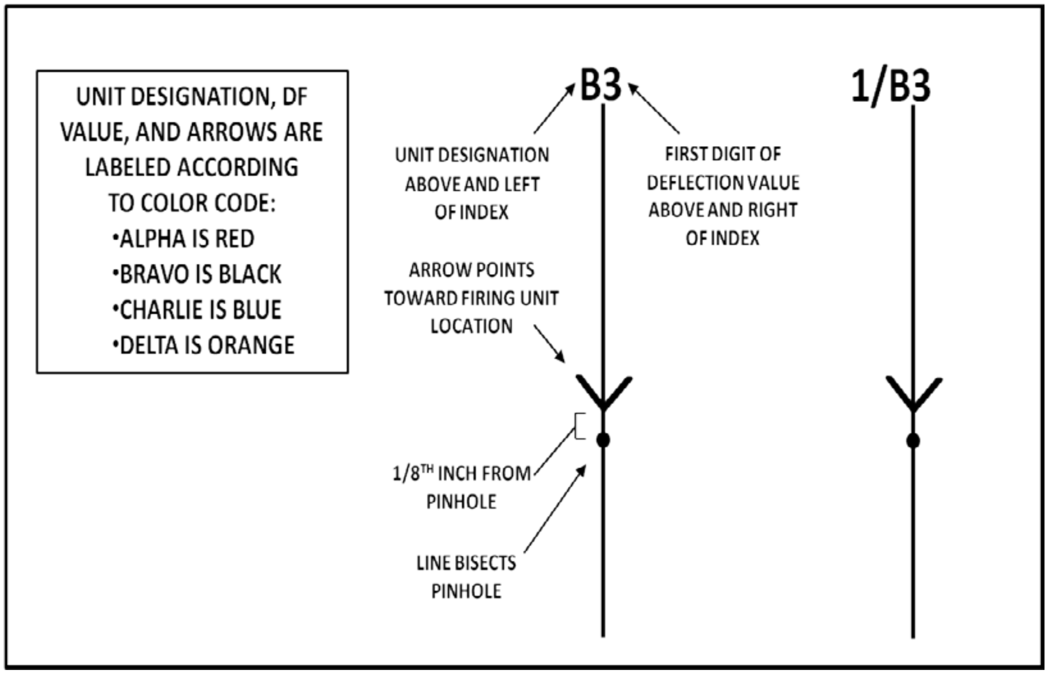
STEP	***ACTION***
14	Label the deflection index with the appropriate unit designation and deflection value. Record only the first digit of the deflection value. Unit designation is recorded immediately above and to the left of the index. Deflection values are recorded immediately above and to the right of the index. Figure 6-24 shows a 3,000-mil deflection index for Bravo Battery. When creating a deflection index for a specific platoon, record the platoon number first. For example, for First Platoon, Bravo Battery, label the index with 1/B 3.  **Figure 6-24. Deflection Index.**

Table 6-7. Constructing Deflection Indexes (continued).

STEP	*ACTION*
	Note: The deflection index just constructed is the primary deflection index. Other deflection indexes are constructed by measuring successive 1,000-mil increments to the left and right of the primary index. These supplementary deflection indexes have the same color labeling as the primary index, and the deflection value should reflect the 1,000-mil change in deflection. If the supplementary index is to the right of the primary index, it will decrease in deflection. If the supplementary index is to the left of the primary index, it will increase in deflection. This is because deflection increases to the left and decreases to the right. An easy rule to remember is the **LARS rule (left, add; right, subtract**). Figure 6-25 shows a plotted position with seven deflection indexes.

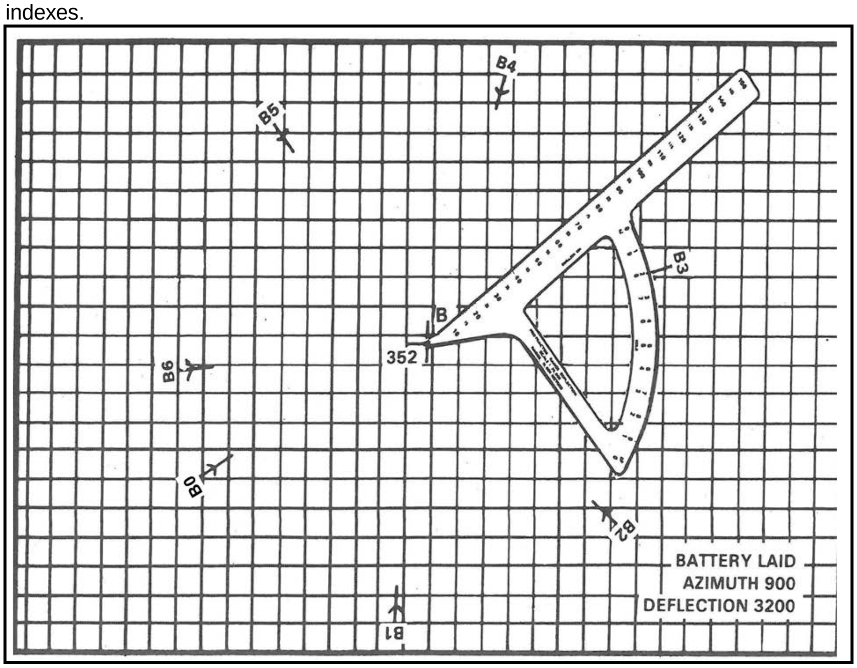


Figure 6-25. Deflection Indexes for 6400 mils.

Legend: LARS – left add right subtract   RDP – range deflection protractor   US – United States

PLOTTING TARGETS

6-36. The observer can use three methods of target location: grid coordinate, polar plot, and shift from a known point. The grid coordinate method (table 6-8) utilizes the same steps outlined in table 6-3 (on page 6-9), The Four-Step plotting Method. The two remaining methods of target location are discussed in tables 6-9 and 6-10 (on pages 6-25 and 6-26).

Table 6-8. Grid Coordinate Method (Four-Step Plotting Method).

STEP	*ACTION*
1	Place a plotting pin in the upper right-hand corner of the grid square where the point is to be plotted.
2	Place the plotting scale along the left edge of the grid square so that the 0 on the bottom scale is at the lower left-hand comer of the grid square.
3	Slide the plotting scale to the right, and set off the target easting by using the vertical grid line as an index.
4	With the bottom edge of the plotting scale precisely aligned on the horizontal grid line, plot the target northing on the vertical scale with a plotting pin. This is the target location.

Table 6-9. Polar Plot Method of Target Location.

STEP	***ACTION***
1	Place a plotting pin at the observer's location.
2	Place the vertex of the RDP against the pin.
3	Align the RDP in the direction announced by the observer. Use the appropriate azimuth index for that observer and the arc of the RDP.
4	Place a pin along the arm of the RDP at the distance reported by the observer. This is the target location. Figure 6-26 shows a polar plot method of target location where the call for fire was received from Observer 1 for direction 6200 and distance 8700.

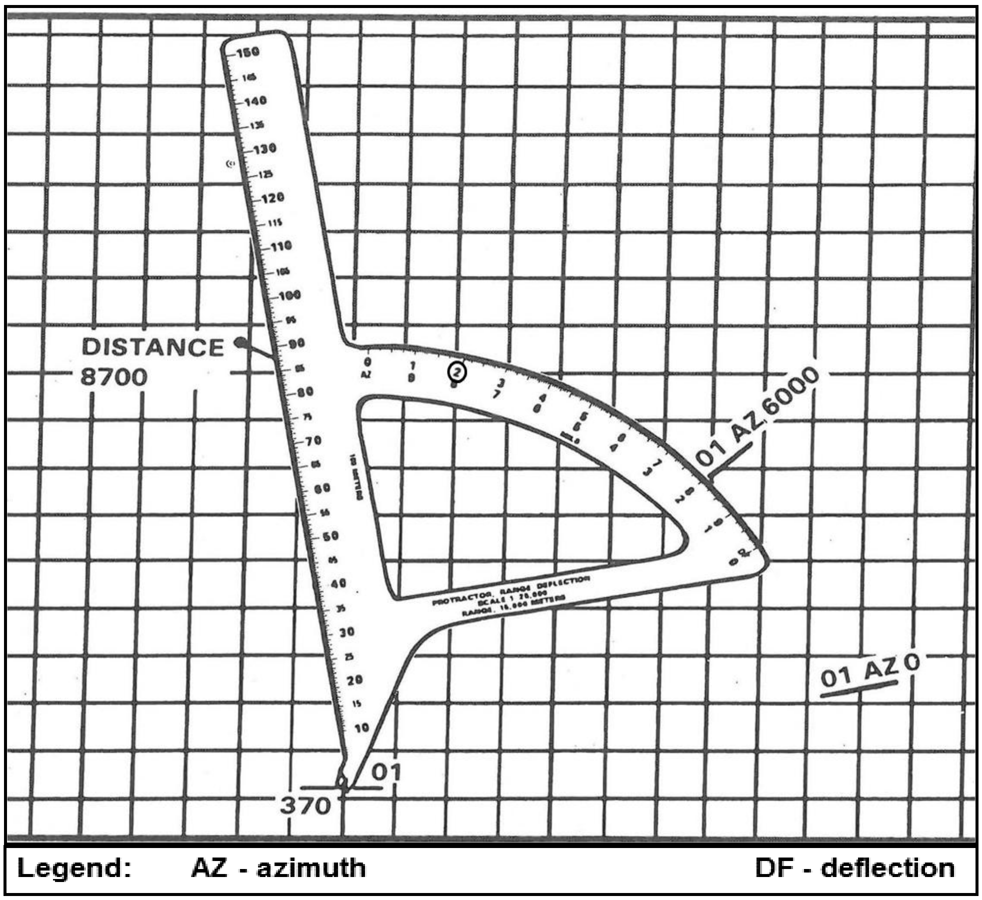


Figure 6-26. Polar Plot the Target Location.

Legend: AZ – azimuth DF – deflection RDP – range deflection protractor

Table 6-10. Shift from a Known Point Method of Target Location.

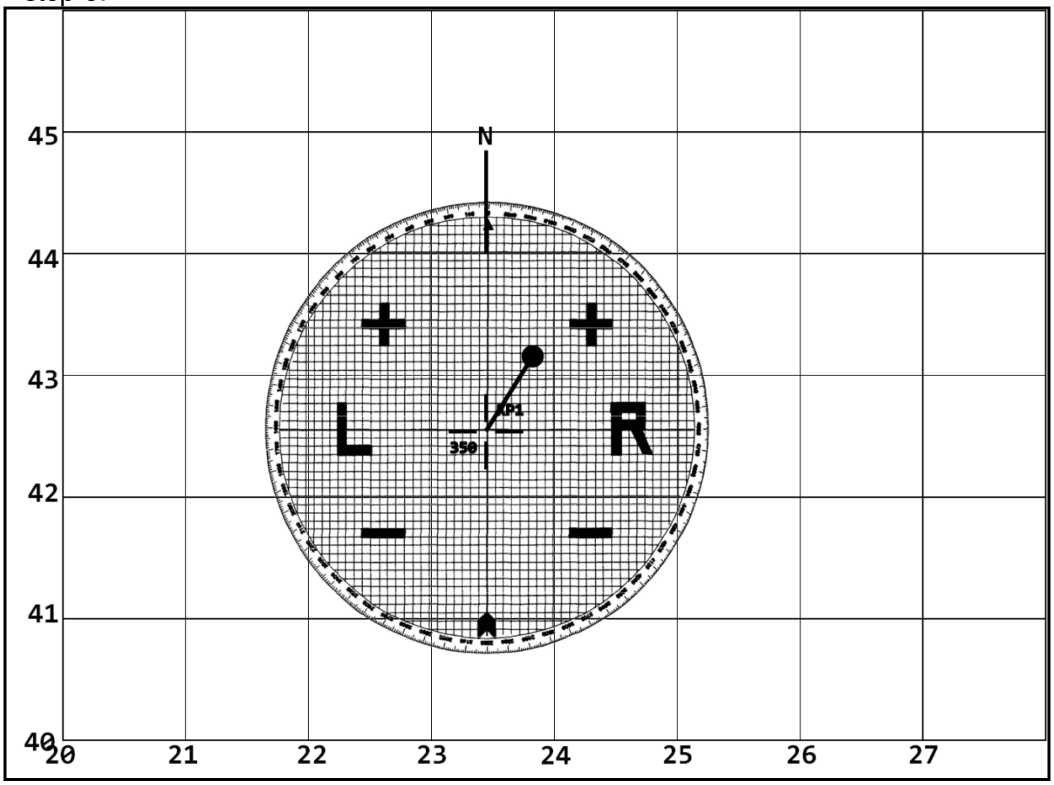
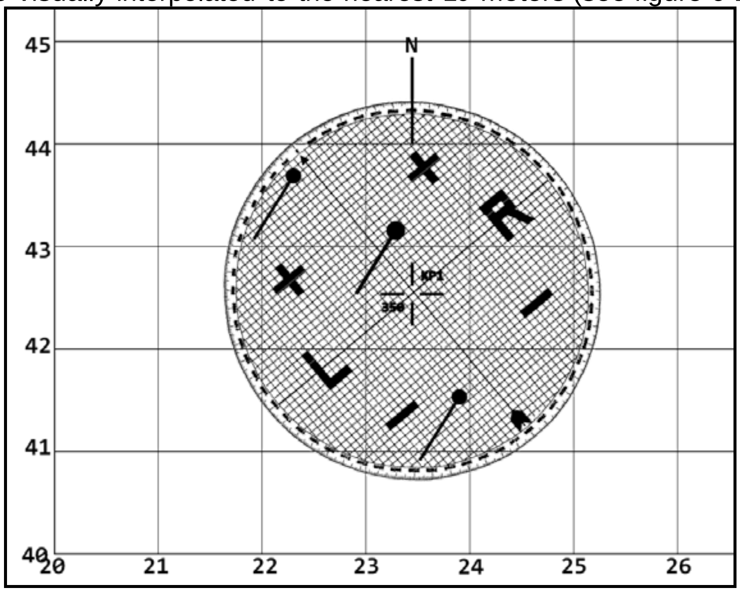
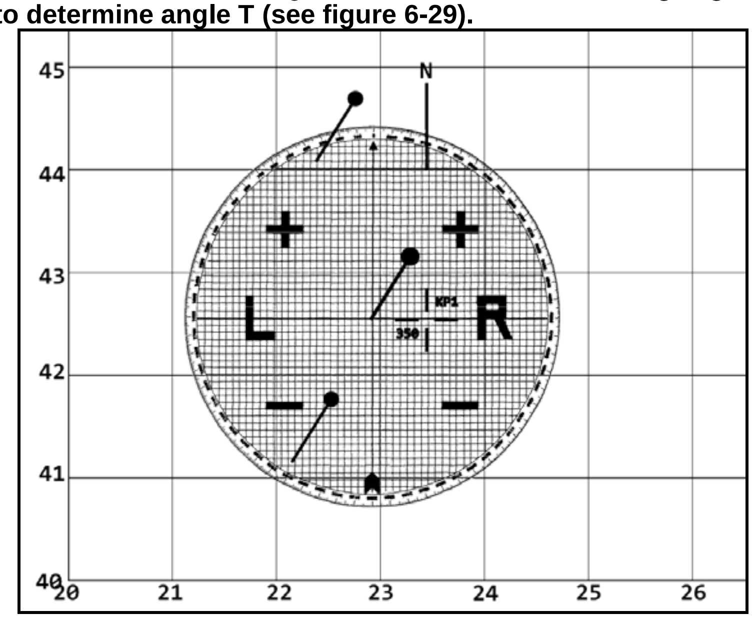
<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td>1</td><td>Insert a pin through the center of the target grid.</td></tr>
<tr><td>2</td><td>Place the pin in the pinhole marking the point from which the observer is shifting.</td></tr>
<tr><td>3</td><td>Align the arrow on the target grid so that it is parallel to a north-south grid line (see figure 6-27). If a permanent north index has been constructed for the known point, orient the target grid so that the 0 graduation is at the north index and go to step 5.


Figure 6-27. Orienting the Target Grid.</td></tr>
<tr><td>4</td><td>Place a pin opposite the 0 on the outer scale of the target grid. This is a temporary north index.</td></tr>
<tr><td>5</td><td>Rotate the target grid until the announced direction is at the north index (pin or permanent index). Once the target grid is oriented for direction, a minimum of two pins should be used to secure it. This will prevent unintentional movement.</td></tr>
</table>

Table 6-10. Shift from a Known Point Method of Target Location (continued).

STEP	*ACTION*
6	Plot the left or right shift given by the observer by measuring the appropriate number of squares left or right of the pin. Each square represents 100 meters and can be visually interpolated to the nearest 10 meters (see figure 6-28).  **Figure 6-28. Orienting the Target Grid (Continued).**
7	Plot the add or drop corrections given by the observer by measuring the appropriate number of squares (plus or minus) from the point plotted in step 6 and insert the plotting pin. This is the initial target location. **Reorient the target grid over this location to determine angle T (see figure 6-29).**  **Figure 6-29. Re-orienting the Target Grid on Initial Target Location.** Note: If the initial shift plots the point off the target grid, plot the portion of the shift that will fit on the target grid and then reorient on the last plotted point and plot the remaining portion of the shift

DETERMINING AND ANNOUNCING CHART DATA

6-37. Chart data consist of **chart range** and **chart deflection** from the firing unit to the target and **angle T**. In a manual FDC, two firing charts will be constructed and used to check each other. Use the steps in table 6-11 to determine chart data.

6-38. One chart may differ slightly from another because of small differences in construction caused by human limitations in reading the graphical equipment. Because of these differences, the following tolerances between charts are permissible:

- -Range and/or distance ±30 meters.
- -Azimuth and/or deflection ±3 mils.
- -Angle T ±30 mils.

6-39. All firing unit locations must be checked for accuracy. For checking the accuracy of two or more charts, plot the same grid intersection on all charts. Determine range and deflection to that grid intersection. If all ranges agree within ±30 meters in range and ±3 mils in deflection, the charts are accurate for that firing unit location. If not, all charts must be checked for errors.

6-40. To ensure accuracy, enough points in the zone of operation of a firing unit should be checked. For example, an error in plotting the unit location on one chart could compensate for an error in constructing the deflection index on the other chart. Checking at least two points will reveal the error. This should be done as a matter of unit SOP.

Table 6-11. Determining and Announcing Chart Data.

STEP	***ACTION***
1	Place a plotting pin in the base piece location.
2	Place the vertex of the RDP against the pin.
3	Move the RDP so that the left edge of the arm is against the pin at the target location.
4	Determine the range, to the nearest 10 meters, along the arm opposite the pin in the target location.
5	When the computer requests the range, announce the range. The platoon identification is announced followed by the range; for example, **"1/A RANGE 3250" (ONE ALPHA, RANGE THREE, TWO, FIVE, ZERO).**
6	Determine the chart deflection from the arc of the RDP opposite the appropriate deflection index. To determine the deflection, combine the 1,000-mil designation of the index with the reading on the arc. Deflection is determined to the nearest 1 mil.
7	Announce the determined deflection. The platoon designation is not announced; for example, **"DEFLECTION 3288" (DEFLECTION THREE, TWO, EIGHT, EIGHT).**
	Note: If the data announced by the HCO is greater than ±30 meters in range and/or ±3 mils in deflection from the VCO's data, the VCO will announce "HOLD" (and the total difference between his data and the data that the HCO announced). If the data are within tolerance, the VCO simply announces "CHECK".
8	Move the RDP away from the target location.
9	Attach and orient the target grid over the target location. First, insert a pin through the center of the target grid. Next, using shaft-to-shaft contact, insert the pin in the pinhole marking the target location. Orient the target grid as in the shift from known point method of plotting target location (Table 6-10). Once the target grid is oriented for direction, a minimum of two pins are inserted along the outer edge of the target grid to keep it from slipping when subsequent corrections are plotted. The pins should be positioned so that they do not interfere with the RDP. **If the shift from known point method of target location is used, the target grid must be reoriented over the target location.**
10	With the vertex of the RDP still at the base piece location, move the RDP so that the left edge of the arm of the RDP is against the pin at the target location.

Table 6-11. Determining and Announcing Chart Data (continued).

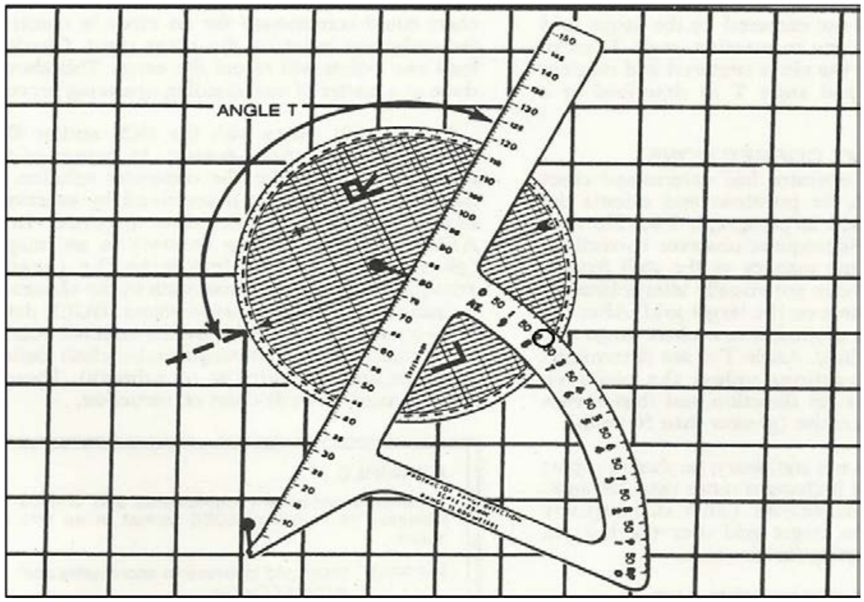
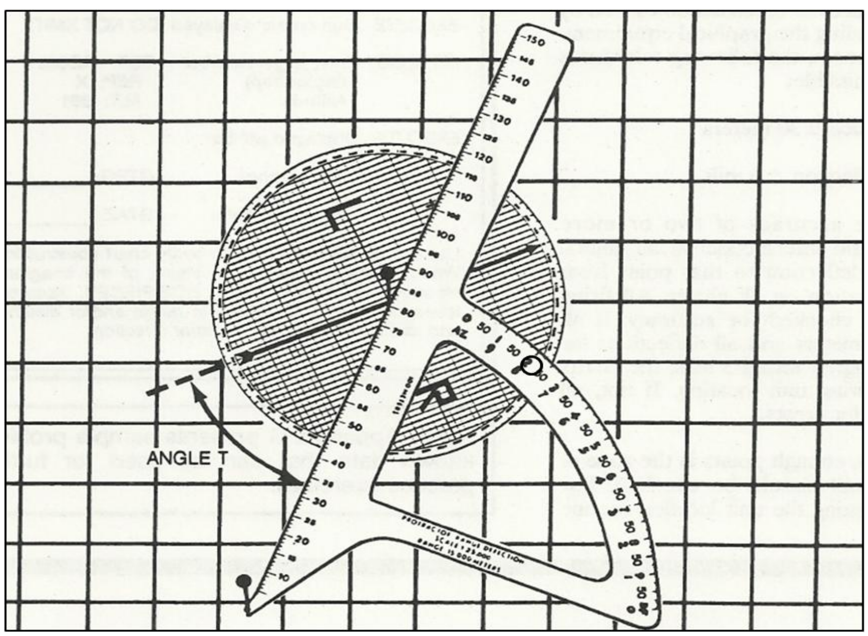
10	Note: Angle T is the angle formed by two rays beginning at the target and extending to the firing unit and observer locations. Angle T will never be greater than 3200 mils. An easy rule to remember when determining Angle T is to read Head-to Head or Tail-to-Tail. (See figure 6-30 and 6-31).  **Figure 6-30. Determining Angle T (Head-to-Head).**  **Figure 6-31. Determining Angle T (Tail-to-Tail).**
11	Determine the number of mils between the head of the arrow on the target grid and the upper left-hand edge of the RDP or the tail of the arrow on the target grid and the lower left-hand edge of the RDP. Angle T is determined to the nearest 10 mils.
12	The chart operator announces the determined angle T; for example,**"ANGLE T 560" (ANGLE T FIVE, SIX, ZERO).**

Table 6-11. Determining and Announcing Chart Data (continued).

	Note: If the angle T announced by the HCO is greater than ±30 mils from what the VCO determines, the VCO will announce "HOLD" (and the total difference between his data and the data that the HCO announced). If the data are within tolerance, the VCO simply announces "CHECK."
13	After receiving subsequent corrections from the observer, plot left or right corrections by measuring the appropriate number of squares left or right of the last plotted location.
14	Plot add or drop corrections by measuring the appropriate number of squares (plus or minus) from the point plotted in Step 13, and insert a pin. This is the adjusted aimpoint.
15	Determine and announce chart range and deflection as in Steps 1 through 7.
	Note: If the observer or target is moving, the observer will report changes of direction to the target to the FDC if the change is greater than 100 mils. If this occurs, the chart operator reorients the target grid over the last plotted location on the new direction, then plots the subsequent corrections as announced by the observer, and redetermines angle T. After the initial correction is made from the target location, all further corrections are made from the last pin (aimpoint) location. The observer's final refinement that is transmitted with end of mission need not be plotted by the chart operator unless the observer requests RECORD AS TARGET or unless the chart operator is instructed to do so by the FDO.
Legend: FDC – fire direction center FDO – fire direction officer HCO – horizontal control operator RDP – range deflection protractor VCO – vertical control operator	

SECTION V: OBSERVED FIRING CHART

6-41. When survey control and maps are not available, delivery of indirect fires is possible by using observed firing charts. An ***observed firing chart*** **is a firing chart on which all units and targets are plotted relative to each other from data determined by firing a registration.** Observed firing charts are an expedient method that should only be use under emergency conditions and every attempt should be made to construct a surveyed firing chart as soon as possible. Since all locations are based upon firing data, observed firing charts contain errors because of nonstandard conditions.

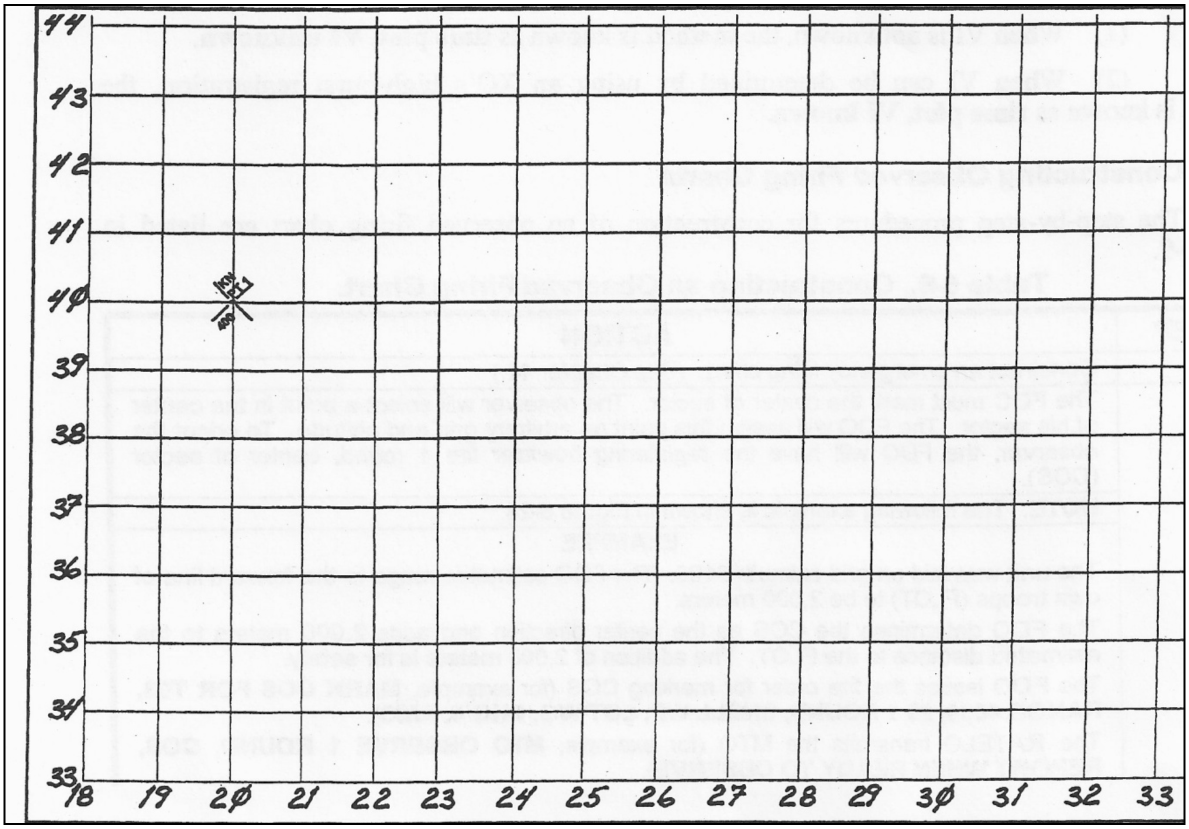
OVERVIEW

6-42. All observed firing charts are based on a registration. Once a registration is complete, the unit location is polar plotted from the point of registration (normally assumed to be a grid intersection) by using the direction that is based on the back azimuth to the point and a range corresponding to the adjusted elevation, or more preferably, a range corresponding to the adjusted time.

6-43. Because maps and survey are not available, altitudes cannot be accurately determined. When vertical interval and site are assumed to be zero, a false range is introduced into the polar plot range. This inaccuracy can be reduced by trying to determine site. Site may be determined by estimating vertical interval or by conducting an executive officer's (XO) high burst.

6-44. The general procedures for constructing an observed firing chart are listed below:

- Mark the center of sector for observers.
- The observer selects a point in the center of the sector of fire that can be identified on the ground.
- Assign the point an arbitrary grid coordinate and altitude. Plot this location on the firing chart. The grid coordinates assigned to the point are completely arbitrary. A grid intersection is preferred for simplicity. The grid coordinates of the known point will serve as the basis for establishing a common grid system. For example, the point could be assigned the grid coordinates of easting (E):20000 northing (N):40000, altitude 400 meters. (See figure 6-32 on page 6-31.)



Legend: KN PT – known point

Figure 6-32. Observed Firing Chart Grid.

- Conduct a precision registration (fuze time, if possible) on the point by using emergency firing chart procedures. (See Chapter 14.)
- Determine the adjusted data (to include orienting angle, if possible).
- From the adjusted data, determine direction (azimuth) and distance (range) from the point to the unit.
- Polar plot the base piece from the point.

METHODS OF DETERMINING POLAR PLOT DATA

6-45. All observed firing charts are constructed by using polar plot data. The method for obtaining these data depends on the type of registration conducted and whether site can be estimated or whether it is unknown.

6-46. Percussion plot is used when an impact registration has been conducted.

- When the vertical interval (VI) is unknown and cannot be estimated, the method is known as **percussion plot, VI unknown.**
- When vertical interval can be estimated, a site can be determined and inaccuracies reduced. This method is known as **percussion plot, VI estimated.**

6-47. Time plot is used when a time registration has been conducted.

- When VI is not known, the method is known as **time plot, VI unknown.**
- When VI can be determined by using an XO's high-burst registration, the method is known as **time plot, VI known.**

CONSTRUCTING OBSERVED FIRING CHARTS

6-48. The step-by-step procedures for construction of an observed firing chart are listed in table 6-12.

Table 6-12. Constructing an Observed Firing Chart.

STEP	*ACTION*
1	Construct an emergency firing chart. (See Chapter 14.)
2	The FDC must mark the center of sector. The observer will select a point in the center of his sector. The FDO will assign this point an arbitrary grid and altitude. To orient the observer, the FDO will have the registering howitzer fire 1 round, center of sector (COS).
	Note: The following example is shown in Figure 6-33.
	EXAMPLE The unit was laid on grid azimuth 6100. The FDO estimates range to the forward line of own troops (FLOT) to be 7500 meters. The FDO determines the COS as the center direction and adds 2000 meters to the estimated distance to the FLOT. The addition of 2000 meters is for safety. The FDO issues the fire order for marking COS (for example, **MARK COS FOR T03, RANGE 9500, #3, 1 ROUND, SHELL WP, LOT WH, CHG 3, AMC).** The RTO transmits the MTO (for example, **MTO: OBSERVE 1 ROUND, COS, REPORT WHEN READY TO OBSERVE).**
	The computer determines firing data to mark COS by placing the manufacturer's hairline (MHL) of the appropriate GFT over the COS range announced in the fire order. The HE elevation and drift are determined by using the appropriate scales.
	Note: The WP weight correction is ignored for speed, but the weight correction may be applied at the FDO's discretion.
	The computer determines the deflection to fire by adding drift to the center deflection. An example is as follows: **CENTER DF 3200** **+ DRIFT L8** **DF TO FIRE 3208**
	The computer determines the quadrant elevation (QE) to fire. This is the elevation corresponding to the range announced in the fire order. Site is 0. Elevation corresponding to range 9500 equals 276. An example is as follows: **ELEVATION 276** **+SITE 0** **QE 276**
	The computer announces the fire commands (for example, **FIRE MISSION, NUMBER 3, 1 ROUND, AMC, SHELL WP, LOT WH, CHG 3, DF 3208, QE 276)** and commands **FIRE** when the observer reports back **READY**.
3	The HCO will construct the known point as directed by the FDO.
4	The grid sheet will now be numbered on the basis of the known point grid.
5	Conduct a precision registration by using emergency firing procedures. (See Chapter 14.)
	Note: The purpose of the precision registration in observed firing charts is to accurately locate a point. This is performed by moving the mean point of impact (MPI) over the observer's known point. The more met corrections that the FDC can account for, the more accurate the chart becomes. It does not lose any accuracy as met corrections change if we continue to account for nonstandard conditions.

Table 6-12. Constructing an Observed Firing Chart (continued).

STEP	*ACTION*
6	The FDO issues the fire order for the precision registration, and directs the observer to conduct a precision registration. Fuze time will yield the most accurate results for the observed firing chart polar plot data and is therefore preferred (for example, **PRECISION REGISTRATION WITH T03, SELECT KNOWN POINT, VICINITY COS, NUMBER 3, 1 ROUND, Q AND TI Special Instructions Use Gunners Quadrant).**
	The RTO issues the MTO (for example, **MTO: SELECT KNOWN POINT, VICINITY COS, Q AND TI).**
	Note: Since no known point exists, the observer will select one near the center of sector and locate it for the FDC as a shift from the COS.
	The HCO plots the direction and shift announced by the observer and determines chart data. The computer records the observer's correction on the record of fire (for example, **DIRECTION 5160, LEFT 40, ADD 200).**
	The HCO centers the target grid over the new target location and determines angle T.
	The FDC processes the registration by using the procedures outlined in Chapter 10 for a precision registration.
	The computer will determine the adjusted time (if applicable), the adjusted deflection, and the adjusted quadrant elevation.
Legend: AMC – at my command CHG – charge COS – center of sector DF – deflection FDC – fire direction center FDO – fire direction officer FLOT – forward line of own troops GFT – graphical firing table HCO – horizontal control operator HE – high explosive MHL – manufacturer's hair line MPI – mean point of impact MTO – message to observer Q – quick QE – quadrant elevation TI – time WP – white phosphorus	

DETERMINATION OF DIRECTION FOR POLAR PLOTTING

6-49. Once the registration has been completed, the azimuth of the line of fire (LOF) must be determined. No matter what technique (percussion or time plot) is used, the direction (azimuth) of the firing unit from the known point is computed in the same manner.

6-50. There are two methods to determine the azimuth of the line of fire. They are as follows:

- The XO or platoon leader will determine the azimuth of the line of fire in accordance with ATP 3-09.50 and report it to the FDC.
- The drift corresponding to the adjusted elevation is stripped out of the adjusted deflection; the result is the chart deflection. The chart deflection is then converted to an azimuth. For example in figure 6-33 (on page 6-35), the firing unit was laid on grid azimuth 6100; common deflection (DF) 3200. The adjusted deflection was 3406, and the adjusted elevation (EL) was 293.

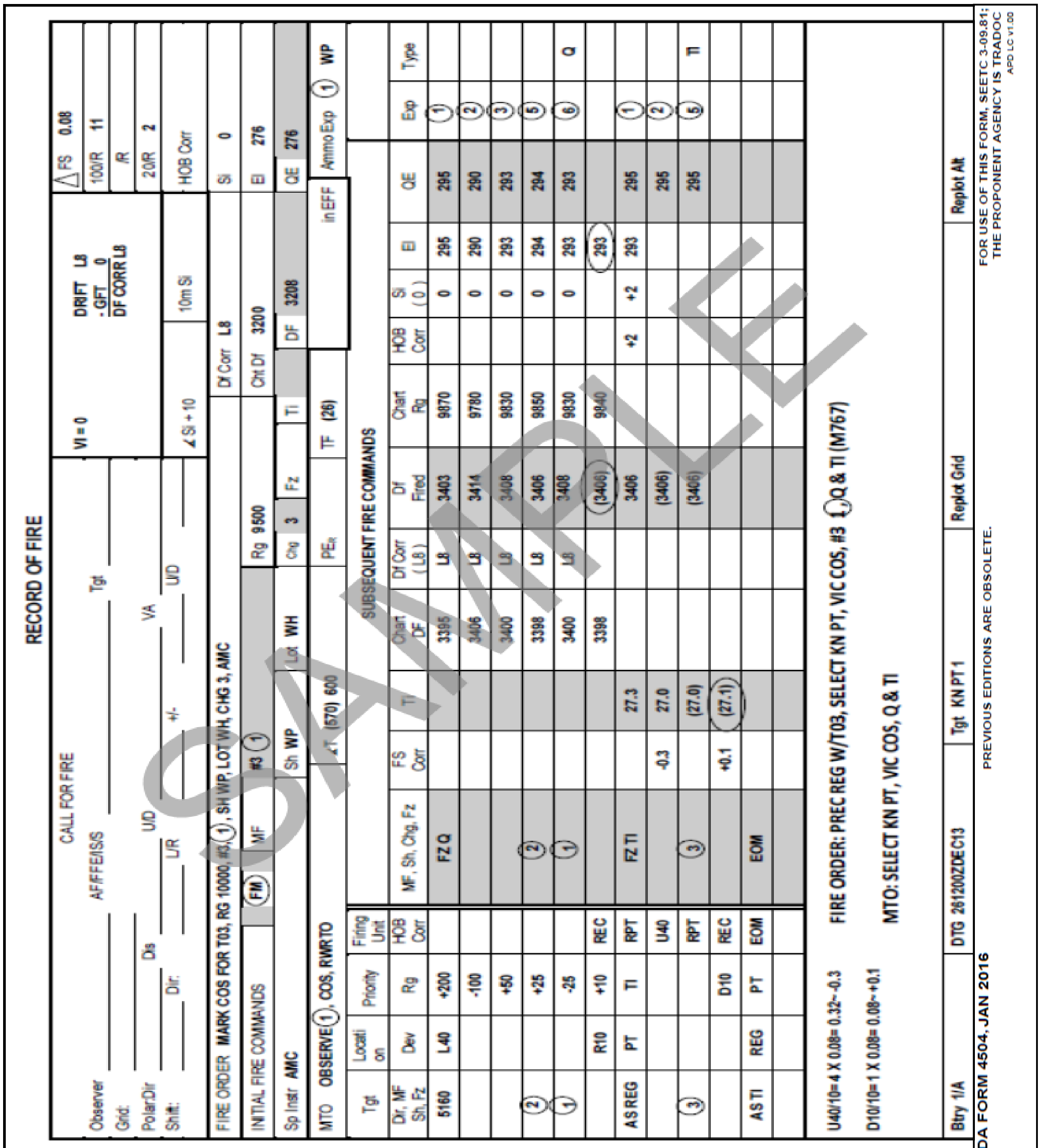
ADJUSTED DF	**3406**
-DRIFT AT ADJ EL	**- L9**
CHART DF	**3397**
CHART DF	**3397**
-COMMON DF	**-3200**
DIFFERENCE IN DF	**L197**
GRID AZIMUTH	**6100**
+DIFFERENCE IN DF	**+L197**
AZIMUTH OF THE LOF	**5903**

- Because the firing unit will be polar plotted from the known point, the FDC must convert the azimuth of the line of fire to a back azimuth. The polar plot direction is simply the back azimuth of fire to the known point. The polar plot direction equals the azimuth of the line of fire ± 3200 mils. If the adjusted azimuth of fire is less than 3200 mils, add 3200 mils to it. If the adjusted azimuth of fire is greater than 3200 mils, subtract 3200 mils from it.

AZIMUTH OF THE LOF	**5903**
± 3200 MILS	**-3200**
POLAR PLOT DIRECTION	**2703**

Note**:** When the azimuth of the line of fire is measured, the howitzer is aimed with the adjusted deflection. This will result in a polar plot azimuth that compensates for drift. If the drift corresponding to the adjusted elevation is removed and a chart deflection is determined, all nonstandard conditions (other than drift) affecting the deflection are accounted for in the plot of the known point

- Once the polar plot direction has been computed, the remaining polar plot data must be computed by using one of the methods listed below.
  - If the impact registration was conducted and VI is unknown and cannot be estimated, use the percussion plot, VI unknown method, as shown in paragraph 6-47.
  - If the impact registration was conducted and VI can be estimated, use the percussion plot, VI estimated method, as shown in paragraph 6-48.
  - If time registration was conducted and VI is unknown, use the time plot, VI unknown method, as shown in paragraph 6-49.
  - If time registration was conducted and VI is to be determined by using the XO's high burst, use the time plot, VI known method, as shown in paragraph 6-51.



RECORD OF FIRE

CALL FOR FIRE

Observer ___ AF/FFE/IS/S ___ Tgt ___

Grid: ___

PolarDir ___ Dis ___ VA ___

Shift: Dir: ___ L/R ___ U/D ___ +/- ___ U/D ___

VI = 0 | DRIFT L8, -GFT 0, DF CORR L8 | △FS 0.08 | 100/R 11 | /R | 20/R 2 | ∠Si + 10 | 10m Si | HOB Corr

FIRE ORDER MARK COS FOR T03, RG 10000, #3 (1), SH WP, LOT WH, CHG 3, AMC | Df Corr L8 | Si 0

INITIAL FIRE COMMANDS (FM) | MF #3 (1) | Rg 9500 | Cht Df 3200 | El 276

Sp Instr AMC | Sh WP | Lot WH | Chg 3 | Fz | Ti | DF 3208 | QE 276

MTO OBSERVE (1), COS, RWRTO | ∠T (570) 600 | PE_R | TF (26) | in EFF | Ammo Exp (1) WP

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L8)	Df Fired	Chart Rg	HOB Corr	Si (0)	El	QE	Exp	Type
5160	L40	+200		FZ Q			3395	L8	3403	9870		0	295	295	(1)	
		-100					3406	L8	3414	9780		0	290	290	(2)	
		+50					3400	L8	3408	9830		0	293	293	(3)	
(2)		+25		(2)			3398	L8	3406	9850		0	294	294	(5)	
(1)		-25		(1)			3400	L8	3408	9830		0	293	293	(6)	Q
	R10	+10	REC				3398		(3406)	9840			(293)			
AS REG	PT	TI	RPT	FZ TI		27.3			3406		+2	+2	293	295	(1)	
			U40		-0.3	27.0			(3406)					295	(2)	
(3)			RPT	(3)		(27.0)			(3406)					295	(5)	TI
		D10	REC		+0.1	(27.1)										
AS TI	REG	PT	EOM	EOM												

U40/10=4 X 0.08= 0.32~-0.3

D10/10=1 X 0.08= 0.08~+0.1

FIRE ORDER: PREC REG W/T03, SELECT KN PT, VIC COS, #3 (1), Q & TI (M767)

MTO: SELECT KN PT, VIC COS, Q & TI

Btry 1/A | DTG 261200ZDEC13 | Tgt KN PT 1 | Replot Grid | Replot Alt

DA FORM 4504, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC. APD LC v1.00

SAMPLE

Legend:
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
COS – center of sector
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
IS – immediate suppression
KN PT – known point
L/R – left/right
MF – method of fire
MPI – mean point of impact
PER – probable error in range
PREC – precision
PT – point
Q – quick
QE – quadrant elevation
REC – record
REG – registration
RG – range
RPT – repeat
RWRTO – report when ready to observe
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VIC – vicinity
WP– white phosphorous

Figure 6-33. Completed Record of Fire.

PERCUSSION PLOT, VI UNKNOWN

6-51. Percussion plot is used when an impact registration has been conducted. When VI is unknown and cannot be estimated, the method is known as percussion plot, VI unknown. The percussion plot technique assumes that site is zero. The range used to polar plot is the range corresponding to the adjusted elevation. Since site is zero, the adjusted quadrant elevation is the same as the adjusted elevation.

UNIT ALTITUDE = KNOWN POINT ALTITUDE
POLAR PLOT RANGE = RANGE AT ADJ EL

PERCUSSION PLOT, VI ESTIMATED

6-52. When site is assumed to be zero, a large error can be introduced into the computation of range by using the percussion plot technique. This error can be minimized and the accuracy of the chart improved by estimating a vertical interval between the firing unit and the known point. The firing unit altitude is then determined by applying the estimated VI from the assumed altitude of the known point to the firing unit altitude. (See figure 6-34 on page 6-37.) The estimated VI is used to compute site as shown in table 6-13.

TIME PLOT, VI UNKNOWN

6-53. The lack of an accurate site and nonstandard conditions are the major sources of error in range on an observed firing chart. If the site is unknown or incorrect, the derived adjusted elevation is in error by the amount of error in site. Determining the polar plot range from the false elevation produces a false range. However, the effect of site on fuze settings is usually small. Therefore, the adjusted time can be used as a good indicator of the adjusted elevation and the polar plot range. Because the adjusted fuze setting is a function of elevation and complementary angle of site (CAS), the angle of site (∡SI) and hence the VI may be determined after the firing of fuze time.

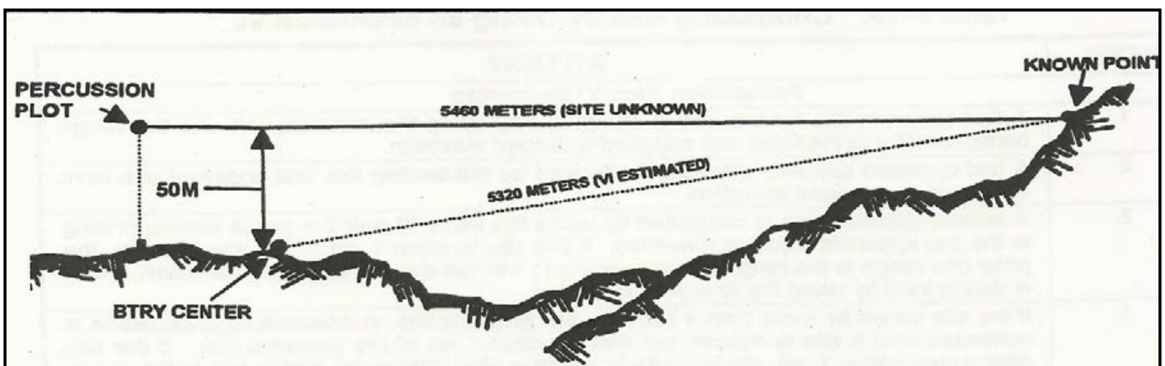
6-54. To derive angle of site, subtract the elevation corresponding to the adjusted time plus the CAS from the adjusted quadrant elevation. Using the graphical site table (GST), determine the VI by multiplying the polar plot range by the derived angle of site. To determine range, place the maufacturer's hairline (MHL) of the GFT over the adjusted time and read range under the MHL from the range scale. Determine altitude of the firing unit by applying the VI to the assumed altitude of the known point.

Table 6-13. Computing Site by Using an Estimated VI.

STEP	***ACTION***
	Percussion Plot, VI Estimated
1	A first apparent site for the unit is computed by using the estimated VI and the range corresponding to the firing unit adjusted quadrant elevation.
2	A first apparent adjusted elevation is derived by subtracting the first apparent site from the adjusted quadrant elevation.
3	A second apparent site is computed b using the same VI and the range corresponding to the first apparent adjusted elevation. If this site is within 1 mil of the previous site, the polar plot range is the range corresponding to the last derived adjusted elevation, which is determined by using the final site computed.
4	If the site varies by more than 1 mil from the previous site, successive approximation is continued until a site is determined that is within 1 mil of the previous site. If the two sites agree within 1 mil, the last site is the true site. The polar plot range is the range corresponding to the last derived adjusted elevation, which is determined by using the final site computed.
5	The firing unit altitude equals the known point altitude minus the VI.
	Note: The following equations may be used to simplify Steps 1-5. TRUE SITE = ESTIMATED VI/ RANGE AT ADJ QE (USE SUCCESSIVE APPROXIMATION AND THE GST). TRUE ADJ EL = ADJ QE – TRUE SITE. POLAR PLOT RANGE = RANGE AT LAST DERIVED ADJ EL (USE GST).

Table 6-13. Computing Site by Using an Estimated VI (continued).

STEP	***ACTION***
	Time Plot, VI Unknown
6	The computer places the MHL over the adjusted fuze setting and extracts the adjusted elevation plus CAS from the elevation scale.
7	An angle of site may be derived by subtracting the elevation corresponding to the adjusted time plus CAS from the adjusted quadrant elevation.
	ADJ QE **-(ADJ EL + CAS)** **∡SI**
8	Range from the known point to the firing unit is determined at the range corresponding to the adjusted time.
9	By using the GST, determine the vertical interval by multiplying the range from the known point to the firing unit by the derived angle of site.
10	The unit altitude is computed by applying the vertical interval to the assumed altitude of the known point.
	Note: The following equations may be used to simplify Steps 6-10. ADJ QE = (ADJ EL + CAS) + ∡SI. FS IS A FUNCTION OF (ADJ EL + CAS). ∡SI = ADJ QE – (ADJ EL + CAS). POLAR PLOT RANGE = RANGE AT ADJ TI. COMPUTED VI = ∡SI x POLAR PLOT RANGE IN THOUSANDTHS (USE GST). UNIT ALTITUDE = KNOWN POINT ALTITUDE – COMPUTED VI.
Legend: ADJ – adjusted CAS – complementary angle of site EL – elevation FS – fuze setting GST – graphical site table MHL – manufacturer's hair line QE – quadrant elevation SI – site TI – time VI – vertical interval	



Legend: BTRY – battery M – meters VI – vertical interval

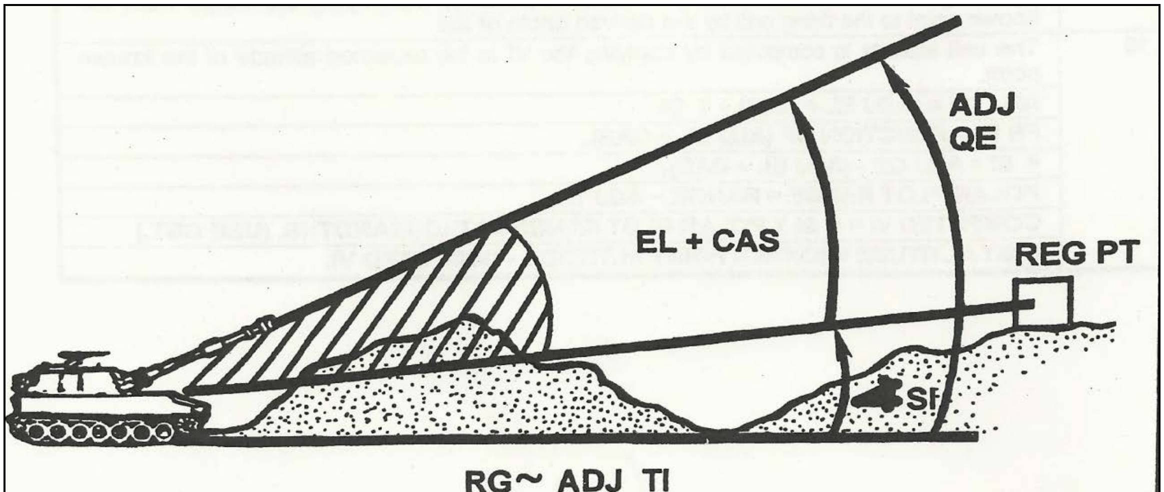
Figure 6-34. Difference in Range Resulting from Difference in Vertical Interval.

TIME PLOT, VI KNOWN (PREFERRED TECHNIQUE)

6-55. When site can be determined by using an XO's high-burst (HB) registration, the method is known as time plot, VI known. This provides a more accurate relative location.

- This technique is based on a rough approximation of site. This approximation can be refined to an accuracy approaching survey accuracy by the firing of a modified HB registration after the completion of a precision registration with fuze time.
- The objective of an XO's HB registration is to determine precisely what portion of the adjusted quadrant elevation (QE) is angle of site and what portion is elevation plus complementary angle

of site (CAS). (See figure 6-35). The vertical interval and site to the known point can be computed by using the angle of site and range corresponding to the adjusted time.



Legend: ADJ TI – adjusted time ADJ QE – adjusted QE CAS – complementary angle of site EL – elevation REG PT – registration point RG - range

Figure 6-35. Comparison between the Adjusted QE and EL + CAS.

6-56. This XO’s HB registration is based on the principle that fuze setting is a function of elevation plus CAS. The XO’s HB registration is fired immediately after the time portion of the registration is completed. The firing of three such high airbursts is specifically what is called XO’s HB registration. The height of burst is raised vertically to enable the burst to be seen by an aiming circle (AC) located within 30 meters of the registering piece. The burst is raised by increasing quadrant. Three rounds are fired with the adjusted time. The XO measures the angle of site to each burst and determines the average angle of site. Because the fuze setting was not changed (the adjusted time was freed), the elevation plus CAS determined is the true elevation plus CAS. This value is then subtracted from the adjusted QE, yielding a true angle of site. Site is then computed. The procedures for conducting an XO’s HB registration are outlined in table 6-14.

Table 6-14. Computing an XO’s HB Registration.

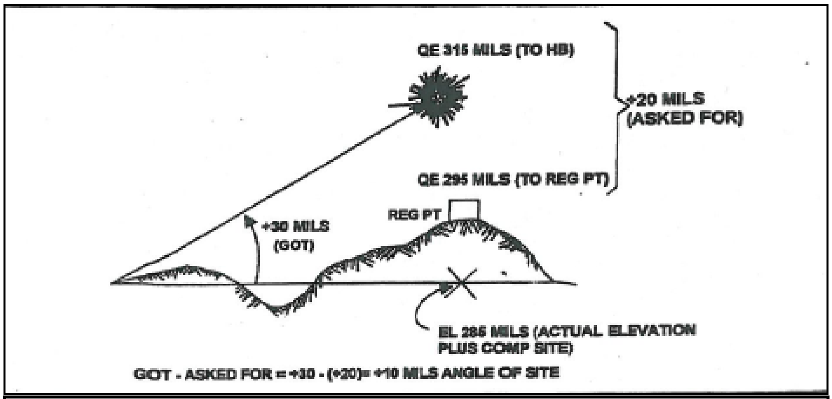
STEP	***ACTION***
1	The FDC determines the height of burst (HOB) correction needed to raise the burst so that it may be observed at the aiming circle near the registering piece. There are two methods to determine the needed HOB correction.
50-Meter-Addition Method	
1a	The FDO directs the VCO to multiply the angle of site to crest for the registering piece by the range corresponding to the adjusted quadrant. The VCO uses the GST to perform this computation.
	The angle of site to crest is extracted from the XO’s report.
	The VCO determines the minimum HOB using the “C” and “D” scales of the GST.
	The FDO adds 50 meters to the minimum HOB and expresses the result to the nearest 10 meters to determine the HOB to fire.
	The adjusted QE must be raised, so the computer converts the HOB to fire announced by the FDO to a HOB correction.
	HOB TO FIRE ÷ RG IN THOUSANDS (USE THE RG AT ADJ QE FROM THE REGISTRATION) = HOB CORRECTION
10-mil Assurance Factor Method	
1b	The XO or platoon leader measures or extracts the angle of site to crest from the XO’s report for the registering piece.

Table 6-14. Computing an XO's HB Registration (continued).

STEP	***ACTION***
1b	The XO or platoon leader applies an additional 10-mil assurance factor to the angle of site to crest.
	∡SI TO CREST **<u>+ 10-MIL ASSURANCE FACTOR</u>** **HOB CORRECTION**
2	The FDO alerts the XO or platoon leader to set up an aiming circle within 30 meters of the registering piece.
3	The FDO announces the fire order (for example, XO's HB REGISTRATION, HOB (so many meters), NUMBER 3, 3 ROUNDS, BRAMC).
4	The computer determines the data to fire. The adjusted time and deflection from the registration will be fired. The computer adds the HOB correction to the adjusted QE to determine the XO's HB QE to fire.
5	The computer transmits direction to the target and HOB correction (actually vertical angle [VA]) to the XO or platoon leader as orienting data.
6	When the XO or platoon leader reports READY, the computer fires the three rounds and records the angle of site (VA) reported for each round.
7	The computer determines the average angle of site. Because both the adjusted QE and XO's QE were fired at the same range, the elevation to both remains the same. The difference in QEs is site. Site cannot be accurately determined because accurate range to the known point is unknown. The computer is able to determine the elevation plus CAS by subtracting the measured angle of site from the XO's QE.
	XO's HB QE **<u>-XO's AVERAGE ∡SI</u>** **EL + CAS**
8	The angle of site to the known point may be determined by subtracting the elevation plus CAS from the adjusted QE to the known point.
9	Determine the VI by using the GST. Angle of site multiplied by the range corresponding to the adjusted fuze setting equals the VI. Place the meter (M) gauge point opposite the angle of site on the D scale of the GST. Move the MHL over the range that corresponds to the adjusted fuze setting on the C scale. Read the VI under the MHL on the D scale.
10	Determine site. Place the MHL over the VI on the D scale of the GST. Set off under the MHL the range corresponding to the adjusted fuze setting on the appropriate site-range scale (TAG or TBG) for the selected charge. Determine the site from the D scale opposite the M gauge point.
11	Determine the adjusted elevation. The adjusted QE minus site equals the adjusted elevation.
	ADJ QE **<u>- SITE</u>** **ADJ EL**
12	Determine the firing point altitude. The known point altitude minus the VI equals the firing point altitude.
13	The polar plot range is the range corresponding to the adjusted fuze setting.

Legend: BRAMC – by round at my command CAS – complementary angle off site EL – elevation
FDC – fire direction center FDO – fire direction officer GST – graphical site table HB – high burst HOB – height of burst
M – meter MHL – manufacturer's hair line QE – quadrant elevation RG – range SI – site TAG – target above gun
TBG – target below gun VA – vertical angle VCO – vertical control operator VI – vertical interval XO – executive officer

6-57. 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 to determine the angle of site. As shown in figure 6-36, the angle of site to the known point equals **got minus (-) asked for.** The procedures for the GOT MINUS ASKED FOR rule are in table 6-15.



Legend: EL – elevation HB – high- burst QE – quadrant elevation REG PT – registration point QE – quadrant elevation

Figure 6-36. GOT MINUS ASKED FOR Diagram.

Table 6-15. Procedure for GOT MINUS ASKED FOR Rule.

STEP	***ACTION***
1	The FDC determines the HOB correction with either of the two methods discussed in paragraph 6-34. The HOB correction (angle of site) is the asked for angle of site.
2	The asked for angle of site is added to the adjusted QE to determine the XO's HB QE.
	ADJ QE **<u>+ASKED FOR</u>** **XO's HB QE**
3	The asked for angle of site is the HOB correction (VA) announced to the XO or platoon leader.
4	Once the three rounds have been fired, the computer determines the XO's HB average angle of site. The average XO's HB angle of site is referred to as "got."
5	The computer determines the angle of site to the known point.
	GOT **<u>-ASKED FOR</u>** **∡SI TO KN PT**
6	Once the angle of site to the known point has been determined, polar plot data are computed in the same manner discussed in Table 6-14 (page 6-38), Steps 9 through 13.
Legend: ADJ – adjusted FDC – fire direction center HB – high burst HOB – height of burst KN PT – known point QE – quadrant elevation SI – site VA – vertical angle XO – executive officer	

SETTING UP THE OBSERVED FIRING CHART

6-58. At the completion of any of the four techniques demonstrated, the HCO will construct an observed firing chart by using the steps in table 6-16 on page 6-41.

Table 6-16. Construction of an Observed Firing Chart.

STEP	ACTION
1	The HCO selects a grid intersection and tick-marks this location as Known Point 1. An altitude is arbitrarily assigned.
	Note: This point should allow space for the plotting of the firing unit.
2	Polar-plot the firing unit center from the known point. Place the vertex of the RDP against the pin in the known point. Using a temporary azimuth index, orient the RDP for direction by using the direction from the known point to the firing unit. Place a pin opposite the polar plot range on the range scale. The pin is the firing unit location.
3	Construct a tick mark at the pin location.
4	Label the tick mark with the firing unit location and altitude.
	FIRING UNIT ALT = KNOWN PT ALT - VI
	After the unit has been polar plotted on the chart, the deflection index is constructed by using the adjusted deflection.
5	Construct a deflection index. Place the vertex of the RDP in the firing unit location. Place the arm of the RDP against the known point location. Place a pin opposite the last three digits of the adjusted deflection on the arc of the RDP.
6	Construct a deflection index at the pin location.
7	Label the deflection index with the first digit of the adjusted deflection.
Legend: ALT – altitude HCO – horizontal control operator PT – point RDP – range deflection protractor VI – vertical interval	

EXAMPLE OF PERCUSSION PLOT, VI UNKNOWN.

6-55. A registration was conducted with shell HE, charge 3H. The site and firing unit altitude are unknown.

- The following data are known:

Adjusted quadrant elevation:	**293**
Azimuth of the line of fire reported by the XO or platoon leader:	**5903**
Adjusted deflection:	**3406**
Assumed altitude of the known point:	**400**

- Determine the direction, altitude, and range from the known point to the firing unit.
  - Determine the polar plot direction. The azimuth of the line of fire ±3200 equals polar plot direction.

5903-3200 = 2703 (BACK AZIMUTH [AZ] OF FIRE)

  - Determine the firing unit altitude. The firing unit altitude equals the knownpoint altitude.

FIRING UNIT ALTITUDE = 400 METERS

  - Determine the polar plot range. The polar plot range equals the range that corresponds to the adjusted QE.

POLAR PLOT RG = 9840 TO ADJ QE (293)

EXAMPLE OF PERCUSSION PLOT, VI ESTIMATED

6-56. The observer passes the firing unit position on his way to his location and estimates the VI to be +60 meters. Use the known data from paragraph 6-54.

6-57. Determine the first apparent site. **RG AT ADJ QE = 9840 METERS.** Using the GST, set +60 underneath the MHL on the D scale. Move the site-range scale for charge 3H target above gun (TAG) until range 9840 is underneath the MHL. Read site underneath the meter (M) gauge point on the D scale.

FIRST APPARENT SITE = +7 MILS

6-58. Determine the first apparent elevation.

RG AT FIRST APPARENT EL = 9700 METERS

6-59. Determine the second apparent site. **RG AT FIRST APPARENT EL = 9700 METERS.** Using the GST, set +60 underneath the MHL on the D scale. Move the site-range scale for charge 3H TAG until range 9700 is underneath the MHL. Read site underneath the M gauge point on the D scale.

SECOND APPARENT SITE = +7 MILS

6-60. Because the first and second apparent sites are within 1 mil, the last site determined, **+7 mils,** is the **true site.**

6-61. Determine the true adjusted elevation.

ADJUSTED QE	**293**
-TRUE SITE	**+7**
TRUE ADJUSTED EL	**286**

RG AT TRUE ADJ EL =9700, which is the polar plot range.

6-62. Using the GST, determine the VI by placing the M gauge point above the true site on the D scale. Next, move the MHL until it is over the polar plot range, 9700 on the site-range scale for charge 3H TAG. Read the VI under the MHL on the D scale.

6-63. Determine the vertical interval.

POLAR PLOT RG	**9700**
TRUE SITE	**+7**
VI	**+63**

6-64. Determine the firing unit altitude (ALT).

KN PT ALT	**400**
-VI	**+63**
FIRING UNIT ALT	**337**

6-65. The introduction of an estimated VI of +60 meters changes the polar plot range from the firing unit to the known point by 140 meters (9840 to 9700). The polar plot direction is determined as shown in paragraph 6-45.

EXAMPLE OF TIME PLOT, VI UNKNOWN

Note: Use the known data from paragraph 6-54.

6-66. At the completion of the registration, the adjusted data are as follows:

Adjusted time (M767): **27.1**
Adjusted deflection: **3406**
Adjusted quadrant: **293**

Note: The adjusted data is from the example shown in figure 6-33 on page 6-35.

6-67. Determine the angle of site.

Note: EL + CAS ~ TO ADJ FUZE SETTING (FS) = (291 + 0.066) ~ +291

ADJUSTED QE	**293**
-EL + CAS	**+291**
ANGLE OF SITE	**+2**

6-68. Using the GST, determine the VI.

Note: RG ~ ADJ FS = 9790, which is the polar plot range.

ANGLE OF SITE	**+2**
x POLAR PLOT RG	**9790 (C scale)**
VI	**+19**

6-69. Determine the firing unit altitude.

KN PT ALT	**400**
-VI	**+19**
FIRING UNIT ALT	**381**

6-70. Determine the polar plot direction as discussed in paragraph 6-45.

EXAMPLE OF TIME PLOT, VI KNOWN, XO'S HIGH BURST

Note: Use the known data from paragraph 6-54.

6-71. The site to crest from the XO's report is +32 mils for the registering piece. This example will demonstrate how to determine the HOB correction by using the 10-mil assurance factor.

6-72. Determine the **asked for** HOB correction.

SITE TO CREST	**+32**
+ASSURANCE FACTOR	**+10**
ASKED FOR HOB CORR	**+42**

6-73. Determine the XO's high-burst QE.

ADJUSTED QE	**+293**
+ ASKED FOR	**+42**
XO'S HB QE	**+335**

6-74. The computer announces orienting data to the XO or platoon leader.

DIRECTION 5959, VERTICAL ANGLE +42

6-75. Three rounds are fired, and the following angles of site are reported by the XO or platoon leader.

Round 1:	**∡SI +54**
Round 2:	**∡SI +54**
Round 3:	**∡SI +57**
Average ∡SI:	**+55 (Determined by XO or platoon leader)**

Note: AVG ∡SI = +55, which equals GOT.

6-76. Determine the angle of site to the known point.

GOT	**+55**
- ASKED FOR	**+42**
∡SI TO KN PT	**+13**

6-77. Using the GST, determine the VI.

Note: RG ~ ADJ FS = 9790, which is the polar plot range.

POLAR PLOT RG	**9790**
x ANGLE OF SITE	**+13**
VI	**+12**

6-78. Determine the firing unit altitude.

KN PT ALT	**400**
- VI	**+12**
FIRING UNIT ALT	**+388**

6-79. Determine the polar plot direction as discussed in paragraph 6-45.

LOCATE AN OBSERVER

6-80. If the observer is equipped with a laser, his location maybe established by resection. The procedures are listed below.

6-81. The observer lases the known point and determines a direction, distance, and vertical angle (VA). These are reported to the FDC.

6-82. The HCO determines the observer location as follows:

- Polar plots the back azimuth to the known point.
- Inserts a plotting pin along the back azimuth at the announced distance.
- Constructs a tick mark and labels it with the observer's call sign.

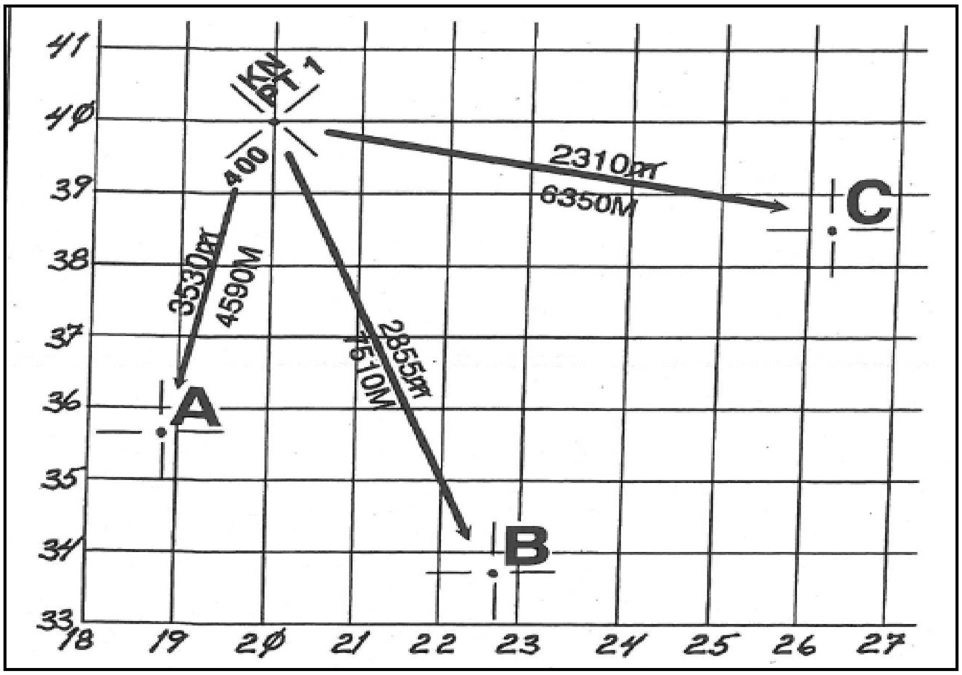
6-83. Using the GST, the VCO determines the observer's VI as follows:

- Places the M gauge point opposite the VA or **∡S** on the D scale.
- Moves the MHL over the distance/ range on the C scale.
- Reads the VI under the MHL from the D scale.

6-84. To determine the observer's altitude, subtract the VI from the known point altitude.

BATTALION OBSERVED FIRING CHARTS

6-85. Battalion observed firing charts are based on the concept that if any two points can be located by reference to a third point, the two points can be located in reference to each other. All batteries register on the same known point. For example, using the techniques for battery or platoon observed firing charts discussed in Section II of this chapter, firing units can be located in relation to the known point. After all the firing unit locations are plotted on a single firing chart in relation to the knownpoint, the firing chart provides an accurate graphical representation of the location of the firing units in relation to each other. (See figure 6-37.) This accurate portrayal of the relationship among the firing unit locations allows for the accurate massing of fires within the battalion on any target located by adjustment of one of the firing units, or by a shift from a known point (known to all firing units).



Legend: KN PT – known point m – mils M – meters

Figure 6-37. Location of Batteries in Relation to the Known Point.

6-86. The techniques used in the construction of a battalion observed firing chart are very similar to those used for the construction of a single firing unit observed firing chart. The direction used for polar plotting each firing unit is determined by using the same procedures as the battery or platoon observed firing chart.

- **Percussion Plot, VI Unknown.** Range and altitude may be determined for each firing unit by using the procedures in paragraph 6-47. The accurate massing of fires **is not** possible when this method is used.
- **Percussion Plot, VI Estimated.** Range and altitude for each firing unit may be determined by using the same procedures listed in table 6-13 (on page 6-36). If the relative altitude of the firing units can be estimated, the accuracy of the firing chart can be improved. One firing unit is selected as a reference unit and is assigned the same altitude as the known point. The vertical intervals of the other units are estimated and compared with the altitude of the reference firing unit to obtain their altitudes.
- **Time Plot.** Range and altitude for each firing unit may be determined by using the same procedures listed in paragraphs 6-49 and 6-51. This provides a more accurate means of determining relative location. One firing unit is selected as a reference unit. The vertical intervals of the other firing units are estimated and compared with the altitude of the reference firing unit to obtain their altitudes.

OBSERVED FIRING CHART WITH INCOMPLETE SURVEY

6-87. A position area survey maybe used in conjunction with the observed firing chart until the surveyed firing chart is available. The part of the chart established by firing must be plotted to the same scale as the part obtained by survey.

6-88. The procedure for constructing a battalion observed firing chart that is based on the registration of one unit and that has position area survey is listed in table 6-17.

Table 6-17. Construction of an Observed Firing Chart, Position Area Survey Only.

STEP	*ACTION*
1	Establish a common orienting line for the battalion.
2	Starting at any point, conduct directional traverse to locate all battalion positions horizontally and vertically in relation to each other and to establish common directional control for all orienting lines.
3	Plot all unit positions, altitudes, and orienting lines on tracing paper to the same size as that of the chart to be used. The overlay, including the measured grid azimuth of the orienting lines, constitutes the position area survey as given to the fire direction center.
4	Register one unit on the known point. From the adjusted data, start the observed firing chart by plotting the registering unit.
5	Derive the azimuth of fire from the measured azimuth of the line of fire from the registering unit. Use the derived azimuth of fire as the direction of fire of the registering unit on the overlay.
6	Orient the overlay so that the center of the registering unit is over the registering unit's center on the chart. Rotate the overlay until the lines denoting direction of fire on the chart and on the overlay coincide. From the overlay, mark the locations of the nonregistering units on the chart. Label these locations with the proper altitudes in relation to the registering unit.
7	Measure the azimuth on the chart from each nonregistering unit to the known point. The azimuth of the unit's orienting line minus the measured direction of fire equals the orienting angle for laying the unit.

SECTION VI: USING MAP SPOT DATA TO CONSTRUCT FIRING CHARTS

6-89. The surveyed location and azimuth of lay should be established as soon as possible. Surveyed locations can be determined by map spot survey or by normal survey procedures. Map spot is less accurate than actual survey. If survey teams cannot immediately provide the needed data, the firing unit conducts a map spot survey to establish the unit center and azimuth of lay. For a map spot survey, fire direction personnel use hasty survey methods to associate terrain features with the locations of those features on a map and to locate the unit's center in relation to the terrain features.

MAP SPOT SURVEY

6-90. Map spot survey is the application of basic map and terrain association. It should be as accurate as possible. Three-point resection is the preferred technique for establishing the unit center by map spot survey. The map spotted location of the unit center will include an eight-digit grid coordinate and an altitude in meters.

6-91. Directional control (an orienting station and the direction to the end of the orienting line [EOL]) also must be provided. Common directional control should be established as soon as possible, preferably by simultaneous observation or directional traverse during daylight or by Polaris-Kochab method at night. If none of these procedures can be done quickly, the firing unit must be laid magnetically.

Note: ATP 3-09.50 includes a detailed discussion of hasty survey techniques.

CONSTRUCTING A FIRING CHART FROM MAP SPOT SURVEY

6-92. To construct a firing chart based on map spot survey, the FDC must have three items of information:

- Assumed grid coordinates of the firing unit center.
- Assumed altitude of the firing unit.
- Assumed azimuth of lay.

6-93. When met + VE techniques cannot be used, the firing unit will register as the situation permits.

6-94. A firing chart based on map spot survey is only as accurate as the following:

- The map spotted location of the unit center and the known point.
- The azimuth of lay.
- The construction of the chart.

6-95. When a firing chart based on map spot survey is used, the orienting angle must be recorded when the firing unit is laid. This orienting angle is used to determine the actual azimuth of lay when directional control is provided.

6-96. The FDC replots all fired targets.

TRANSFERRING TO A SURVEYED FIRING CHART

6-97. When the position and target area surveys are completed, the FDC is provided the following information:

- Firing unit center grid coordinates and altitude to the nearest 0.1 meter and azimuth to the EOL to the nearest 0.1 mil.
- Known point coordinates and altitude to the nearest 0.1 meter.

6-98. The surveyed firing chart is constructed to show the accurate locations of the firing unit center, the known point, and the actual azimuth of lay.

6-99. The firing unit was initially laid, and the orienting angle was recorded. When the surveyed azimuth to the EOL is determined, the actual azimuth of lay is computed by using the following formula:

SURVEYED AZ TO EOL – ORIENTING ANGLE = AZ OF THE LINE OF FIRE.

6-100. The initial (map spot) azimuth of lay may be inaccurate. The actual azimuth of the line of fire may differ from the surveyed azimuth of lay. When survey data are provided, the FDC must construct a surveyed firing chart and compute GFT settings.

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Chapter 7

Firing Tables

Field artillery firing data are determined by use of various firing tables and equipment. These tables contain the fire control information (FCI) under standard conditions and data correcting for nonstandard conditions. These tables and equipment include the tabular firing tables, graphical firing tables, and graphical site tables. The tabular firing tables are the basic source of firing data. They present fire control information in a tabular format. The data listed are based on standard conditions. The GFT's and GST's are graphical representations of the tabular firing tables.

SECTION I: TABULAR FIRING TABLE

7-1. Tabular firing tables based on test firings and computer simulations of a weapon and its ammunition correlated to a set of conditions that are defined and accepted as standard (See figure 7-1.) These standard conditions are points of departure. Corrections are used to compensate for variables in the weather-weapon-material combination that are known to exist at a given instant and location. The atmospheric (weather) standard conditions are established by the International Civil Aviation Organization (ICAO). The values representing 100 percent of the standard for Air Temperature and Air Density are based on surface conditions of the ICAO standard atmosphere. TFTs are developed for weapons ranging from crew-served to heavy artillery. The format of artillery firing tables are based on standardized agreements (STANAG), and with small exceptions, are very similar.

STANDARD CONDITIONS	
WEATHER	
1	AIR TEMPERATURE 100 PERCENT
2	AIR DENSITY 100 PERCENT
3	NO WIND
POSITION	
1	GUN, TARGET AND MDP AT SAME ALTITUDE
2	ACCURATE RANGE
3	NO ROTATION OF THE EARTH
MATERIAL	
1	STANDARD WEAPON, PROJECTILE, AND FUZE
2	PROPELLANT TEMPERATURE (70º F)
3	LEVEL TRUNNIONS AND PRECISION SETTINGS
4	FIRING TABLE MUZZLE VELOCITY
5	NO DRIFT

Figure 7-1. Standard Conditions.

ELEMENTS AND PURPOSE

7-2. The principal elements measured in experimental firings include the following:

- Angle of elevation.

- Angle of departure.
- Muzzle velocity.
- Achieved range.
- Drift.
- Concurrent atmospheric conditions.

7-3. The main purpose of the TFT is to provide the data to bring effective fire on a target under any set of conditions. Data for firing tables are obtained from firings of a weapon conducted at various quadrant elevations. Computed trajectories are based on the equations of motion and are compared with the data obtained in the firings. The computed trajectories are 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 standard conditions.

COVER INFORMATION

7-4. The cover of the TFT provides information concerning the weapon system(s) and projectile(s) to which data in the TFT apply. Several projectiles may be listed on the cover if they are within the same projectile family because of ballistic similarity.

Note: When a change to the content of a TFT is required it is impractical to issue a new version of the same TFT. Therefore, changes are published containing only the new and/or additional information and must be applied (in accordance with the instructions) to the respective TFT

Note: The FT-155-AM-3 is used as the example throughout this section. Figure 7-2 shows a portion of the Symbols and Abbreviations table found on page V of the FT-155-AM-3

1. Symbols and Abbreviations

AD	Air Density
APERS	Antipersonnel
AT	Air Temperature
BD	Base Detonation
BE	Base Ejection
C	Ballistic Coefficient, Centigrade (Celsius)
COMP	Complementary
CORR	Correction
COT	Cotangent
CP	Concrete Piercing
CS	Complementary Site
CAS	Complementary Angle of Site
CHG	Charge
CTG	Cartridge
CW	Cross Wind
D	Decrease, Deflection

Figure 7-2. Symbols and Abbreviations.

7-5. **Introduction.** The introduction contains general information about the weapon, ammunition, and the TFT. This information specifically includes the items below.

- **Table of contents.**
- **Table of symbols and abbreviations used in the TFT (see figure 7-2.)**
- **General information.** This portion of the introduction outlines the standard weapon and ammunition applicable to the specific TFT. It also outlines what other weapons and ammunition

are applicable provided the appropriate corrections are made to compensate for muzzle velocity or projectile square weight.

Note: The M284 cannon tube is the standard cannon tube for the FT 155-AM-3 The M185, M199, and M776 cannon tubes need to be corrected for variations in muzzle velocity due to cannon tube characteristics, see FT 155-AM-3, page VIII

- **Interchangeability of ammunition.** This table shows the ammunition combination held in stock by other NATO nations for a particular weapon caliber and cannon tube that can be used by the US during joint operations, to include training exercises. Because of safety, the ammunition listed in the **shaded portions** may **only** be used in combat operations. A completely black cell means do not use the particular nation's ammunition in the specified weapon because no comparable ammunition exists in the particular nation. Diagonal lines through certain cells illustrate a ballistics match of that particular nation's projectile to the nation that has the specified weapon system and provided data reflected in the chart (Noted by an asterisk next to the country code). Certain TFT's contain different tables for interchangeability of ammunition restrictions based on cannon tube. (See figure 7-3.)

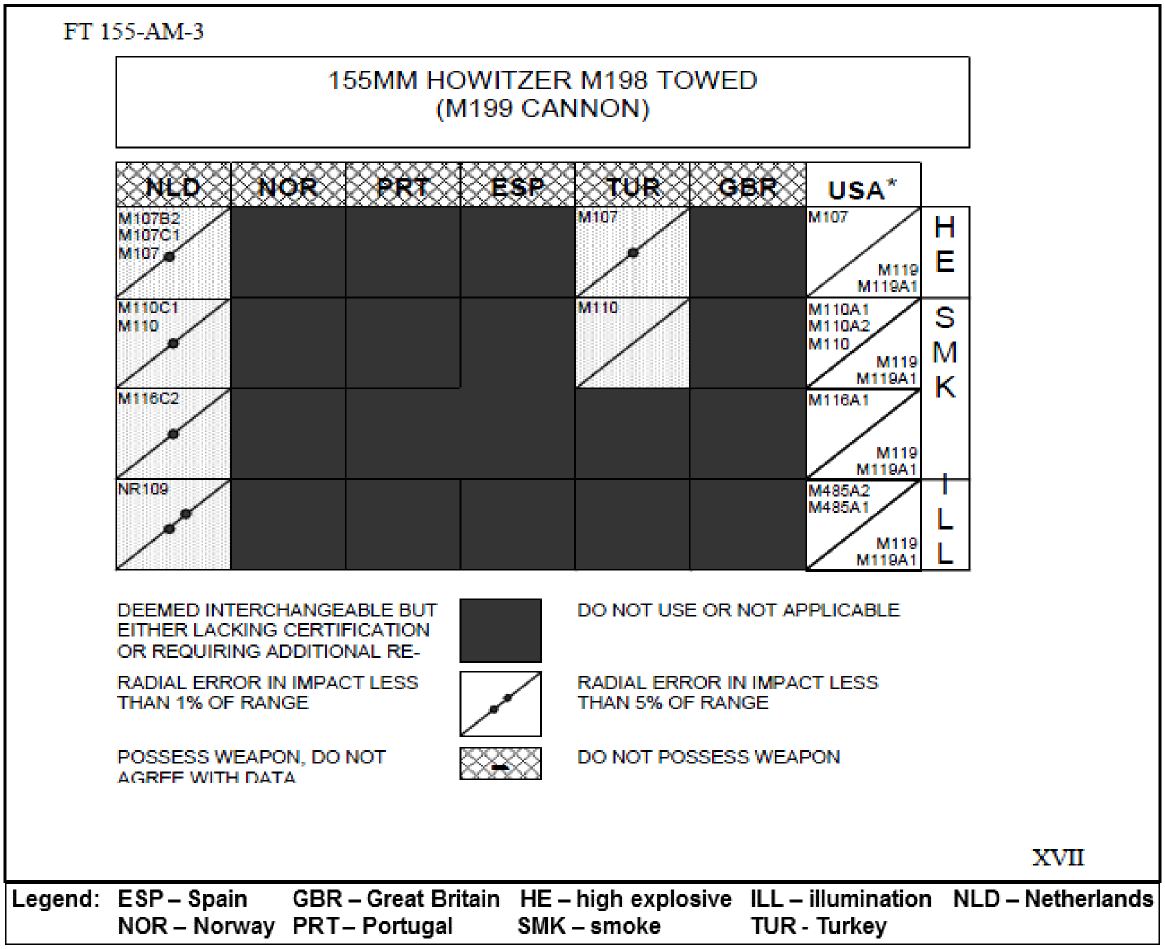

Figure 7-3. Interchangeability of Ammunition Tables.

- **Weapon characteristics**. (See figure 7-4 on page 7-4.)

Howitzer	M109A1 Series	M198	M109A5 and M109A6	M777and M777A1/A2
Cannon	M185	M199	M284	M776
Total Traverse – mils	6400	L 400 R 400	6400	L 400 R 400
Maximum Elevation – mils	1300	1275	1344	1275
Minimum Elevation – mils	-36	-75	-38	-43
Change in elevation for one turn of elevating handwheel – mils	5	10	5	10
Change in traverse for one turn of traversing handwheel – mils	10	10	10	10

Figure 7-4. Weapon Characteristics.

- **Projectile-fuze combinations and mean weights**. (See figure 7-5.)

FT 155-AM-3

4. Projectile/Fuze Combinations and Mean Weights

Projectile	Fuze		Fuze Weights	Weight of Fuzed Projectile (lb)			
	Type	Model		2 sq	3 sq	4 sq	5 sq
HE, M107	PD[(a)]	M557	2.2	92.8	93.9	95.0	96.1
		M739	1.5	92.1	93.2	94.3	95.4
		M739A1	1.5	92.1	93.2	94.3	95.4
	MTSQ[(b)]	M582	1.5	92.1	93.2	94.3	95.4
		M582A1	1.5	92.1	93.2	94.3	95.4
		M564	2.1	92.7	93.8	94.9	96.0
	ET[(b)]	M767	1.1	91.7	92.8	93.9	95.0
		M767A1	1.1	91.7	92.8	93.9	95.0
	VT[(c)]	M728	2.2	92.8	93.9	95.0	96.1
		M732	1.8	92.4	93.5	94.6	95.7
		M732A2	1.2	91.8	92.9	94.0	95.1
	MOFA[(d)]	M782	1.7	92.3	93.4	94.5	95.6
	CP[(a)]	MK399 MOD 1	2.7	93.3	94.4	95.5	96.6
ILLUM, M485A2, M485A1	MT	M565	2.1	Not weight zoned			
	MTSQ[(e)]	M577 M577A1	1.4 1.4	Not weight zoned			
	ET[(e)]	M762 M762A1	1.1 1.1	Not weight zoned			

(a) These fuzes have two modes: quick mode and delay mode.

(b) These fuzes have a point detonating (PD) setting.

(c) Fuze M728 is compatible with the deep cavity projectiles only. All of these VT fuzes have a point detonating (PD) setting. The M732A2 fuze can be set to even increments only.

(d) This fuze has four modes: quick, delay, proximity (VT) and electronic time (ET).

(e) These fuzes have a point detonating (PD) setting The PD mode setting is not allowed with projectiles, M485A2 and M485A1.

Figure 7-5. Projectile-Fuze Combinations and Mean Weights.

- **Equivalent full service rounds.** This table provides information on fatigue and erosion effects due to tube wear and erosion. The data is used to determine the number of equivalent full service rounds to enter the table of approximate losses in muzzle velocity and the expected muzzle velocity loss due to wear. This tube can also determine the number of equivalent full service rounds in terms of cannon tube fatigue effects. These fatigue effects are used to determine condemnation life for cannon tubes. The values listed in these tables are based on firings of the highest charge used by that weapon system. (See figure 7-6.)

Charge	Zone	Fatigue Life		Erosion Life	
		No. of rds equivalent in fatigue to one full chg	Equivalent fatigue effect in decimals	No. of rds equivalent in erosion to one full chg	Equivalent erosion effect in decimals
Cannon, 155mm Howitzer, M185[a]					
M119A2	7R	1.00	1.00	1.00	1.00
Cannons, 155mm Howitzer, M199[b], M284[c], M776[d]					
M119A2	7R	4.00	0.25	2.00	0.50
M232 M232	4H 3H	4.00 10.00	0.25 0.10	2.00 5.00	0.50 0.20
M232A1 M232A1	4H 3H	4.00 10.00	0.25 0.10	2.00 5.00	0.50 0.20
M231 M231	2L 1L	6.67 20.00	0.15 0.05	20.00 100.00	0.05 0.01

Figure 7-6. Equivalent Full Service Rounds Table.

- **Approximate losses in muzzle velocity.** These tables may be used as a guide in predicting muzzle velocity variations from the firing table standard that are due to uniform wear in the M185, M199, M284, and the M776 cannon tubes. Certain TFTs contain different tables for approximate losses in muzzle velocity based on the charge. (See figure 7-7 on page 7-6.)

Approximate Losses in Muzzle Velocity

155mm Howitzer, Cannons: M199, M284 and M776; Charges: 7R and 4H (M232 and M232A1)

Number of equivalent full service rounds (erosion)	Wear measurement (inches)*	Muzzle Velocity Loss (m/s)
0	6.100	0.0
100	6.107	0.8
200	6.114	1.6
300	6.121	2.4
400	6.127	3.0
500	6.134	3.9
600	6.141	4.7
700	6.147	5.4
800	6.154	6.2
900	6.160	7.0
1000	6.166	7.6
1100	6.171	8.2
1200	6.176	8.9
1300	6.180	9.5
1400	6.184	10.3
1500	6.188	11.2
1600	6.191	12.0
1700	6.194	12.9
1800	6.197	14.0
1900	6.199	14.7
2000	6.200	15.2
2100	6.201	15.5
2200	6.202	16.3
2300	6.203	16.7
2400	6.204	17.3
2500	6.205	18.0

* The wear measurement is taken 41.75 inches forward of the rear face of the tube.

Figure 7-7. Approximate Losses in Muzzle Velocity Table.

- **Explanation of tables.**
- **Example of met message and sample problems.**
- **Explanation of the probability table.**
- **Table of natural trigonometric functions**.
- **Charge selection table.** This table provides guidance to the FDO on the selection of the charge to fire based on range and probable error in range (PER). Enter the table from the left with the range-to-target expressed to the nearest listed value. Enter from the top of the table with the charge to fire. Extract the PER for a given charge at a given range. The gray shaded area shows those charges with the lowest probable error in range and thereby the charge that should be selected given no other considerations. (See figure 7-8 on page 7-7.)

Charge Selection Table

Probable Error In Range (Meters)
Versus
Range (Meters) And Charge

RANGE METERS	CHARGE						
	7R	1L	2L	3H M232	4H M232	3H M232A1	4H M232A1
0	18	4	8	12	18	13	19
1000	17	5	8	12	18	13	18
2000	17	7	8	12	17	12	17
3000	17	10	9	14	17	12	15
4000	18	13	11	16	18	12	15
5000	20	17	12	19	20	14	14
6000	22	21	14	22	22	16	15
7000	24	27	16	25	24	18	16
8000	27		17	27	27	21	18
9000	30		19	29	30	23	21
10000	33		21	31	33	25	23
11000	35		24	33	35	27	26
12000	38			35	38	29	28
13000	40			37	40	31	31
14000	42			40	42	34	33
15000	44				44	37	35
16000	46				46		37
17000	49				49		39
18000	52				52		41
19000							
20000							
21000							
22000							

*Highlighted areas present the smallest PE for each entry range

Figure 7-8. Charge Selection Table.

- Table of conversion factors. (See figure 7-9.)

Conversion Factors

Multiply	By	To Obtain
yards	0.9144	meters
mph	0.8690	knots
degrees	17.7778	mils
minutes	0.2963	mils

Multi-ply	By	To Obtain
meters	1.0936	yards
knots	1.1508	mph
mils	0.05625	degrees
mils	3.375	minutes

Percent of Standard Temperature
100 + 0.1928 (Air Temperature - 59° F)

Figure 7-9. Conversion Factors.

PART 1

7-6. **Part 1** of the TFT contains firing data and corrections for the base projectile. It is divided into Tables A through K. Additional Tables L and M may be provided in some TFTs, but the format and content vary.

Note: FT-155-AM-3, Charge 4H M232A1 will be used as an example throughout this section

TABLE A

7-7. **Table A** is used for the solution of a concurrent met. It is used to select the line number of the ballistic met message. The entry argument for this table is adjusted quadrant elevation. Entering with the

Adjusted QE (Adj elevation [EL] + Ground SI from registration mission) compensates for the vertical interval between the registering piece and the registration point The adjusted QE best describes the maximum ordinate of the trajectory and, thus, the portion of the atmosphere through which the projectile will pass. The height of the trajectory is determined by computer simulation using equations of motion.

7-8. Enter **Table A** by using the left column with the adjusted quadrant elevation to a target. Extract the line number of the met message from the right column. (See figure 7-10.)

FT 155-AM-3 | TABLE A | CHARGE 4H

PROJ, HE, M107 | LINE NUMBER | M232A1

FUZE, PD, M739A1

LINE NUMBER OF METEOROLOGICAL MESSAGE

QUADRANT ELEVATION MILS	LINE NUMBER
0.0- 68.9	0
69.0- 137.3	1
137.4- 213.0	2
213.1- 289.1	3
289.2- 355.4	4
355.5- 444.7	5
444.8- 552.2	6
552.3- 651.3	7
651.4- 745.1	8
745.2- 881.3	9
881.4- 1068.0	10
1068.1- 1260.0	11

Figure 7-10. Table A.

TABLE B

7-9. **Table B** is used in the solution of concurrent and subsequent met. This table is used to determine the value of complementary range (change in range) to correct for the effects of complementary angle of site. Complementary ranges were determined by computer simulations of the trajectory at each listed range and vertical interval. Table B has two entry arguments; chart range to a target expressed to the nearest 100 meters and the height of target above gun (vertical interval) expressed to the nearest 100 meters. Table B is entered from the range column along the left side, with the chart range to a target; and along the top of the table with the height of target above gun (vertical interval). Extract the value of complementary range where the two columns intersect. The complementary range is the number of meters of range correction that corresponds to the complementary angle of site. This range correction is measured at the base of the trajectory. The sum of the complementary range and the chart range, expressed to the nearest 100 meters, equals the entry range. This is the range for entry into Table F to extract firing data and range corrections during the solution of concurrent and subsequent met. The asterisks extending across the table denote the changeover point from low-angle to high-angle fire.

7-10. **Table B** is also used to determine the line number from a ballistic met message for use in subsequent met applications. The table is divided by heavy black lines. These lines form the boundaries of the met zone. Each particular line number is applicable to all target points lying between the heavy dividing lines containing that number. The line number may be determined by following the lines between which the complementary range is extracted to the outer edge of the table. The bold number in the margin is the met line number. The met message line numbers were determined by the same method used in Table A. (See figure 7-11.)

1-1

Note**: Table A** is more accurate in the determination of the met message line number to be used in the solution of concurrent met

CHARGE 4H M232A1 — TABLE B — FT 155-AM-3

COMPLEMENTARY RANGE LINE NUMBER — PROJ, HE, M107 FUZE, PD, M739A1

CHANGE IN RANGE, IN METERS TO CORRECT FOR COMPLEMENTARY ANGLE OF SITE

LINE NUMBERS OF METEOROLOGICAL MESSAGE

Line No. 0 (left) / Line No. 3 (right)

RANGE METERS	HEIGHT OF TARGET ABOVE GUN - METERS -400	-300	-200	-100	0	100	200	300	400	500	600	700	800	900	1000
0					0										
100					0	0	0	0	0	0					
200					0	0	0	1	2	3	4	5	7	8	
300					0	0	1	3	4	6	8	10	11	13	15
400					0	0	1	3	5	7	9	11	13	16	18
500					0	0	2	3	6	8	11	14	16	19	22
600					0	1	2	4	7	9	12	15	19	22	26
700					0	1	3	5	7	10	13	17	21	24	28
800					0	1	3	5	7	10	14	18	22	26	30
900					0	1	3	5	8	11	15	19	23	27	32
1000					0	1	3	5	8	12	16	20	24	29	34
1100					0	1	3	6	9	12	16	20	25	30	35
1200					0	2	4	6	9	12	16	21	26	31	36
1300					0	2	4	6	9	13	17	22	27	32	37
1400					0	2	4	7	10	14	18	22	27	33	39
1500					0	2	4	7	10	14	18	23	28	33	39
1600					0	2	4	7	10	14	18	23	29	34	40
1700					0	2	4	7	11	15	19	24	29	35	41
1800					0	2	5	8	11	15	19	24	30	36	42
1900					0	3	5	8	11	15	20	25	30	36	43
2000					0	3	5	8	12	16	20	25	31	37	43
2100					0	3	5	8	12	16	21	26	32	37	44
2200					0	3	5	8	12	16	21	26	32	38	45
2300					0	3	6	9	12	17	21	27	32	39	45
2400					0	3	6	9	13	17	22	27	33	39	46
2500					0	3	6	9	13	17	22	27	33	40	46
2600					0	3	6	9	13	17	22	28	34	40	47
2700					0	3	6	9	13	18	23	28	34	41	48
2800					0	4	6	10	14	18	23	29	35	41	48
2900					0	4	6	10	14	18	23	29	35	42	49
3000				-2	0	4	7	10	14	19	24	29	35	42	49
3100				-2	0	4	7	10	14	19	24	30	36	42	49
3200				-2	0	4	7	10	14	19	24	30	36	43	50
3300				-2	0	4	7	10	15	19	24	30	36	43	50
3400				-2	0	4	7	11	15	20	25	31	37	43	51
3500				-2	0	4	7	11	15	20	25	31	37	44	51
Line No.	0					1			2				3		

Note: In the line-number band, the 100 column falls under line number 0 from 2700 to 3500 m.

Figure 7-11. Table B.

TABLE C

7-11. **Table C** is used in the solution of concurrent and subsequent met. It is entered with the chart direction of wind. The chart direction of wind is the angle formed by the intersection of the direction of the wind from the met message and the direction of fire (that is, the horizontal clockwise angle from the direction of fire to the direction of the wind). This table divides a 1-knot wind into crosswind and range wind components. Components for crosswind and range wind are then extracted. The extracted values are described as the components of a 1-knot wind. The range wind component is the percentage of the wind speed that acted as a range factor. The crosswind component is the percentage of the wind force that acts to blow the projectile laterally and is translated into a lateral correction factor. (See figure 7-12 on page 7-10.)

NOTE: Table C is based on chart direction of wind only and, thus, is the same for all charges and all weapons

CHARGE 4H M232A1

TABLE C

WIND COMPONENTS

FT 155-AM-3

PROJ, HE, M107
FUZE, PD, M739A1

COMPONENTS OF A ONE KNOT WIND

CHART DIRECTION OF WIND MIL	CROSS WIND KNOT	RANGE WIND KNOT	CHART DIRECTION OF WIND MIL	CROSS WIND KNOT	RANGE WIND KNOT
0	0	H1.00	3200	0	T1.00
100	R.10	H.99	3300	L.10	T.99
200	R.20	H.98	3400	L.20	T.98
300	R.29	H.96	3500	L.29	T.96
400	R.38	H.92	3600	L.38	T.92
500	R.47	H.88	3700	L.47	T.88
600	R.56	H.83	3800	L.56	T.83
700	R.63	H.77	3900	L.63	T.77
800	R.71	H.71	4000	L.71	T.71
900	R.77	H.63	4100	L.77	T.63
1000	R.83	H.56	4200	L.83	T.56
1100	R.88	H.47	4300	L.88	T.47
1200	R.92	H.38	4400	L.92	T.38
1300	R.96	H.29	4500	L.96	T.29
1400	R.98	H.20	4600	L.98	T.20
1500	R.99	H.10	4700	L.99	T.10
1600	R1.00	0	4800	L1.00	0
1700	R.99	T.10	4900	L.99	H.10
1800	R.98	T.20	5000	L.98	H.20
1900	R.96	T.29	5100	L.96	H.29
2000	R.92	T.38	5200	L.92	H.38
2100	R.88	T.47	5300	L.88	H.47
2200	R.83	T.56	5400	L.83	H.56
2300	R.77	T.63	5500	L.77	H.63
2400	R.71	T.71	5600	L.71	H.71
2500	R.63	T.77	5700	L.63	H.77
2600	R.56	T.83	5800	L.56	H.83
2700	R.47	T.88	5900	L.47	H.88
2800	R.38	T.92	6000	L.38	H.92
2900	R.29	T.96	6100	L.29	H.96
3000	R.20	T.98	6200	L.20	H.98
3100	R.10	T.99	6300	L.10	H.99
3200	0	T1.00	6400	0	H1.00

Figure 7-12. Table C.

TABLE D

7-12. **Table D** is used in the solution of concurrent and subsequent met. The table provides corrections based on standard departures to correct the ballistic air temperature and ballistic air density in the met message (which is measured at an altitude beginning at the meteorological datum plane [MDP]) to values as if they would be measured initially from the unit altitude. This compensates for the difference in altitude between the firing unit and the meteorological section. The values are standard departures of air temperature and density as a function of height that have been converted to a percentage of standard.

7-13. **Table D** is entered with the height of the unit above or below the MDP or met station. The difference in height is entered on the left side in hundreds of meters and along the top of the table in tens of meters. Extract the corrections to density and temperature from the intersection of the two columns. (See figure 7-13 on page 7-11.)

FT 155-AM-3 | TABLE D | CHARGE 4H
PROJ, HE, M107 | TEMPERATURE | M232A1
FUZE, PD, M739A1 | AND DENSITY CORRECTIONS

CORRECTIONS TO TEMPERATURE (DT) AND DENSITY (DD), IN PERCENT, TO COMPENSATE FOR THE DIFFERENCE IN ALTITUDE, IN METERS, BETWEEN THE BATTERY AND THE MDP

DH		0	+10-	+20-	+30-	+40-	+50-	+60-	+70-	+80-	+90-
0	DT	0.0	0.0	0.0	-0.1+	-0.1+	-0.1+	-0.1+	-0.2+	-0.2+	-0.2+
	DD	0.0	-0.1+	-0.2+	-0.3+	-0.4+	-0.5+	-0.6+	-0.7+	-0.8+	-0.9+
+100-	DT	-0.2+	-0.2+	-0.2+	-0.3+	-0.3+	-0.3+	-0.3+	-0.4+	-0.4+	-0.4+
	DD	-1.0+	-1.1+	-1.2+	-1.3+	-1.4+	-1.5+	-1.6+	-1.7+	-1.8+	-1.9+
+200-	DT	-0.5+	-0.5+	-0.5+	-0.6+	-0.6+	-0.6+	-0.6+	-0.7+	-0.7+	-0.7+
	DD	-2.0+	-2.1+	-2.2+	-2.3+	-2.4+	-2.5+	-2.6+	-2.7+	-2.8+	-2.9+
+300-	DT	-0.7+	-0.7+	-0.7+	-0.8+	-0.8+	-0.8+	-0.8+	-0.9+	-0.9+	-0.9+
	DD	-3.0+	-3.1+	-3.2+	-3.3+	-3.4+	-3.5+	-3.6+	-3.7+	-3.8+	-3.9+

NOTES - 1. DH IS BATTERY HEIGHT ABOVE OR BELOW THE MDP.
2. IF ABOVE THE MDP, USE THE SIGN BEFORE THE NUMBER.
3. IF BELOW THE MDP, USE THE SIGN AFTER THE NUMBER.

Figure 7-13. Table D.

TABLE E

7-14. **Table E** is used in the solution of concurrent and subsequent met. The extracted values list the effect on muzzle velocity (in meters per second) caused by nonstandard propellant temperatures.

7-15. **Table E** is entered with the temperature of the propellant in degrees Fahrenheit by using the left column or Celsius by using the right column. An effect in meters per second is extracted from the center column. This is the change in muzzle velocity due to the temperature of the propellant. Interpolation is needed to determine precise values from this table. (See figure 7-14.)

TABLE E

PROPELLANT TEMPERATURE

EFFECTS ON MUZZLE VELOCITY DUE TO PROPELLANT TEMPERATURE

TEMPERATURE OF PROPELLANT DEGREES F	EFFECT ON VELOCITY M/S	TEMPERATURE OF PROPELLANT DEGREES C
-40	-17.1	-40.0
-30	-15.4	-34.4
-20	-13.8	-28.9
-10	-12.2	-23.3
0	-10.7	-17.8
10	-9.3	-12.2
20	-7.8	-6.7
30	-6.3	-1.1
40	-4.8	4.4
50	3.3	10.0
60	-1.7	15.6
70	0.0	21.1
80	1.8	26.7
90	3.6	32.2
100	5.6	37.8
110	7.7	43.3
120	10.0	48.9
130	12.4	54.4

Figure 7-14. Table E.

TABLE F

7-16. **Table F** lists information needed to determine firing data to attack a target and for solving concurrent and subsequent met. Table F is comprised of 19 columns. Columns 2 through 7 provide information for the computation of basic firing data and are based on a set of standard conditions. The remaining columns provide corrections to range and deflection for nonstandard conditions. The asterisks extending across the table denote the changeover point from low-angle to high-angle fire. The entry argument for this table is either chart range expressed to the nearest 10 meters or entry range expressed to the nearest 100 meters. When entering the table with chart range, interpolation is needed to determine precise values from this table. (See figure 7-15 on page 7-13.)

- **Range (Column 1).** This is the distance measured from the muzzle to the target on the surface of a sphere concentric with the earth. When chart range is used as the entry argument for this table, it is expressed to the nearest 10 meters and interpolation is necessary.
- **Elevation (Column 2).** This is the angle that the cannon tube is elevated from the horizontal plane (base of trajectory) to cause the round to impact at the level point for a given range. The elevations listed are the elevations required under standard conditions to achieve the ranges listed in column 1.
- **Fuze setting for a graze burst (M582) (Column 3).** This is the number to be set to cause the fuze to function at the level point at the given range under standard conditions. The values listed are for valid for fuzes mechanical time super-quick (MTSQ), M582 and electronic time (ET), M767. The values are expressed in tenths of seconds.
- **Change in fuze setting (FS) per 10-meter decrease in height of burst (Column 4).** This is the adjustment to fuze setting required to decrease the height of burst 10 meters along the trajectory. To increase the HOB, change the sign of the value given in the table.
- **Change in range per 1-mil change in elevation (Column 5).** This is the number of meters change in range, along the gun target line, that would result from a 1-mil change in elevation.
- **Fork (Column 6).** This is the change in the angle of elevation needed to produce a change in range, at the level point, equivalent to 4 probable errors in range.
- **Time of flight (Column 7).** This is the number of seconds needed for the round to travel from the muzzle to the level point at the given elevation. This column is also used to determine the fuze setting for variable time fuzes M728 and M732/A2.

7-17. Columns 8 through 19 list range corrections for drift, cross wind, muzzle velocity, range wind, air temperature, air density, and projectile weight. These corrections are used in the solution of concurrent and subsequent met. Correction factors correspond to increases or decreases in relation to standard values for muzzle velocity, air temperature, air density, and projectile weight, except the correction factors for range wind. The correction factors for range wind are listed for both head and tail winds. The factors listed assume that all other conditions are standard.

- **Azimuth correction for drift (Column 8).** This is the number of mils added to deflection to compensate for the drift of the projectile. Because projectiles drift when fired, the drift correction will be to the left.
- **Azimuth correction for a crosswind of 1 knot (Column 9).**This is the correction, in mils, needed to correct for a 1-knot crosswind.
- **Correction for a 1 meter-per-second decrease or increase in muzzle velocity (Columns 10 and 11).** This is a correction to range to compensate for a 1 meter-per-second decrease or increase in muzzle velocity.
- **Correction for a head wind or tail wind of 1 knot (Columns 12 and 13).** This is a correction to range to compensate for a head wind or tail wind of 1 knot.
- **Correction for a 1 percent decrease or increase in air temperature (Columns 14 and 15).** This is a correction to range to compensate for a decrease or increase in air temperature of 1 percent of standard.
- **Correction for a 1 percent decrease or increase in air density (Columns 16 and 17).** This is a correction to range to compensate for a decrease or increase in air density of 1 percent of standard.

- **Correction for a 1 square decrease or increase in projectile weight (Columns 18 and 19).** This is a correction to range to compensate for a decrease or increase of 1 square in projectile weight.

CHARGE 4H M232A1 — TABLE F — BASIC DATA — FT 155-AM-3 — PROJ, HE, M107 FUZE, PD, M739A1

1	2	3	4	5	6	7	8	9
RANGE	ELEV	FS FOR GRAZE BURST FUZE M582	DFS PER 10 M DEC HOB	DR PER 1 MIL D ELEV	FORK	TIME OF FLIGHT	AZIMUTH CORRECTIONS	
							DRIFT (CORR TO L)	CW OF 1 KNOT
M	MIL			M	MIL	SEC	MIL	MIL
0	0.0			100	1	0.0	0.0	0.00
100	1.1			100	1	0.1	0.0	0.00
200	2.1			100	1	0.3	0.1	0.01
300	3.1			99	1	0.4	0.1	0.01
400	4.1			97	1	0.6	0.1	0.01
500	5.1			95	1	0.7	0.2	0.01
600	6.2			94	1	0.9	0.2	0.02
700	7.2			94	1	1.0	0.2	0.02
800	8.3			93	1	1.2	0.3	0.02
900	9.4			92	1	1.3	0.3	0.03
1000	10.5			91	1	1.5	0.3	0.03
1100	11.6			90	1	1.6	0.4	0.03
1200	12.7			89	1	1.8	0.4	0.04
1300	13.9	1.9	1.07	88	1	1.9	0.5	0.04
1400	15.0	2.1	0.99	87	1	2.1	0.5	0.04
1500	16.2	2.3	0.92	86	1	2.3	0.5	0.05
1600	17.3	2.4	0.86	85	1	2.4	0.6	0.05
1700	18.5	2.6	0.81	84	1	2.6	0.6	0.05
1800	19.7	2.7	0.76	83	1	2.7	0.6	0.06
1900	20.9	2.9	0.72	82	1	2.9	0.7	0.06
2000	22.2	3.1	0.68	81	1	3.1	0.7	0.06
2100	23.4	3.2	0.65	80	1	3.2	0.8	0.07
2200	24.7	3.4	0.62	79	1	3.4	0.8	0.07
2300	25.9	3.6	0.59	78	1	3.6	0.9	0.07
2400	27.2	3.8	0.56	77	1	3.8	0.9	0.08
2500	28.5	3.9	0.54	77	1	3.9	0.9	0.08
2600	29.8	4.1	0.51	76	1	4.1	1.0	0.08
2700	31.1	4.3	0.49	75	1	4.3	1.0	0.09
2800	32.5	4.5	0.48	74	1	4.5	1.1	0.09
2900	33.9	4.6	0.46	73	1	4.6	1.1	0.09
3000	35.2	4.8	0.44	72	1	4.8	1.2	0.10
3100	36.6	5.0	0.43	71	1	5.0	1.2	0.10
3200	38.0	5.2	0.41	70	1	5.2	1.3	0.10
3300	39.5	5.4	0.40	70	1	5.4	1.3	0.11
3400	40.9	5.6	0.38	69	1	5.6	1.4	0.11
3500	42.4	5.7	0.37	68	1	5.7	1.4	0.12

Figure 7-15. Table F.

FT 155-AM-3 TABLE F CHARGE 4H

PROJ, HE, M107 CORRECTION FACTORS M232A1

FUZE, PD, M739A1

1	10	11	12	13	14	15	16	17	18	19
RANGE	RANGE CORRECTIONS FOR									
	MUZZLE VELOCITY 1 M/S		RANGE WIND 1 KNOT		AIR TEMP 1 PCT		AIR DENSITY 1 PCT		PROJ WT OF 1 SQ (4 SQ STD)	
	DEC	INC	HEAD	TAIL	DEC	INC	DEC	INC	DEC	INC
M	M	M	M	M	M	M	M	M	M	M
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
100	0.3	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	-1	1
200	0.6	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	-1	2
300	0.9	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	-2	2
400	1.2	-1.1	0.0	0.0	0.0	0.0	0.0	0.1	-3	3
500	1.4	-1.4	0.0	0.0	0.0	0.0	-0.1	0.1	-3	3
600	1.7	-1.7	0.0	0.0	0.0	0.0	-0.2	0.1	-4	4
700	2.0	-1.9	0.0	0.0	-0.1	0.1	-0.3	0.2	-5	5
800	2.3	-2.2	0.0	0.0	-0.1	0.1	-0.4	0.3	-5	5
900	2.5	-2.4	0.0	0.0	-0.1	0.1	-0.4	0.4	-6	6
1000	2.8	-2.7	0.1	-0.1	-0.1	0.1	-0.5	0.5	-6	6
1100	3.1	-3.0	0.1	-0.1	-0.2	0.2	-0.6	0.6	-7	7
1200	3.4	-3.2	0.1	-0.1	-0.2	0.2	-0.7	0.8	-7	7
1300	3.6	-3.5	0.1	-0.1	-0.2	0.2	-0.8	0.9	-8	8
1400	3.9	-3.7	0.1	-0.1	-0.3	0.3	-1.0	1.0	-8	8
1500	4.1	-4.0	0.1	-0.1	-0.3	0.3	-1.1	1.2	-9	9
1600	4.4	-4.2	0.1	-0.1	-0.4	0.4	-1.3	1.3	-9	9
1700	4.7	-4.5	0.2	-0.1	-0.4	0.4	-1.4	1.5	-9	10
1800	4.9	-4.7	0.2	-0.2	-0.5	0.4	-1.6	1.7	-10	10
1900	5.2	-5.0	0.2	-0.2	-0.5	0.5	-1.8	1.8	-10	10
2000	5.4	-5.2	0.2	-0.2	-0.6	0.6	-2.0	2.0	-11	11
2100	5.6	-5.4	0.2	-0.2	-0.6	0.6	-2.2	2.3	-11	11
2200	5.9	-5.7	0.3	-0.2	-0.7	0.7	-2.4	2.5	-11	12
2300	6.1	-5.9	0.3	-0.3	-0.8	0.7	-2.6	2.7	-12	12
2400	6.4	-6.1	0.3	-0.3	-0.8	0.8	-2.9	2.9	-12	12
2500	6.6	-6.4	0.3	-0.3	-0.9	0.9	-3.1	3.2	-12	12
2600	6.8	-6.6	0.4	-0.3	-1.0	0.9	-3.4	3.5	-12	13
2700	7.1	-6.8	0.4	-0.4	-1.0	1.0	-3.6	3.7	-13	13
2800	7.3	-7.1	0.4	-0.4	-1.1	1.1	-3.9	4.0	-13	13
2900	7.5	-7.3	0.4	-0.4	-1.2	1.1	-4.2	4.3	-13	14
3000	7.8	-7.5	0.5	-0.5	-1.3	1.2	-4.5	4.6	-13	14
3100	8.0	-7.7	0.5	-0.5	-1.3	1.3	-4.8	4.9	-13	14
3200	8.2	-7.9	0.5	-0.5	-1.4	1.4	-5.1	5.2	-14	14
3300	8.4	-8.1	0.6	-0.6	-1.5	1.4	-5.4	5.6	-14	14
3400	8.7	-8.4	0.6	-0.6	-1.6	1.5	-5.7	5.9	-14	14
3500	8.9	-8.6	0.7	-0.6	-1.7	1.6	-6.1	6.3	-14	15

Figure 7-15. Table F (Continued).

EXTRACTING BASIC HE DATA FROM TABLE F

7-18. Data may be extracted from Columns 1 through 8 of Table F to compute firing data. It is necessary to relate the data extracted to an entry argument. An element of data is said to be a function of another element when changes in one of the elements will cause a change in the other.

Note**:** Data interpolated from the table are never determined to an accuracy greater than the values listed in the pertinent column

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- **Elevation is a Function of Range.** Enter Column 1 with range expressed to the nearest 10 meters, and extract the elevation to the nearest 1 mil from Column 2.
- **Fuze Setting is a Function of Elevation.** Enter Column 2 with the elevation expressed to the nearest mil, and extract the fuze setting expressed to the nearest 0.1 of a second from Column 3 for fuzes M582 and M767.
- **▲FS for 10-Meter Decrease in HOB is a Function of Fuze Setting.** Enter Column 3 for fuzes M582 and M767 with the fuze setting expressed to the nearest 0.1. Extract the ▲FS expressed to the nearest 0.01 from Column 4.
- **D Range for a 1-Mil D Elevation is a Function of Elevation.** Enter Column 2 with the elevation expressed to the nearest mil, and extract the change in range for a 1-mil change in elevation expressed to the nearest meter.
- **Time of Flight is a Function of Elevation.** Enter Column 2 with the elevation expressed to the nearest mil, and extract the time of flight expressed to the nearest whole second from Column 7.
- **Variable Time Fuze Setting is a Function of Elevation.** Enter Column 2 with the elevation expressed to the nearest mil, and extract the fuze setting expressed to the nearest 0.1 second from Column 7. Express down to the whole second.
- **Drift is a Function of Elevation.** Enter Column 2 with the elevation expressed to the nearest mil, and extract the drift expressed to the nearest 1 mil from Column 8.

TABLE G

7-19. **Table G** is the table of supplementary data containing probable error information and certain trajectory elements. For ranges not listed, data can be determined through interpolation. The entry argument for this table is range expressed to the nearest 10 meters (Column 1). Elevation corresponding to that range is listed in Column 2 for quick reference and will not be used to determine elevation. The asterisks extending across the table denote the changeover point from low-angle to high-angle fire. (See figure 7-16 on page 7-17.)

- **Probable Error (Columns 3 through 7).** Probable error is defined as an error that is exceeded as often as it is not exceeded. Columns 3 through 7 identify probable errors for a particular charge, and range or elevation. These errors are based on the standard probability curve and are explained in more detail in Chapter 3.
- **Probable Error in Range to Impact (Column 3).** Probable error in range is a value in meters that, when added to and subtracted from the range at the mean point of impact along the gun-target (GTL) line, will produce an interval that should contain 50 percent of all rounds fired. PER will vary according to the charge and range.
- **Probable Error in Deflection at Impact (Column 4).** Probable error in deflection is a value in meters when applied to the right and left of the mean point of impact, will produce an interval parallel to the line of fire that should contain 50 percent of the rounds fired. PED will vary based on charge and range.
- **Probable Error in Height of Burst (Column 5).** Probable error in height of burst is a value in meters which, when added to and subtracted from the expected height of burst, will define an area that should contain 50 percent of the rounds fired. The factors that contribute to PEHB include variations in the functioning of the time fuze.

- **Probable Error in Time to Burst (Column 6).** Probable error in time to burst is a value in seconds, which when added to and subtracted from the expected time to burst, will produce a time interval that should contain 50 percent of the rounds fired.
- **Probable Error in Range to Burst (Column 7).** Probable error in range to burst is a value in meters which, when added to and subtracted from the expected range to burst, will produce an interval along the line of fire that should contain 50 percent of the rounds fired.
- **Angle of Fall (Column 8).** The angle of fall is the value in mils of the least angle measured clockwise from the horizontal to a line tangent to the trajectory at the level point.
- **Cotangent of Angle of Fall (Column 9).** The cotangent (cot) angle of fall is the trigonometric function of the angle of fall. When the probable error in range is divided by this factor, the quotient is the vertical probable error. The vertical probable error is the height expected to contain 25 percent of the impacts when firing onto a vertical face.
- **Terminal Velocity (Column 10).** The terminal velocity (tml vel) is the speed of the projectile at the level point of the trajectory under standard conditions.
- **Maximum Ordinate (Column 11).** The maximum ordinate (MO) is the height of the summit above the origin of the trajectory in meters. This is the height of the trajectory above the howitzer expressed in meters under standard conditions.
- **Complementary Angle of Site for Each Mil of Angle of Site (Columns 12 and 13).** This is the correction termed the complementary site factor (CSF) which must be algebraically added to each mil of angle of site to compensate for the nonrigidity of the trajectory. When the CSF is multiplied by the absolute value of the angle of site, the product is the complementary angle of site.

CHARGE 4H M232A1 — TABLE G — FT 155-AM-3

SUPPLEMENTARY DATA — PROJ, HE, M107 FUZE, PD, M739A1

1	2	3	4	5	6	7	8	9	10	11	12	13
RANGE	ELEV	PROBABLE ERRORS					ANGLE OF FALL	COT ANGLE OF FALL	TML VEL	MO	COMP SITE FOR ANGLE OF SITE	
				FUZE M582								
		R	D	HB	TB	RB					+1 MIL SITE	-1 MIL SITE
M	MIL	M	M	M	SEC	M	MIL		M/S	M	MIL	MIL
0	0.0	19	0				0		705	0	0.000	0.00
1000	10.5	18	1				11	91.2	651	3	0.000	0.00
2000	22.2	17	1	1	0.04	24	25	40.8	600	11	0.000	0.00
3000	35.2	15	2	1	0.04	22	42	24.3	551	28	0.001	-0.001
4000	50.0	15	2	1	0.04	21	63	16.1	504	55	0.002	-0.001
5000	66.6	14	3	2	0.04	20	89	11.4	460	94	0.003	-0.002
6000	85.6	15	3	2	0.04	19	122	8.3	419	150	0.004	-0.002
7000	107.4	16	4	3	0.04	18	163	6.2	381	226	0.006	-0.003
8000	132.6	18	4	4	0.04	19	213	4.7	347	329	0.008	-0.003
9000	161.7	21	5	4	0.04	20	274	3.6	326	467	0.011	-0.004
10000	195.2	23	6	6	0.04	21	340	2.9	315	646	0.016	-0.007
11000	232.9	26	6	7	0.05	22	409	2.4	310	872	0.023	-0.011
12000	274.8	28	7	9	0.05	23	478	2.0	309	1150	0.034	-0.020
13000	321.1	31	8	11	0.05	24	548	1.7	309	1484	0.051	-0.033
14000	372.1	33	9	13	0.05	25	618	1.4	311	1884	0.079	-0.053
15000	428.8	35	10	16	0.06	26	689	1.2	313	2360	0.123	-0.086
16000	492.8	37	11	19	0.06	27	762	1.1	317	2936	0.200	-0.141
17000	568.3	39	12	24	0.07	29	840	0.9	320	3658	0.376	-0.245
18000	669.3	41	14	30	0.08	32	935	0.8	324	4689	1.335	-0.549
*****	*******	****	****	****	*****	****	*****	*****	****	*****	******	*******
18000	958.2	48	18	53	0.13	38	1166	0.5	333	7844	-2.478	1.68
17000	1040.0	46	18	60	0.15	37	1226	0.4	335	8713	-1.490	1.36
16000	1096.6	43	18	65	0.16	36	1268	0.3	336	9285	-1.294	1.24
15000	1141.9	40	18	69	0.17	34	1302	0.3	336	9718	-1.198	1.16
14000	1179.9	37	17	73	0.18	32	1332	0.3	337	10060	-1.138	1.12
13000	1212.3	34	17	76	0.18	29	1361	0.2	337	10336	-1.096	1.08
12000	1239.8		16	80	0.19	26	1388	0.2	338	10558	-1.065	1.05

Figure 7-16. Table G.

TABLE H

7-20. **Table H** is used in the solution of concurrent and subsequent met. The extracted value is the correction to range in meters for the rotation of the earth at 0° latitude. A correction for any other latitude is extracted from the small table at the bottom of Table H and is multiplied by the correction from the table. The asterisks extending across the table denote the changeover point from low-angle to high-angle fire.

7-21. **Table H** is entered along the left side with the entry range expressed to the nearest 500 meters and along the top or bottom with the **exact azimuth** (to the nearest mil) to the target (direction of fire) expressed to the nearest listed value. For example, if the azimuth to the target is 1,499 mils, enter Table H with 1400. Whenever the solution determined is exactly halfway between two entry arguments for azimuth to the target use the next higher value. (See figure 7-19 on page 7-20.)

7-22. Background theory of rotational effects may assist in understanding why table H is needed to determine a range correction for rotation of the earth.

- Because of rotation of the earth, a point on the equator has an eastward linear velocity of approximately 457 meters per second. The linear velocity decreases to 0 meters at either pole.
- Given a gun on the equator firing due east at a target (See figure 7-17.), during the time of flight of the projectile, the gun and the target will travel together from G to G' and 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 origin of the trajectory established at the time of firing. At the end of the 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 impact east of the target (over the target in this case). The effect is as if the quadrant elevation fired was in error by the amount of angle *a*. Angle *a* is the angle formed by the base line G'P' and a tangent to the earth at G'. With the gun firing eastward, angle *a* is positive (the projectile impacts over the target).

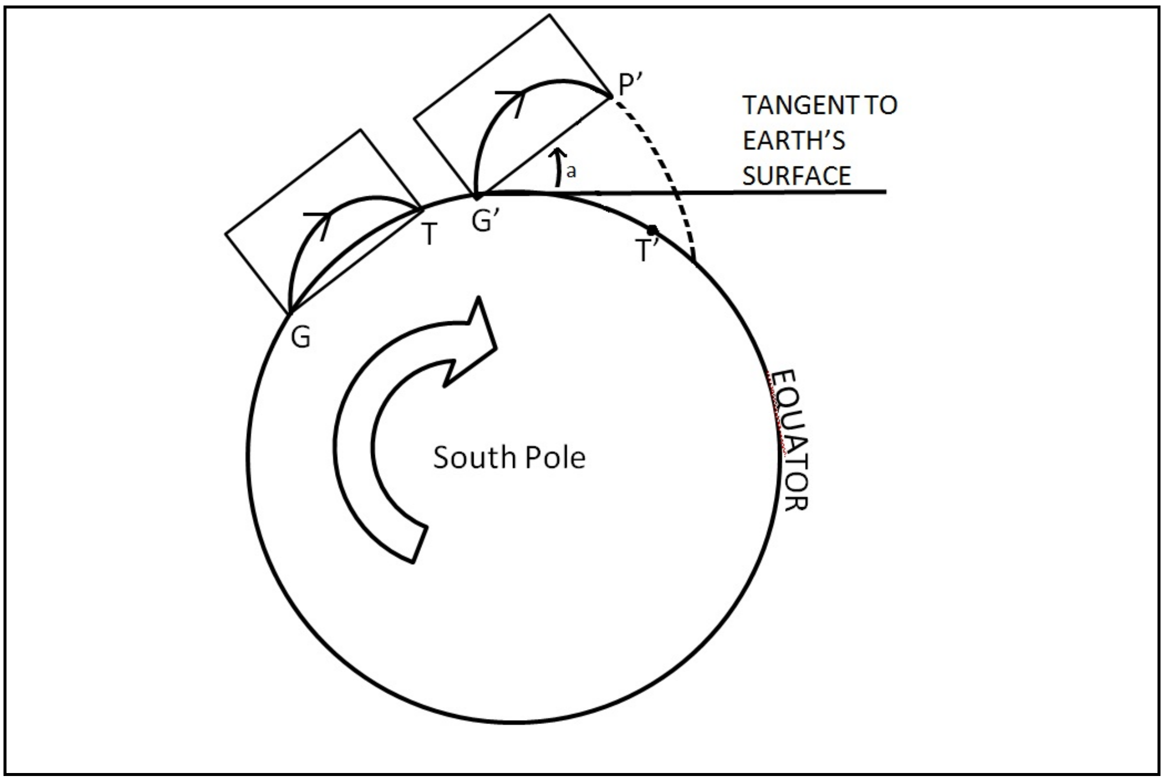

Figure 7-17. Table H (Explanation – Firing East).

- If examined, a gun on the equator firing due west at a target (see figure 7-18 on page 7-19), the trajectory would be interrupted by the earth's surface and the projectile would impact east of the target (short of the target in this case). The value of angle *a* (the angle formed by the base line G'P' and a tangent to the earth at G') is negative (the projectile impacts short of the target).

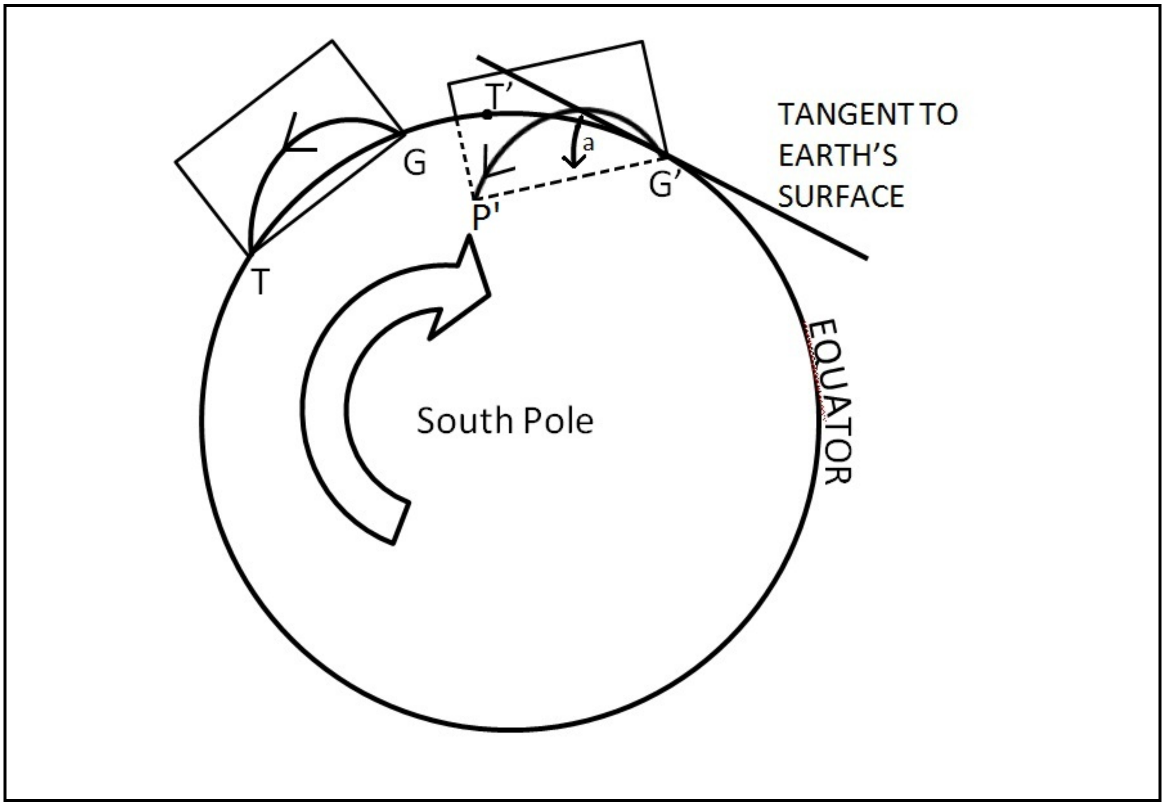

Figure 7-18. Table H (Explanation – Firing West).

FT 155-AM-3 TABLE H CHARGE 4H

PROJ, HE, M107 ROTATION - RANGE M232A1

FUZE, PD, M739A1

CORRECTIONS TO RANGE, IN METERS, TO COMPENSATE FOR THE ROTATION OF THE EARTH

RANGE METERS	AZIMUTH OF TARGET - MILS 0 3200	200 3000	400 2800	600 2600	800 2400	1000 2200	1200 2000	1400 1800	1600 1600
1000	0	-2+	-4+	-5+	-7+	-8+	-9+	-10+	-10+
2000	0	-4+	-7+	-10+	-13+	-15+	-17+	-18+	-18+
3000	0	-5+	-9+	-14+	-17+	-21+	-23+	-24+	-25+
4000	0	-6+	-12+	-17+	-21+	-25+	-28+	-29+	-30+
5000	0	-7+	-13+	-19+	-24+	-28+	-32+	-33+	-34+
6000	0	-7+	-14+	-21+	-26+	-31+	-34+	-36+	-37+
7000	0	-8+	-15+	-22+	-27+	-32+	-36+	-38+	-39+
8000	0	-8+	-15+	-22+	-28+	-33+	-37+	-39+	-40+
9000	0	-8+	-15+	-22+	-29+	-34+	-37+	-40+	-40+
10000	0	-8+	-16+	-23+	-29+	-34+	-38+	-40+	-41+
11000	0	-8+	-16+	-24+	-30+	-35+	-39+	-42+	-42+
12000	0	-9+	-17+	-25+	-31+	-37+	-41+	-43+	-44+
13000	0	-9+	-18+	-26+	-32+	-38+	-42+	-45+	-46+
14000	0	-9+	-18+	-27+	-34+	-40+	-44+	-47+	-48+
15000	0	-10+	-19+	-28+	-35+	-41+	-46+	-49+	-50+
16000	0	-10+	-20+	-28+	-36+	-42+	-47+	-50+	-51+
17000	0	-10+	-20+	-29+	-37+	-43+	-48+	-51+	-52+
18000	0	-10+	-19+	-27+	-35+	-41+	-45+	-48+	-49+
******	****	******	******	******	******	******	******	******	********
18000	0	-3+	-6+	-8+	-10+	-12+	-14+	-14+	-15+
17000	0	0	+1-	+1-	+1-	+2-	+2-	+2-	+2-
16000	0	+3-	+6-	+9-	+11-	+13-	+15-	+16-	+16-
15000	0	+6-	+11-	+16-	+21-	+24-	+27-	+29-	+29-
14000	0	+8-	+17-	+24-	+31-	+36-	+40-	+42-	+43-
13000	0	+12-	+23-	+33-	+42-	+50-	+55-	+58-	+60-
12000	0	+16-	+31-	+45-	+57-	+67-	+75-	+79-	+81-
	3200 6400	3400 6200	3600 6000	3800 5800	4000 5600	4200 5400	4400 5200	4600 5000	4800 4800
	AZIMUTH OF TARGET - MILS								

NOTES - 1. WHEN ENTERING FROM THE TOP USE THE SIGN BEFORE THE NUMBER.
2. WHEN ENTERING FROM THE BOTTOM USE THE SIGN AFTER THE NUMBER.
3. AZIMUTH IS MEASURED CLOCKWISE FROM NORTH.
4. CORRECTIONS ARE FOR 0 DEGREES LATITUDE. FOR OTHER LATITUDES MULTIPLY CORRECTIONS BY THE FACTOR GIVEN BELOW.

LATITUDE (DEG)	10	20	30	40	50	60	70
MULTIPLY BY	.98	.94	.87	.77	.64	.50	.34

Figure 7-19. Table H.

TABLE I

7-23. **Table I** is used in the solution of concurrent and subsequent met. There are tables for every 10° latitude starting from 0° north or south latitude to 70° north or south latitude. The extracted value is the correction to deflection in mils, for the rotation of the earth. The asterisks extending across the table denote the changeover point from low-angle to high-angle free.

7-24. **Table I** is entered along the left side with the entry range expressed to the nearest 500 meters and along the top (for northern latitudes), with the **exact azimuth** (to the nearest mil) to the target (direction of fire) expressed to the nearest listed value. For example, if the azimuth to the target is 1,499 mils, enter Table I with 1600. For southern latitudes, you enter from the bottom with the **exact azimuth** (to the nearest mil) to the target (direction of fire) expressed to the nearest listed value. Whenever the solution determined is exactly halfway between two entry arguments for azimuth to the target, use the next higher value. (See figure 7- 20.)

CHARGE 4H M232A1 | TABLE I | FT 155-AM-3

ROTATION - AZIMUTH | PROJ, HE, M107 FUZE, PD, M739A1

CORRECTIONS TO AZIMUTH, IN MILS, TO COMPENSATE FOR THE ROTATION OF THE EARTH

0 DEGREES LATITUDE

RANGE METERS	AZIMUTH OF TARGET - MILS 0 6400	400 6000	800 5600	1200 5200	1600 4800	2000 4400	2400 4000	2800 3600	3200 3200
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9000	R0.1L	R0.1L	0.0	0.0	0.0	0.0	0.0	L0.1R	L0.1R
10000	R0.1L	R0.1L	R0.1L	0.0	0.0	0.0	L0.1R	L0.1R	L0.1R
11000	R0.1L	R0.1L	R0.1L	0.0	0.0	0.0	L0.1R	L0.1R	L0.1R
12000	R0.2L	R0.2L	R0.1L	R0.1L	0.0	L0.1R	L0.1R	L0.2R	L0.2R
13000	R0.2L	R0.2L	R0.2L	R0.1L	0.0	L0.1R	L0.2R	L0.2R	L0.2R
14000	R0.3L	R0.3L	R0.2L	R0.1L	0.0	L0.1R	L0.2R	L0.3R	L0.3R
15000	R0.4L	R0.3L	R0.3L	R0.1L	0.0	L0.1R	L0.3R	L0.3R	L0.4R
16000	R0.5L	R0.5L	R0.3L	R0.2L	0.0	L0.2R	L0.3R	L0.5R	L0.5R
17000	R0.7L	R0.6L	R0.5L	R0.3L	0.0	L0.3R	L0.5R	L0.6R	L0.7R
18000	R0.9L	R0.9L	R0.7L	R0.4L	0.0	L0.4R	L0.7R	L0.9R	L0.9R
******	******	******	******	******	******	******	******	******	******
18000	R2.3L	R2.1L	R1.6L	R0.9L	0.0	L0.9R	L1.6R	L2.1R	L2.3R
17000	R2.9L	R2.7L	R2.0L	R1.1L	0.0	L1.1R	L2.0R	L2.7R	L2.9R
16000	R3.4L	R3.1L	R2.4L	R1.3L	0.0	L1.3R	L2.4R	L3.1R	L3.4R
15000	R3.9L	R3.6L	R2.7L	R1.5L	0.0	L1.5R	L2.7R	L3.6R	L3.9R
14000	R4.3L	R4.0L	R3.1L	R1.7L	0.0	L1.7R	L3.1R	L4.0R	L4.3R
13000	R4.8L	R4.4L	R3.4L	R1.8L	0.0	L1.8R	L3.4R	L4.4R	L4.8R
12000	R5.2L	R4.8L	R3.7L	R2.0L	0.0	L2.0R	L3.7R	L4.8R	L5.2R
	3200 3200	2800 3600	2400 4000	2000 4400	1600 4800	1200 5200	800 5600	400 6000	0 6400
	AZIMUTH OF TARGET - MILS								

0 DEGREES LATITUDE

NOTES - 1. WHEN ENTERING FROM THE TOP USE THE SIGN BEFORE THE NUMBER.
2. WHEN ENTERING FROM THE BOTTOM USE THE SIGN AFTER THE NUMBER.
3. R DENOTES CORRECTION TO THE RIGHT, L TO THE LEFT.
4. AZIMUTH IS MEASURED CLOCKWISE FROM NORTH.

Figure 7-20. Table I (0 Degrees Latitude).

TABLE J

7-25. **Table J** is used in the solution of concurrent and subsequent met. This table provides corrections to fuze setting to compensate for the effects of nonstandard conditions. The data are arranged in 11 columns, each of which gives values for the various quantities as a function of the fuze setting tabulated in the first column.

7-26. The fuze setting used as an entry argument corresponds to the adjusted elevation from a registration (concurrent met) or corresponds to the elevation determined in the solution of a subsequent met. (See figure 7-21 on page 7-23.)

- **Fuze setting (Column 1).**The FS corresponding to the adjusted elevation expressed to the nearest whole increment is the entry argument for Table J.
- **Correction for a 1 meter-per-second decrease or increase in muzzle velocity (Columns 2 and 3).** This is the correction for the FS to compensate for a 1 meter-per-second decrease or increase in muzzle velocity.
- **Correction for a head wind or tail wind of 1 knot (Columns 4 and 5).** This is the correction to FS to compensate for a head wind or tail wind of 1 knot.
- **Correction for a 1 percent decrease or increase in air temp (Columns 6 and 7).** This is the correction to FS to compensate for a decrease or increase in air temperature of 1 percent of standard.
- **Correction for a 1 percent decrease or increase in air density (Columns 8 and 9).** This is the correction to FS to compensate for a decrease or increase in air density of 1 percent of standard.
- **Correction for a 1 square decrease or increase in projectile weight (Columns 10 and 11).** This is the correction to FS to compensate for a decrease or increase of 1 square in projectile weight.

CHARGE 4H M232A1 — TABLE J — FT 155-AM-3

FUZE CORRECTION FACTORS

PROJ, HE, M107
FUZE, MTSQ, M582

1	2	3	4	5	6	7	8	9	10	11
FS	FUZE CORRECTIONS FOR									
	MUZZLE VELOCITY 1 M/S		RANGE WIND 1 KNOT		AIR TEMP 1 PCT		AIR DENSITY 1 PCT		PROJ WT OF 1 SQ (4 SQ STD)	
	DEC	INC	HEAD	TAIL	DEC	INC	DEC	INC	DEC	INC
0										
1										
2	-.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.007	-.007
3	-.004	0.004	0.000	0.000	0.000	0.000	0.001	-.001	0.009	-.010
4	-.005	0.005	0.000	0.000	0.000	0.000	0.001	-.001	0.012	-.012
5	-.007	0.007	0.000	0.000	0.001	-.001	0.002	-.002	0.014	-.015
6	-.008	0.008	0.000	0.000	0.001	-.001	0.003	-.003	0.017	-.017
7	-.009	0.009	0.000	0.000	0.001	-.001	0.004	-.004	0.018	-.019
8	-.010	0.010	0.000	0.000	0.001	-.001	0.005	-.005	0.020	-.020
9	-.012	0.012	0.000	0.000	0.002	-.002	0.006	-.006	0.022	-.022
10	-.013	0.013	0.000	0.000	0.002	-.002	0.008	-.008	0.023	-.023
11	-.014	0.014	0.000	0.000	0.003	-.003	0.009	-.009	0.024	-.025
12	-.015	0.015	0.000	0.000	0.003	-.003	0.011	-.011	0.025	-.026
13	-.016	0.016	-.001	0.001	0.004	-.003	0.013	-.012	0.026	-.027
14	-.017	0.017	-.001	0.001	0.004	-.004	0.014	-.014	0.026	-.027
15	-.018	0.018	-.001	0.001	0.005	-.004	0.016	-.016	0.027	-.028
16	-.019	0.019	-.001	0.001	0.005	-.005	0.018	-.018	0.027	-.028
17	-.020	0.020	-.001	0.001	0.006	-.007	0.021	-.021	0.027	-.028
18	-.021	0.021	-.001	0.001	0.007	-.009	0.023	-.024	0.026	-.028
19	-.023	0.023	-.001	0.001	0.009	-.011	0.027	-.028	0.024	-.026
20	-.024	0.024	-.001	0.001	0.011	-.014	0.031	-.031	0.022	-.025
21	-.025	0.025	-.001	0.001	0.014	-.016	0.035	-.035	0.020	-.023
22	-.026	0.026	-.001	0.001	0.017	-.018	0.039	-.039	0.018	-.021
23	-.027	0.027	-.001	0.001	0.019	-.020	0.043	-.043	0.015	-.019
24	-.028	0.028	-.001	0.001	0.022	-.022	0.048	-.046	0.013	-.016
25	-.029	0.029	-.001	0.001	0.024	-.023	0.052	-.050	0.011	-.014
26	-.030	0.029	-.001	0.001	0.027	-.025	0.056	-.054	0.009	-.012
27	-.031	0.030	-.001	0.001	0.029	-.026	0.061	-.057	0.006	-.010
28	-.031	0.031	-.001	0.001	0.031	-.027	0.065	-.060	0.005	-.008
29	-.032	0.032	-.001	0.001	0.032	-.027	0.069	-.063	0.003	-.006
30	-.033	0.033	-.001	0.001	0.034	-.028	0.073	-.066	0.001	-.005
31	-.034	0.034	-.001	0.001	0.035	-.028	0.077	-.069	0.000	-.003
32	-.035	0.035	-.001	0.001	0.037	-.028	0.080	-.072	-.002	-.002
33	-.036	0.036	-.001	0.002	0.038	-.028	0.084	-.074	-.003	-.001
34	-.037	0.036	-.002	0.002	0.039	-.028	0.087	-.077	-.004	0.000
35	-.037	0.037	-.002	0.002	0.039	-.028	0.091	-.080	-.005	0.001

Figure 7-21. Table J.

TABLE K

7-27. **Table K** provides corrections to be applied to M582 fuze settings when time fuze M564 is being fired. (See figure 7-22.)

FT 155-AM-3 TABLE K CHARGE 4H

PROJ, HE, M107 FUZE SETTING M232A1

FUZE, MTSQ, M582

CORRECTIONS TO FUZE SETTING OF FUZE, MTSQ, M582

FOR FUZE, MTSQ, M564

FUZE SETTING FUZE M582		CORRECTIONS
FROM	TO	
2.0	4.7	0.0
4.8	9.1	0.1
9.2	13.5	0.2
13.6	17.9	0.3
18.0	22.2	0.4
22.3	26.6	0.5
26.7	31.0	0.6
31.1	35.4	0.7
35.5	39.8	0.8
39.9	44.1	0.9
44.2	48.5	1.0

Figure 7-22. Table K.

ILLUMINATING PROJECTILES

7-28. Illuminating projectiles are available for the 105-mm and the 155-mm howitzers. They are used to illuminate a designated area for observing enemy night operations, for adjusting artillery fires at night, for marking locations, or for harassment purposes.

7-29. Illuminating projectiles are base-ejecting projectiles fired with mechanical or electronic time fuzes. The filler consists of an illuminating canister and a parachute assembly. The FDO selects the charge to fire, selecting the lowest practical charge to prevent a malfunction caused by the parachute ripping when the flare is ejected from the projectile. The illuminating projectile for the 105-mm howitzer is the M314A3. The 155-mm howitzer has the M458 series of illuminating projectiles and the M1066 Infrared illuminating projectile.

Note**:** Part 2 of the 155-AM-2 and 155-AM-3 TFTs apply to the **M485 series only**

PART 2

7-30. **Part 2** of the AM-3 TFT provide data for the illuminating projectile. Most illumination data are provided in a single table. However, TFTs may contain additional tables to provide corrections for mechanical time fuzes other than that tabulated in the first table. When more than one table is provided, the tables are identified by letters.

TABLE A

7-31. **Table A** provides basic firing data and corrections to firing data for illuminating projectiles. The data are arranged in seven columns. Interpolation is required for table A. The shaded portion of Columns 1 and 2 indicate function during the ascending branch

- **Range to target (Column 1).** This is the distance measured from the muzzle to the target on the surface of a sphere concentric with the earth. When range is used as the entry argument for this table, it is expressed to the nearest 10 meters.
- **Quadrant elevation (Column 2).** This is the angle of the tube in the vertical plane. This QE, when used in conjunction with the fuze setting given in Column 3, produces an airburst such that the ignition of the illuminant occurs 600 meters (105-mm is 750 meters) above the level point at the given range.
- **Fuze setting (Column 3).** This is the fuze setting for the M577 fuze. When used in conjunction with the QE given in Column 2, it produces an airburst such that the ignition of the illuminant occurs 600 meters above the level point at the range (105-mm is 750 meters).
- **Change in QE and FS for an increase of 50 meters in HOB (Columns 4 and 5).** These corrections are added to the QE and FS to increase the height of burst by 50 meters. By changing the sign of the correction, the factor is used to lower the height of burst. This factor is also used to correct the QE and FS from Columns 2 and 3 for the VI. **These factors must be applied in conjunction with each other.**
- **Range to fuze function (Column 6).** This is the horizontal distance from the gun to the point at which the fuze functions.
- **Range to impact (Column 7).** This is the horizontal distance from the gun to the point at which a nonfunctioning projectile will impact.

TABLE B

7-32. **Table B** provides corrections to fuze setting for MTSQ, M577 to obtain a fuze setting for fuze mechanical time (MT), M565. The corrections are either added to or subtracted from the fuze setting of the MTSQ, M577 to obtain the fuze setting for fuze MT, M565.

TABLE C

7-33. **Table C.** Some TFT's include table C in part 2 which contains trajectory data to be used in the computation of safety data. Table C consists of 5 columns, Range, Elevation, Fuze Setting for a Graze Burst, Time of Flight, and Azimuth corrections to compensate for drift.

Note: If the corresponding TFT does not have a table C, then the appropriate addendum must be used to compute safety data.

TFT PART 3 AND PART 4

7-34. Certain TFTs provide data in two additional parts. Part 3 contains firing data for cartridge, HEP-T, M327 and consists of one table for a single charge. Part 4 contains firing data for cartridge APERS, M546 and consists of one table for a single charge.

APPENDIXES

7-35. The last portion of the TFT are the appendixes. They contain trajectory charts for projectile HE. Altitude in meters above the origin is plotted against range in meters for every 100 mils of elevation up to the maximum trailing angle. Time of flight, by 5-second intervals, is marked on the trajectory.

SECTION II: GRAPHICAL FIRING TABLES

7-36. To eliminate the difficulties in computing firing data that result from the need to interpolate, the graphical firing table (GFT) was created. The GFT provides all the information needed to compute firing data in a slide rule form.

> Note: Determining data by interpolating in the TFT is more accurate; however the GFT provides the optimal compromise between speed and accuracy

OVERVIEW

7-37. **Parts.** All GFTs are made in two parts (figure 7-23). The rule is a rectangular wooden base on which is printed one or more sets of scales. With a few exceptions, GFTs are printed on both sides. The second part of the GFT is the cursor. This is a transparent plastic square that slides on the rule. Engraved in the plastic of the cursor is a manufacturer's hairline used to determine values from the scales.

7-38. **Types.** The basic GFT format is the same for all weapons. These formats may be divided into three types: low-angle GFTs, high-angle GFTs, and illumination GFTs.

7-39. **Identification.** All GFTs are labeled (figure 7-24 on page 7-27) for identification. The first line of the label on low and high-angle GFTs indicates the type of weapon in bold type; that, i.e.: **155MM or HOW155MM.** Immediately below or beside the weapon type is the identification of the TFT on which the GFT is based; for example, "AM-3." This is followed by the projectile type and nomenclature, such as "HE M107." The next line of identification of low-angle GFTs tells the charge for which the GFT may be used, such as "CHARGE M232A1 4H." High-angle GFTs indicate the trajectory "HIGH ANGLE." Illumination GFTs (figure 7-24) reverse the label with "PROJECTILE ILLUMINATING" on the top and the weapon type on the bottom.

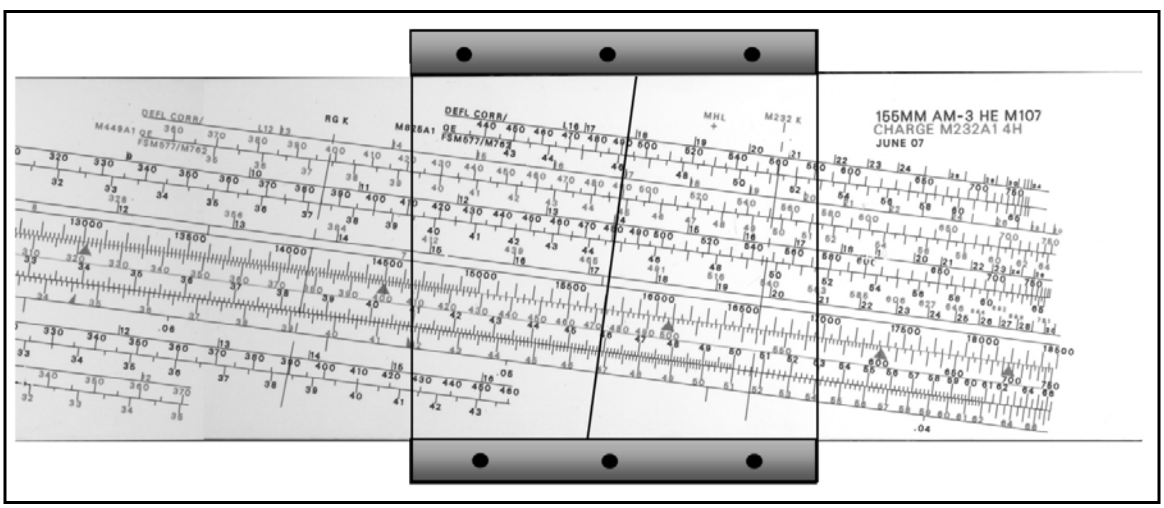

Figure 7-23. Graphical Firing Table.

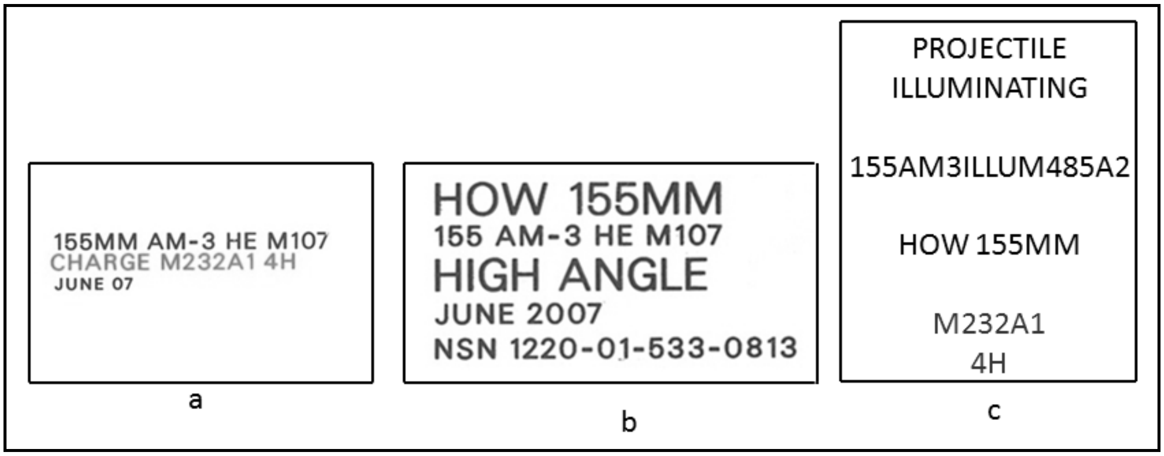

Figure 7-24. GFT Label.

LOW-ANGLE GFTS

7-40. Low-angle GFTs are available for all weapon systems and were developed from the data contained in the TFT of the weapon and projectile. All GFTs are printed with a base scale which represents the data for the base projectile as indicated on the label; that is, "HE M107." One or more ICM/M825 scales may be provided above or below the base scale. The scales are as follows:

- **Drift Scale.** This scale, which is printed in black, gives the projectile drift in mils. Since the projectile drifts to the right, the drift correction is always made to the left. Each elevation at which the drift is exactly halfway between the values is printed in red above the drift scale. Artillery expression is applied to determine the value of drift at each of these elevations. For example, the drift correction determined at elevation 353 is L 10.5, expressed to L10 mils. In determining drift, it is important to note that drift is a function of elevation. The corresponding portion of the TFT is Table F, Column 8.
- **100/R Scale.** This scale lists the number of mils needed to move the burst laterally or vertically 100 meters at a given range. The numbers on this scale are printed in red. The scale is based on the mil relation formula= W/R x 1.0186). 100/R is a function of range. There is no corresponding table in the TFT for 100/R.
- **Range Scale.** This scale is the base scale and all other scales are plotted in relation to it. Range is expressed in meters. The range scale was 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. The corresponding portion of the TFT is Table F, Column 1.
- **Elevation Scale.** This scale is graduated in mils and is read to the nearest mil. The numbers on this scale are printed in red and black. The red numbers denote elevations that are within range transfer limits for a one-plot GFT setting. The corresponding portion of the TFT is Table F, Column 2.
- **Time of Flight/Fuze Setting MTSQ/Electronic Time Scale.** This scale lists the time of flight and the fuze settings for time fuzes M582, M577, M767, M728, M732, and 732A2 corresponding to a given elevation. Time of flight is determined to the nearest whole second. Fuze settings for time fuzes M582, M577, and M767 are determined to the nearest 0.1 fuze setting increment. Fuze setting for fuze VT is determined from the time fuze (TF)/FS MTSQ/ET (electronic time) scale by vanishing the tenths and applying a .0. Time of flight and the fuze settings for M582, M577, M767, M732, and M732A2 are functions of elevation. The corresponding portion of the TFT is Table F, Columns 3 and 7.
- **Fuze Setting M564 Scale.** This scale lists the settings for time fuzes M564 and M565. The values are read to the nearest 0.1 fuze setting increment. Fuze settings for M564 and M565 are functions of elevation. There is no corresponding column in table F of the 155-AM-3. To obtain a fuze setting for a M564 fuze, enter table K and extract the correction to apply to the M582 fuze

setting. Certain older TFTs such as the FT155-AM-2 contain column 3 in table F corresponding to the FS M564 scale.

- **FS/10M HOB Scale.** This scale lists the corrections to fuze setting for fuzes M582, M564 or M767 that are needed to raise or lower the HOB 10 meters along the trajectory. FS/10M HOB is a function of fuze setting. The corresponding portion of the TFT- is Table F, Column 4.
- **Met Check Gauge Points.** These are red equilateral triangles above the TF/FS MTSQ/ET fuze setting scale. The apex of each triangle points to the QE that under standard conditions results in the maximum ordinate of the trajectory passing through a whole line number of a met message. The range and QE at the met check gauge points are preferred for registration aiming points, for met plus velocity error (met + VE) computations, and for determining GFT settings, when using a ballistic met message. There is no corresponding table in the TFT.

Note: Chapter 10 explains registrations and determining GFT settings, and Chapter 11 explains met + VE computations

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- **Height-of-Burst Probable Error Gauge Points.** These gauge points appear on some GFTs above the fork scale or on the M564 fuze setting scale. They are red right triangles and indicate the range and fuze settings at which the PE_{HB} is 15 meters. Larger HOB dispersion must be expected when time fuzes are used with a particular charge at ranges exceeding the gauge point. Some charges have two such gauge points. The one on the left of the GFT indicates the range at which the PE_{HB} for the next lower charge is 15 meters. The PE_{HB} can be determined from Table G, Column 5, of the TFT.
- **Range Probable Error Gauge Point.** This is a black equilateral triangle located above the ▲FS/▲10MHOB scale. It indicates the range at which the range probable error equals 25 meters. Ranges to the left of the gauge point have a PE_R of less than 25; ranges to the right of the gauge point have a PE_R of greater than 25. The PE_R can be determined from Table G, Column 3, of the TFT.
- **Range K and Fuze K Lines.** These are based on data derived from computer simulations of artillery firing. The computer program uses 50 sets of weighted nonstandard conditions of temperature, density, range wind, and muzzle velocity. Firing simulations were made by using these 50 sets of nonstandard conditions for each of a number of ranges within the range limits for each charge. Every group of 50 firings for each range provided data to calculate a total average range correction (range K) and total average fuze correction (fuze K) for that particular range. These values of range K and fuze K were graphically plotted versus the corresponding range for all simulated ranges for each charge. These curves were simplified as tight line approximations and were used to create the data to construct the range K and fuze K lines on the GFT. These approximations were considered to be acceptable, up to the point where no more than 1 PE_R was introduced. This acceptable range area is denoted on the GFT by the elevation numbers printed in red. Those numbers corresponding to an error larger than 1 PE_R are printed in black. From this is derived the range transfer limits for a one-plot GFT setting.
- **M232 K Line.** This line appears on some GFTs for propellant type M232A1. When using these GFTs with propellant type M232, a M232K line must be drawn on the curser. This adjustment is necessary to account for the difference in muzzle velocity between the M232 and the M232A1propellants. To construct the line, place the manufacturer’s hairline over the middle of the + under the MHL label. Next, trace the M232K line on the cursor and label it with M232 above the line.

Note: Disregard the M232 K line if a unit determines a GFT setting with propellant type M232

- **Improved Conventional Munitions/ Improved Smoke Scales.** These scales are on some graphical firing tables. They are located above the deflection correction (DEFL CORR)/DRIFT scale and below the ▲FS/▲10MHOB scale. The scales apply to a specific type of ammunition as indicated by the model number at the left end of the scale.

- DEFL CORR. This is the top scale on GFT ICM/Smoke scales. This scale incorporates base scale drift and the ballistic correction as tabulated in Table A of the appropriate addendum.
- The next scale (the top scale on older GFTs) is the quadrant scale. This scale provides the quadrant to fire for the ICM/Smoke projectile. The ICM quadrant is read to the nearest mil by placing the manufacturer's hairline over the base scale quadrant and reading up under the MHL to the appropriate ICM quadrant scale. This QE incorporates the ballistic correction given in Table A of the appropriate addendum.
- The last scale provides the fuze setting to fire on the ICM/Smoke projectile. The FS is read to the nearest 0.1 increment by placing the MHL over the base scale FS and reading up under the MHL to the appropriate ICM FS scale. This FS incorporates the ballistic correction given in Table B of the appropriate addendum.

HIGH-ANGLE GFT

7-41. High-angle fire is delivered at elevations greater than the elevation corresponding to the maximum range for a charge. ***High-angle fire* is delivered at elevations greater than the elevation corresponding to the maximum range for a charge.** Range decreases as the angle of elevation increases. High-angle fire is achieved by a weapon system firing at an elevation (angle) greater than is required for its maximum range. All howitzers can deliver high-angle fire effectively.

7-42. The high-angle GFT (figure 7-25) consists of one rule with ballistic data for multiple charges on each side. The scales on the high-angle GFT from top to bottom are as follows:

- **100/R.** This scale lists the number of mils needed to move the burst laterally or vertically 100 meters at a given range. The scale increases from right to left, is read to the nearest mil, and applies to all charges printed on that side of the GFT. There is no corresponding portion in the TFT.
- **Range.** The range scale is expressed in meters and applies to all charges appearing on that side of the GFT. Range increases from left to right and is read to the nearest 10 meters. The corresponding portion of the TFT is Table F, Column 1.
- **Elevation.** Elevation is expressed in mils and increases from right to left. It is visually interpolated to the nearest mil. The corresponding portion of the TFT is Table F, column 2.
- **10-Mil site factor.** The values on this scale denote the site for each 10 mils of angle of site. The numbers are printed in red and are negative values. This factor actually reflects the complementary angle of site for a positive VI. Consequently, a slightly more accurate solution for negative angles of site can be determined from the TFT. The scale increases from left to right and is read to the nearest tenth (0.1) of a mil. There is no corresponding portion in the TFT.
- **Drift.** The values on this scale are in mils. The scale increases from right to left and is read to the nearest mil. The corresponding portion of the TFT is Table F, Column 8.
- **Time of flight.** This scale is graduated in seconds and is used to determine both time of flight (to the nearest whole second) and VT fuze setting (to the next lower whole second). The scale increases from right to left. The corresponding portion of the TFT is Table F, Column 7.

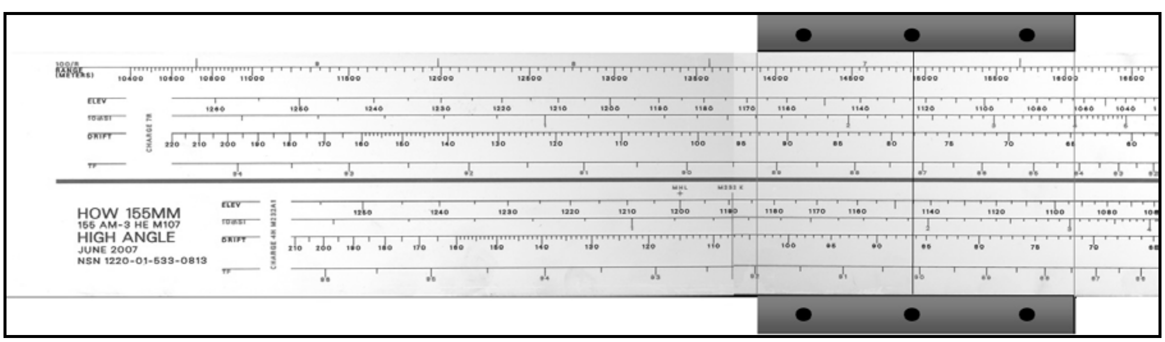

Figure 7-25. High Angle GFT.

Note: Because the scales increase in different directions, the computer must be careful in reading the high-angle GFT. The elevation, 100/R, drift, and TF scales increase from right to left. The range and 10-mil site scales increase from left to right

Note**:** A GFT setting can be applied to a High Angle GFT. Instructions are contained in Chapter 10

ILLUMINATING PROJECTILE GFT

7-43. Graphical firing tables have been developed for use with all 155-mm M485A2 illuminating projectiles and with the 105-mm M314A1, M314A2, and M314A3E1 projectiles. Illumination scales are provided for enough charges to cover the spectrum of range for the shell and weapon.

7-44. The Illumination GFT consists of one rule. The scales on the high-angle GFT from top to bottom are as follows:

- **100/R.** This scale is printed along the top edge of the GFT. For a given range, the 100/R scale denotes the number of mils needed to shift the burst 100 meters laterally or vertically. The scale is based on the mil relation formula= W/R x 1.0186). The 100/R is read to the nearest mil. There is no corresponding portion in the TFT.
- **Range.** The range scale is the base scale of the illuminating GFT. All other scales are plotted with reference to the range scale. Range is read to the nearest 10 meters. The corresponding portion of the TFT is Part 2, Table A, Column 1.
- **Elevation to Impact.** This scale is graduated in mils. Low-angle elevation increases from left to right and is read to the nearest mil. The scale is used to determine the range (on the range scale) to which a nonfunctioning projectile will impact. There is no corresponding portion in the TFT.
- **Height of Burst.** These scales are graduated in 50-meter increments. The HOB is determined by expressing the VI to the nearest 50 meters and algebraically applying the VI to the optimum HOB. There is no corresponding portion in the TFT.
- **QE.** The QE scale shown for each listed height of burst gives the QE needed to achieve the height of burst at the desired range. The scale is graduated in mils and is visually interpolated to the nearest mil. A heavy black arrow on the QE scale indicates the part of the trajectory that is at or near the summit and that does not exceed by 50 meters the height of burst that it represents. (See figure 7-26.) The corresponding portion of the TFT for a 600-meter (750 meters for 105 mm) HOB is Part 2, Table A, Column 2.

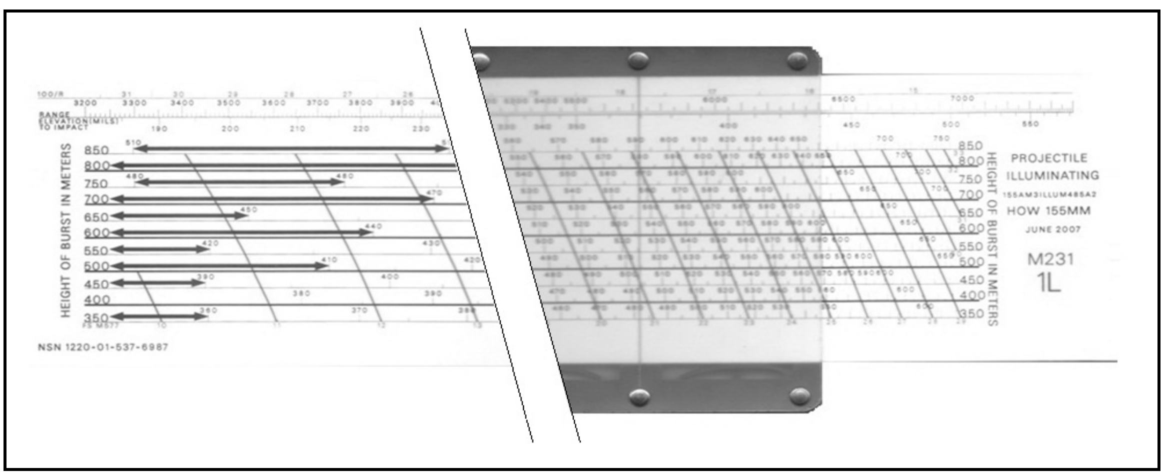

Figure 7-26. Illuminating Projectile M485 GFT, Charge 1L.

7-45. Figure 7-27 illustrates the trajectory of an illuminating projectile and the height of burst change between ranges 3,200 to 3,830 for charge 1L.

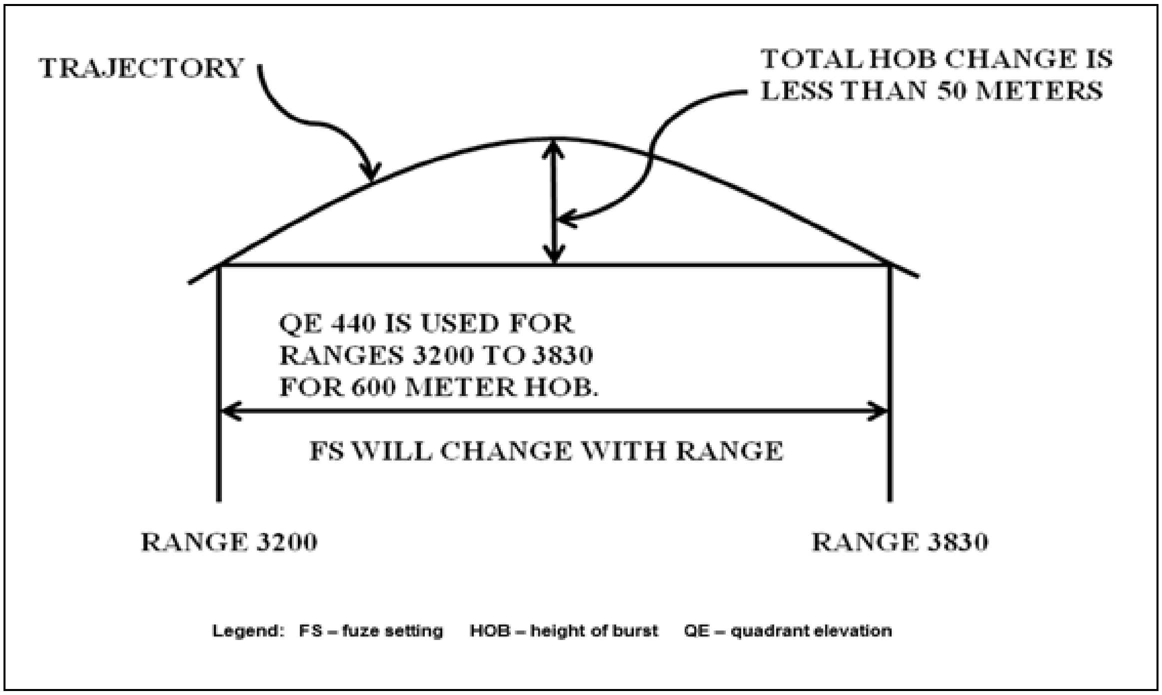

Figure 7-27. Trajectory of an Illuminating Projectile M485, Charge 1L.

- **FS M577.** This scale consists of a series of red arcs. The scale includes a red line for each whole fuze setting increment for the MT, M577 fuze. The value of each line is printed in red at the bottom of the scale. The fuze setting is read for the desired range and HOB to an accuracy of 0.1 FS increment by visual interpolation between the red arcs. The corresponding portion of the TFT for a 600-meter (750 meters for 105 mm) HOB is Part 2, Table A, Column 3.

Chapter 8

Site

In a situation where the target is not at the same altitude as the firing battery, the elevation determined from the tabular firing table may not achieve effects on the target. Site is a correction factor for a trajectory which is computed in such a situation. The VCO computes site using either a Graphical Site Table (GST) or manual computations. In order to understand site, a brief description of certain elements of the trajectory is necessary.

INITIAL ELEMENTS OF THE TRAJECTORY

8-1. **Vertical Interval**. The vertical interval (VI) is the difference in altitude between the unit (or observer) and the target or point of burst. (See figure 8-1 on page 8-2.) The VCO determines the vertical interval by subtracting the altitude of the unit or observer from the altitude of the target or point of burst. The vertical interval is determined to the nearest meter and is a signed value.

8-2. **Angle of Site**. The angle of site (∡SI) is a geometric angle which compensates for the vertical interval at a given range between the firing unit and the target. (See figure 8-1 on page 8-2.) The VCO determines the angle of site by dividing the vertical interval by the range (or distance) in thousands of meters and applying a correction factor to account for the conversion from meters to mils. The angle of site has a positive value when the target is above the base of the trajectory and a negative value when the target is below the base of the trajectory. The angle of site is determined to the nearest 0.1 mil and is a signed value. Angle of site carries the same sign as the VI.

8-3. **Complementary Angle of Site**. When angle of site is added to the elevation from the tabular firing tables it will impart a change on the trajectory. It is too simple to assume that the projectile fired at a higher elevation will simply go further or that one fired at a lower elevation will simply not go as far. For example, a projectile fired at a higher elevation will also experience a steeper angle of ascent, a higher maximum ordinate, and a steeper angle of descent as well as many other small changes. This is referred to as “trajectory non-rigidity.” **The *complementary angle of site* (CAS) is an angle that is algebraically added to the angle of site to compensate for the non-rigidity of the trajectory.** (See figure 8-1 on page 8-2). Complementary angle of site (is a function of the following factors:

- Charge.
- Range.
- Angle of site.
- Weapon system.
- Projectile family.
- Angle of fire (high or low).

8-4. The VCO determines the complementary angle of site by multiplying the absolute value of the angle of site by a pre-determined correction factor for that charge and range located in Table G of the associated TFT, Columns 12 and 13. This correction factor is referred to as the complementary site factor (comp site factor or CSF) and is determined by interpolating from a chart range listed to the nearest 10 meters. Complementary angle of site is computed to the nearest 0.1 mil and is a signed value. Complementary angle of site will always have the same sign as of the CSF value.

8-5. **Site**. ***Site* is the algebraic sum of the angle of site and the complementary angle of site.** (See figure 8-1 on page 8-2.) Site **(SI)** is determined by the VCO to the nearest mil and it is a signed value.

8-6. **Angle of Elevation**. **The *angle of elevation* is the vertical angle between the base of the trajectory and the axis of the bore required for a projectile to achieve a prescribed range under standard conditions.** (See Chapter 3.) It is determined by the computer for that range and charge from Table F, Column 2 of the associated TFT. Elevation **(EL)** is determined to the nearest mil.

8-7. **Quadrant Elevation**. ***Quadrant elevation* (QE) is the algebraic sum of site and the angle of elevation. It is determined by the computer to the nearest mil**.

Note: For precision fires, site and elevation may be determined to the nearest 0.1 mil. The algebraic sum of those two values will yield a precision quadrant determined to the nearest 0.1 mil

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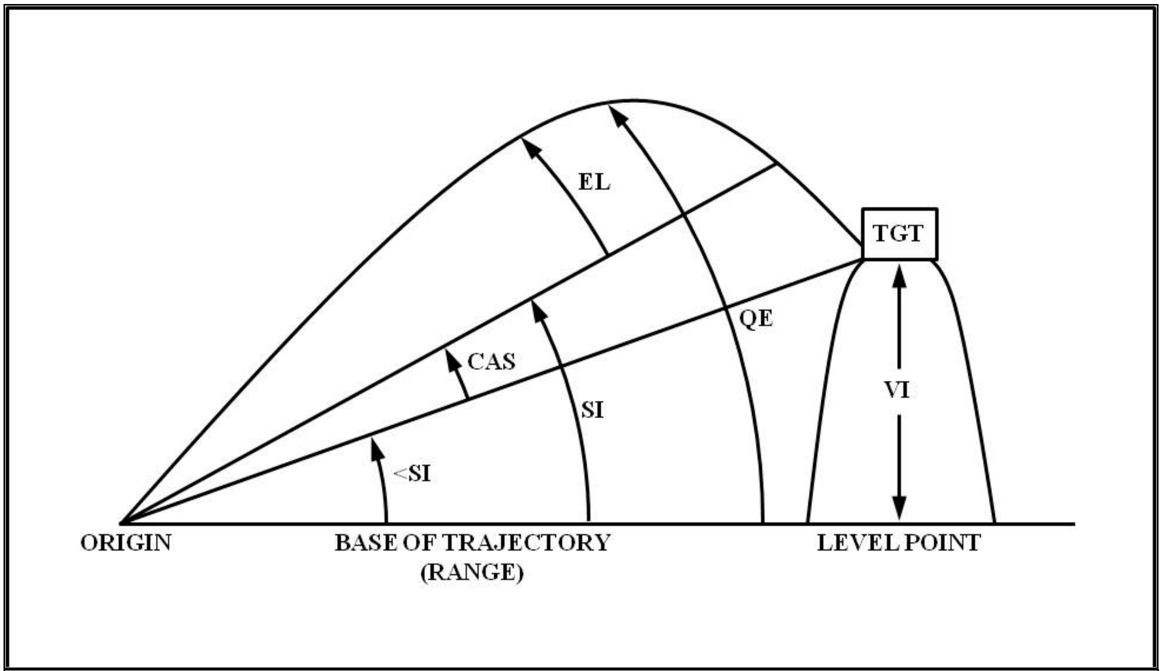


Legend: CAS – complementary angle of site EL – elevation QE – quadrant elevation SI – site <SI – angle of site TGT – target VI – vertical interval

Figure 8-1. Elements of a Trajectory.

SITE IN HIGH ANGLE FIRE

8-8. Site has a relatively small effect in high-angle fire because of the large angle of fall. In high-angle missions, a negative site must be used to compensate for a positive vertical interval and a positive site must be used to compensate for a negative vertical interval. Therefore, high-angle site will have the opposite sign of the VI.

DETERMINATION OF ALTITUDES

8-9. The altitude of the unit or base piece is normally determined by map spot or survey and labeled on the firing chart. To determine the target altitude, the VCO must analyze the call for fire sent by the observer.

- In a call for fire where the target is identified by grid coordinate, the observer may announce the altitude of the target.
- In a polar call for fire, the observer may identify the target altitude by transmitting an up or down vertical shift from the altitude at his location. If the observer transmits a vertical shift, the altitude of the target is determined in relation to the observer by applying the vertical shift to the observer's altitude.

OBS ALT + VERTICAL SHIFT = TGT ALT

- In a shift from known point call for fire, the vertical shift transmitted by the observer is applied to the known point altitude to determine the target altitude.

KN PT ALT + VERTICAL SHIFT = TGT ALT

- All altitudes transmitted in the call for fire by the observer will be verified by the FDO on a situation map as part of mission processing. In the case that the observer does not transmit an altitude or the FDO does not agree with transmitted altitude, the FDO's determined altitude will be used for the computation of site.

DETERMINATION OF SITE USING MANUAL COMPUTATIONS

8-10. Table 8-1 contains the procedures for determining site without the use of a Graphical Site Table.

Table 8-1. Determination of Site without a GST.

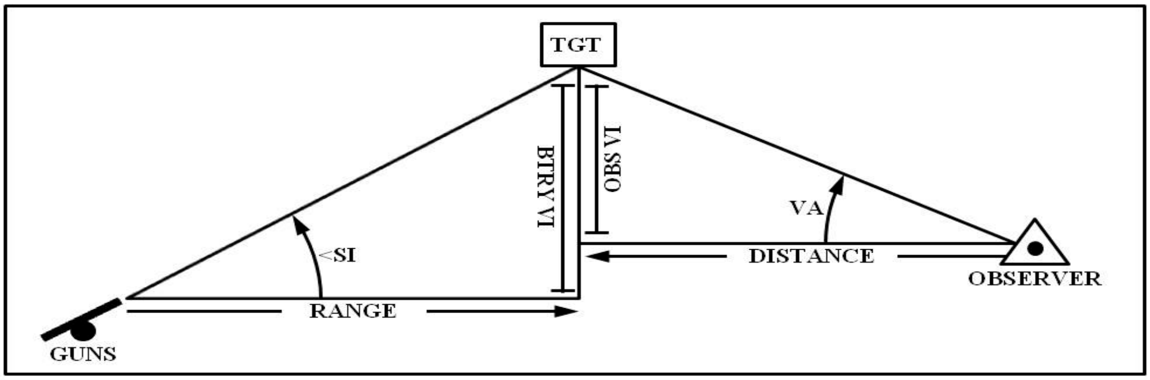
STEP	***ACTION***
1	Determine the vertical interval. Use the following equation: **TGT ALT** **<u>- UNIT ALT</u>** **VI (±) NEAREST 1 METER**
2	Determine the angle of site. To compute angle of site, use the following equation: $\frac{\textbf{VERTICAL INTERVAL}}{\textbf{RG (IN 1,000s OF METERS)}} \times 1.0186 = \measuredangle SI\ (\pm) \approx$ **NEAREST 0.1 MIL**
	Note: 1.0186 is a correction factor utilized when a certain range or distance measured in meters is converted into an angular measurement in mils. The angle of site (and the vertical angle) is based on the mil relation formula, which assumes that an angle of 1 mil will subtend an arc of 1 meter at a distance of 1,000 meters. However, performing the math reveals that the subtended arc is actually only 0.98175 meters: 1mil × 2πR = ARC $\frac{1}{6400} \times 2(3.14159)1000 = 0.98175$ M This error is insignificant when the angle of site is a small value, but for greater angles of site it is enough to significantly affect the accuracy of a projectile. To yield a more precise solution, a correction factor must be determined. By dividing the subtended number of meters (0.98175) into 1 meter, a multiplication factor of 1.0186 is determined. $\frac{1}{0.98175} \approx 1.0186$ Multiplying the angle of site by this value, as shown in the equation for angle of site above, will fulfill the assumption of the mil relation formula. When utilizing the GST, reading the value of angle of site (or vertical angle) from underneath the M gauge point will automatically apply this conversion factor.
	Note: If the angle of site is greater than ±100 mils, it must be computed by using the following formula: TANGENT (∡SI) = VI/RG. For example: GIVEN: Vertical Interval: +840 meters Chart Range: 7,000 meters 1. Tangent(∡SI) = +840/7,000 2. Tangent(∡SI) = + 0.12 3. Arctangent (+0.12) = <SI 4. ∡SI = +6.84277341 deg 5. ∡SI = +6.84277341 × 17.7778 (Conversion factor from degrees to mils.) 6. ∡SI = +121.649 mils ≈ +121.6 mils

Table 8-1. Determination of Site without a GST (continued).

STEP	ACTION
3	Determine the value for complementary angle of site. **|∡SI| × CSF = CAS (±) ≈ NEAREST 0.1 MIL**
3a	Determine the value for the CSF from the TFT, Table G, Column 12 or 13. The entry argument for this table is chart range (to the nearest 10 meters.) If the angle of site is positive, use Column 12. If the angle of site is negative, use Column 13. Interpolate as necessary.
	Note: Interpolation in Table G to the nearest 10 meters will provide a more accurate CAS, however, if speed is more important to the FDO, he may direct the VCO to use chart range to the nearest 500 meters as the entry argument for Table G to avoid interpolation. This technique should be used in special situations and not as a general practice for an FDC.
3b	Multiply the CSF by the absolute value of the angle of site (step 2), and express the result to the nearest 0.1 mil. This is the complementary angle of site; it will always have the same sign as the CSF.
4	Determine the value of site. Site is the algebraic sum of the angle of site and the complementary angle of site and is expressed to the nearest mil. **∡SI (±)** **+ CAS (±)** **SI (±) ≈ NEAREST 1 MIL**
5	Determine the quadrant elevation. Once site has been determined, the computer algebraically applies it to the angle of elevation from the TFT at the given range. The sum of this computation is quadrant elevation. QE is expressed to the nearest 1 mil. **EL** **+ SI** **QE ≈ NEAREST 1 MIL**
Note: For a sample problem demonstrating the determination of site with manual computations requiring interpolation, see table 8-6 on page 8-11.	
Legend: ALT – altitude CAS – complementary angle of site CSF – complementary site factor EL – elevation FDC – fire direction center FDO – fire direction officer GST – graphical site table M – meter QE – quadrant elevation RG – range SI – site TFT – tabular firing tables TGT – target VCO – vertical control operator VI – vertical interval	

DETERMINATION OF VERTICAL ANGLE

8-11. Vertical Angle. ***Vertical angle* (VA) is the angle measured vertically, up or down, from a horizontal plane of reference and expressed in plus or minus in mils depending on whether the position is above or below the horizontal plane**. The angle of site and the vertical angle are essentially the same angles viewed from different perspectives. (See figure 8-2 on page 8-5.) As such, the computations for vertical angle are very similar to angle of site and can be found in table 8-2 on page 8-5.



Legend: BTRY – battery OBS – observer SI – site <SI – angle of site TGT – target VA– vertical angle VI – vertical interval

Figure 8-2. Vertical Angle.

Table 8-2. Determination of Vertical Angle.

STEP	***ACTION***
1	Determine the vertical interval. Use the following equation: **TGT ALT** **<u>- OBS ALT</u>** **VI (±) NEAREST 1 METER**
2	Determine the vertical angle. To compute the vertical angle, use the following equation: $\dfrac{\textbf{VERTICAL INTERVAL}}{\textbf{DISTANCE (IN 1,000s OF METERS)}} \times \textbf{1.0186} = \textbf{VA} (\pm) \approx \textbf{NEAREST 1 MIL}$
	Note: If VA is greater than ±100 mils, it must be computed by using the following formula: TANGENT (VA) = VI/R. (See Table 8-1 (on page 8-4), Step 2 for general procedures.)
Note: For a sample problem demonstrating the determination of vertical angle, see Table 8-7 on page 8-11.	
Legend: ALT – altitude OBS – observer R – range TGT – target VA – vertical angle VI – vertical interval	

THE GRAPHICAL SITE TABLE

8-12. Manual computation of site utilizing the TFT is time consuming. The GST was developed to provide a quick and accurate computation of vertical angle, angle of site, and site. The GST can also be used to compute the vertical interval when the site, charge, and range are known or when the vertical angle and distance are known. It can also be used to convert yards to meters or meters to yards and to multiply and divide. Each GST is designed with values from the associated TFT, and thus computations are only valid for the weapon system, projectile family, and propelling charges listed on the slide.

8-13. The GST consists of three parts: a base, a slide, and a cursor with a manufacturer’s hairline. (See figure 8-3 on page 8-6.)

8-14. **Base**. The base is marked by the D scale, which is a logarithmic scale of variable graduations. This scale is used to determine the vertical interval, vertical angle, angle of site, and site. The accuracy depends on the values read off the scale. The reverse sides of the base on some GSTs have instructions on how to use it.

8-15. **Slide**. The slide is marked with a C scale, gauge points, and site-range scales. Most GSTs contain printed values on both sides of the slide.

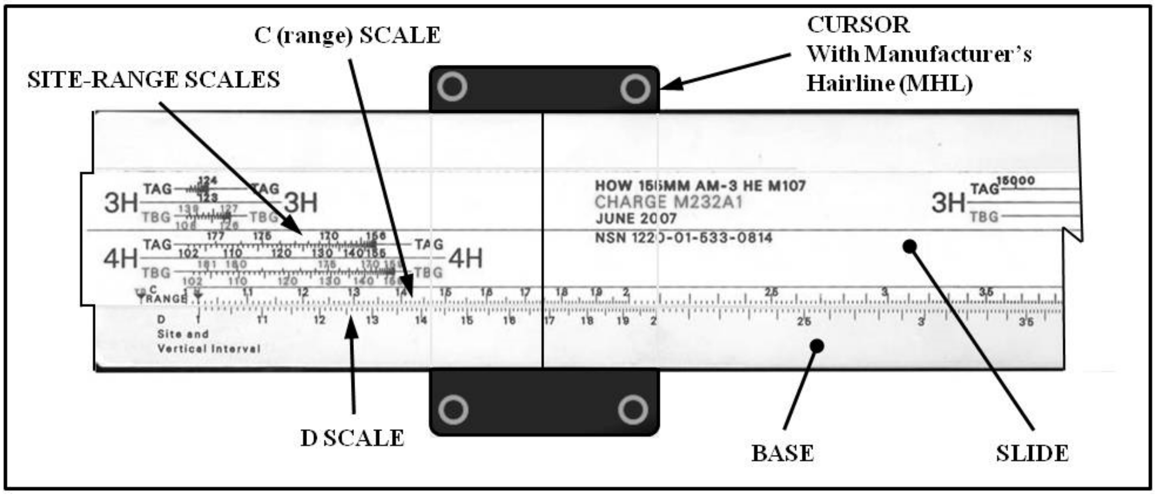


Figure 8-3. Graphical Site Table.

- **C (range) scale**. This scale is identical to the logarithmic D scale, and it is found on either side of the slide if applicable. The C and D scales, along with the M gauge point, are used for computing vertical interval, vertical angle, and angle of site. Multiplication and division may also be performed by using the C and D scales.
- **Gauge points**. The C scale is marked with two M (meter) and two YD (yard) gauge points. The meter gauge point (MGP) is offset 1.0186 from the 1 value on the C scale and thus corrects all computations it is used with for the approximation of the mil-relation formula. The YD gauge points are used to convert between yards and meters. Place the MGP over the value of yards you wish to convert to meters, and read the corresponding meters value from underneath the closer of the two YD gauge points. This gives a solution to the formula: YARDS × 0.9144 = METERS.
- **Site-range scales**. These scales are used to compute site when the VI and range are known or to compute the VI when the site and range are known. For each charge indicated, there are two site-range scales. One is black, marked "TAG" for "Target Above Gun," and the other is red, marked "TBG" for "Target Below Gun." Each scale is placed in relation to the M gauge point so that site is read on the D scale opposite the M gauge point when VI on the D scale is divided by range on the site-range scale. The TAG and TBG scales are constructed to include CAS. They differ from each other just as the CSF for a plus angle of site differs from the CSF for a minus angle of site. The TAG scale is used when the VI is positive, and the TBG scale is used when the VI is negative. The value of site is read or placed opposite the M gauge point. When there are no site range scales for a particular charge or the scale does not include the appropriate gun target range, site for that charge must be computed manually.
- **Range changeover point**. On all GSTs for all charges, there is a point on all site-range scales where the scales begin to "double back"; that is, the cursor is moved to the left rather than to the right for an increase in range for a given VI. The range at which each scale reverses direction is called the range changeover point. The location of the changeover point can be shown by plotting site as a function of site in mils and range in meters (figure 8-4 on page 8-7). Recall that site equals the angle of site plus the complementary angle of site. In figure 8-4, at the lesser ranges (5,000 to 7,000 meters), the angle of site is decreasing at a greater rate than complementary angle of site is increasing; thus, site decreases. At the longer ranges (7,500 to 9,000 meters), the angle of site is decreasing at a lesser rate than the complementary angle of site is increasing; thus, site increases. The site curve shows decreasing values up to a range of about 7,200 meters and then increasing values beyond. The range at which site is at an absolute minimum value is 7,200 meters and is the range changeover point for that charge and projectile.

8-16. **Cursor**. The cursor has a vertical hairline, known as the manufacturer's hairline (MHL). It enables the user to place or read a value on the slide opposite another value on the base.

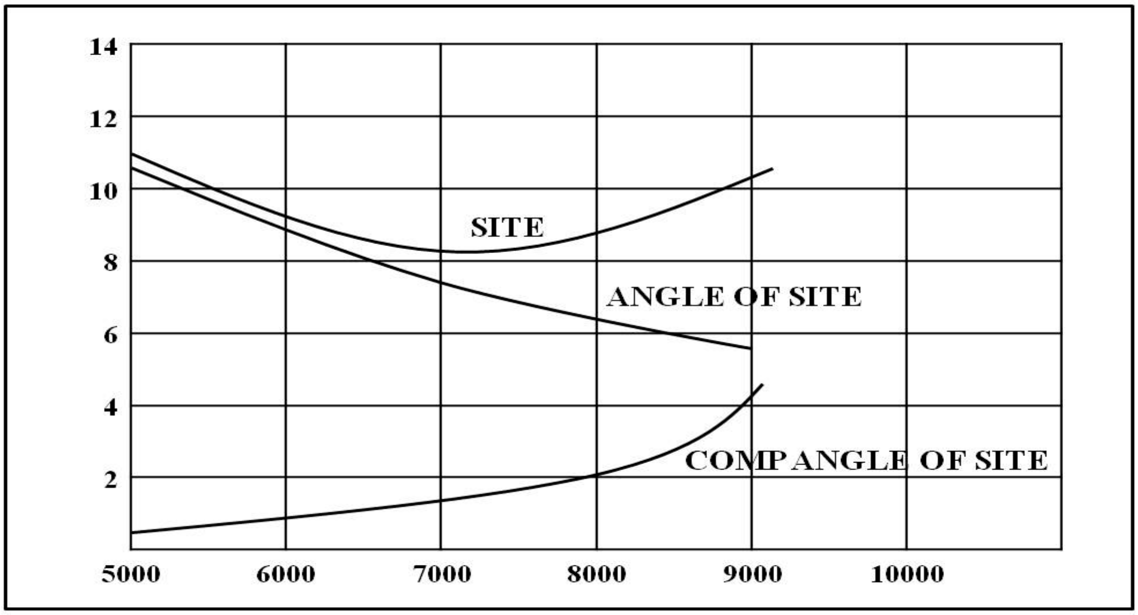
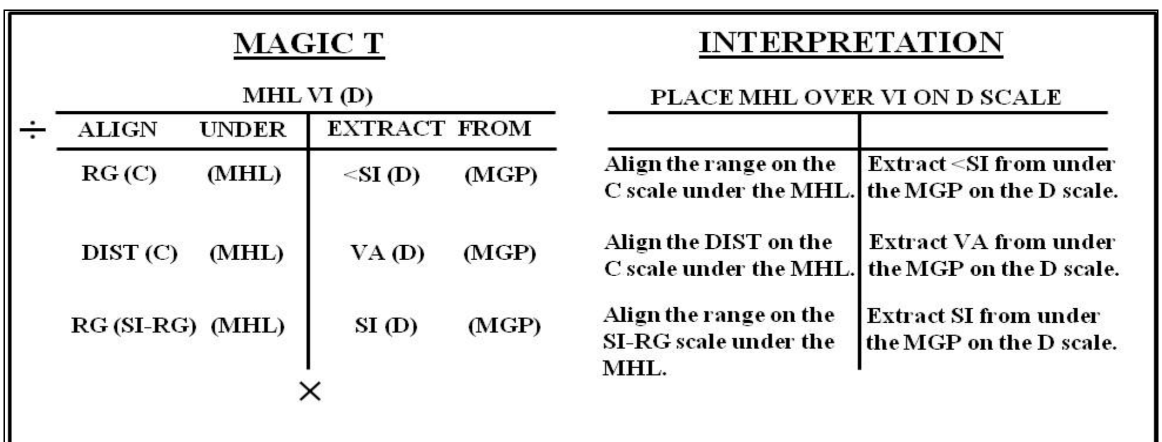


Figure 8-4. Range Changeover Graph.

DETERMINATION OF ANGLE OF SITE AND VERTICAL ANGLE WITH THE GST

8-17. The procedures for computing angle of site and vertical angle are the same. Both are computed by using the C and D scales and are not associated with a particular charge or a particular weapon. In either case, two values are needed: the range (or distance) to the target in meters and the number of meters the target is above or below the howitzer or observer (vertical interval.)

8-18. The diagram in figure 8-5 is known as the "Magic T." It can be used to help determine angle of site, VA and site when using the GST. The horizontal lines in the Magic T represent division, and the vertical line represents multiplication.



Legend: DIST – distance MGP – meter gauge point MHL – manufacturer's hair line RG – range SI – site <SI – angle of site TGT – target VA – vertical angle VI – vertical interval

Figure 8-5. Magic T.

8-19. Angle of site and the vertical angle are computed by using the C and D scales on the GST. Two values are needed for computing these angles – the range or distance to the target, and the vertical interval. Use the steps outlined in table 8-3 in order to compute angle of site and the vertical angle.

Table 8-3. Determination of Angle of Site and VA Using the GST.

STEP	*ACTION*
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. (In the case of determining VA, substitute the observer altitude for the unit altitude.) **TGT ALT** **- UNIT ALT (OBS ALT)** **VI (±) NEAREST 1 METER**
2	Move the MHL until it is over the value of the VI on the D scale.
3	Without moving the cursor, slide the C scale until the range is directly beneath the MHL. (For VA, use distance in the place of range.)
4	Determine the angle of site (VA) from beneath the meters gauge point on the D scale.
4a	Reading the D scale left to right like a ruler, extract a value consisting of three numbers.
4b	In order to determine the correct magnitude of the extracted value, a decimal point must be placed in the appropriate location. “Rough math” is utilized to determine the approximate magnitude of the angle of site (VA), and this approximation is used to place the decimal point in the extracted value from Step 4a in order to determine the exact angle of site (VA). For rough math, divide the VI by the range (distance) in thousands, the decimal point should be placed in the extracted value so that it is of a similar magnitude to the rough math approximation. **VI ÷ RG/DIST (IN 1,000s) =∡SI (VA) (APPROX)**
	Note: In the case of low ranges, the magnitude of the extracted value can also be determined by comparing it to the VI. When range or distance is less than 10,000 meters, the decimal point may simply be placed in the extracted value so that the <SI or VA is as large an integer as possible without exceeding the value of the VI. When range or distance exceeds 10,000 meters the above equation should be used.
4c	Express the value to the nearest 0.1 mil for angle of site or the nearest 1 mil for VA. The angle of site or VA will have the same sign as the VI.
Note: For a sample problem demonstrating the determination of angle of site with the GST, see table 8-8 on page 8-12.	
Legend: ALT – altitude DIST – distance GST – graphical site table MHL – manufacturer’s hair line OBS – observer RG – range SI – site TGT – target VA – vertical angle VI – vertical interval	

DETERMINATION OF SITE WITH THE GST

8-20. Site is computed by using the SI-RG and D scales on the GST. The value determined will be valid for a particular charge, weapon and projectile family. Three values are needed in order to compute site with the GST the range to the target, vertical interval, and charge. Use the steps outlined in table 8-4 to determine site with a GST.

Table 8-4. Determination of Site Using the GST.

STEP	*ACTION*
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. **TGT ALT** **- UNIT ALT** **VI (±) NEAREST 1 METER**

Table 8-4. Determination of Site Using the GST (continued).

STEP	*ACTION*
2	Move the MHL until it is over the value of the VI on the D scale.
3	Without moving the cursor, move the slide until the range is directly beneath the MHL on the appropriate site-range scale for the charge being fired. There are two site-range scales for each charge. If the VI is positive, use the TAG scale (black numbers). If the VI is negative, use the TBG scale (red numbers).
4	Determine the site from beneath the meters gauge point on the D scale.
4a	Reading the D scale left to right like a ruler, extract a value consisting of three numbers.
4b	In order to determine the correct magnitude of the extracted value, a decimal point must be placed in the appropriate location. “Rough math” is utilized to determine the approximate magnitude of the SI, and this approximation is used to place the decimal point in the extracted value from Step 4a in order to determine the exact SI. For rough math, divide the VI by the range in thousands, the decimal point should be placed in the extracted value so that it is of a similar magnitude to the rough math approximation. **VI ÷ RG (IN 1,000s) = SI (APPROX)**
	Note: In the case of low ranges, the magnitude of the extracted value can also be determined by comparing it to the VI. When range or distance is less than 10,000 meters, the decimal point may simply be placed in the extracted value so that the SI is as large an integer as possible without exceeding the value of the VI. When range exceeds 10,000 meters the above equation should be used.
4c	Express the value to the nearest mil. Site will have the same sign as the VI.
Note: For a sample problem demonstrating the determination of SI with the GST, see table 8-9 on page 8-13.	
Legend: ALT – altitude MHL – manufacturer’s hair line RG – range SI – site TAG – target above gun TGB – target below gun TGT – target VI – vertical interval	

HIGH ANGLE SITE

8-21. Site is always computed for high-angle fire and added to the determined angle of elevation, which yields high-angle QE. However, site may have a relatively small effect in high-angle fire because of the large angle of fall. Therefore, if the angle of site is small and the FDO directs to ignore it, then site may be ignored.

8-22. In high-angle fire, an increase in the angle of elevation decreases range. A decrease in the angle of elevation increases range. The complementary site factors, found in Table G of the TFT, are relatively large (greater than 1) and are the opposite sign of the VI and angle of site. Therefore, the site will have the opposite sign of the VI and angle of site.

8-23. High-angle site is determined by using the CSF (TFT) or the 10-mil site factor from the GFT or manual computations. Use of the 10-mil site factor is the preferred method. The 10-mil site factor is a value which represents the actual site for each 10 mils of angle of site. High-angle site is computed using the 10-mil site factor by dividing the angle of site by 10 and multiplying that value by the 10-mil site factor. The 10-mil site factor is always negative.

DETERMINING HIGH-ANGLE SITE WITH THE 10-MIL SITE FACTOR

8-24. As previously stated, computing high-angle site with the 10-mil site factor is the preferred method. The VCO computes angle of site using either the GST or manual computations, there is no change from low-angle procedures. This value is divided by 10 and then multiplied by the 10-mil site factor. The 10-mil site factor may either be computed manually or, in some cases, may be extracted from the associated high-angle GFT. See table 8-5 (on page 8-10) for procedures.

Table 8-5. Determination of High-Angle Site Using the 10-Mil Site Factor.

STEP	***ACTION***
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. **TGT ALT** **- UNIT ALT** **VI (±) NEAREST 1 METER**
2	Determine the value for <SI/10.
2a	Determine angle of site with the GST (table 8-3) or manual procedures (table 8-1, Step 2.)
2b	Divide the resulting angle of site by 10. ∡SI/10 is expressed to the nearest 0.1 mil and will have the same sign as the VI.
3	Determine the 10-mil site factor. The 10-mil site factor is expressed to the nearest 0.1 mil and is always a negative value.
3a	For a positive VI use the following order of preference to determine the 10-mil site factor: If the 10-mil site factor is listed on the high-angle GFT for the given range and charge, use the listed value. If given range exceeds the last listed 10-mil site factor for that charge on the high-angle GFT, use the last listed value. If given range is less than the first listed 10-mil site factor for that charge on the high-angle GFT, compute the 10-mil site factor manually. Use the following equation: **(Positive VI) 10-mil site factor = 10(1+CSF)**
3b	For a negative VI, the 10-mil site factor must always be manually computed. Use the following equation: **(Negative VI) 10-mil site factor = 10(1-CSF)**
Note: In either case when the 10-mil site factor is manually computed, the CSF is extracted from the high-angle portion of Table G for the given charge in the associated TFT. As in low angle procedures, in certain situations the FDO may direct to save interpolation time by determining CSF to the nearest 500 meters.	
NOTE: If interpolation is not possible because the TFT does not list a CSF for a range lower than the determined range to the target, the last listed value for CSF should be used.	
4	Determine high-angle site by multiplying the ∡SI/10 by the 10-mil site factor. High-angle site is expressed to the nearest 1 mil and is a signed value. The sign should be the opposite than that of the VI. Use the following equation: **∡SI/10 × 10-mil site factor = SI (±) ≈ NEAREST 1 MIL**
Note: For a sample problem demonstrating the determination of high-angle site using the 10-mil site factor, see table 8-10 on page 8-14.	
Legend: ALT – altitude CSF – complementary site factor FDO – fire direction officer GFT – graphical firing table GST – graphical site table RG – range SI – site TFT – tabular firing table TGT – target VI – vertical interval	

DETERMINING HIGH-ANGLE SITE WITH THE TFT

8-25. The procedures of determining high-angle site with a TFT are the same as low-angle manual computations of site. A GST can be used to compute the angle of site. See table 8-6 for procedures.

Table 8-6. Determination of High-Angle Site with the TFT.

STEP	***ACTION***
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. **TGT ALT** **- UNIT ALT** **VI (±) NEAREST 1 METER**

Table 8-6. Determination of High-Angle Site with the TFT (continued).

STEP	***ACTION***
2	Determine the angle of site. To compute angle of site, use the following equation: $\frac{\textbf{VERTICAL INTERVAL}}{\textbf{RG (IN 1,000s OF METERS)}}$ **× 1.0186 = ∡SI (±) ≈ NEAREST 0.1 MIL**
3	Determine the value for complementary angle of site. **|∡SI| × CSF = CAS (±) ≈ NEAREST 0.1 MIL**
3a	Determine the value for the CSF from the TFT, Table G, Column 12 or 13. The entry argument for this table is chart range (to the nearest 10 meters). If the angle of site is positive, use Column 12. If the angle of site is negative, use Column 13. Interpolate as necessary.
Note: Interpolation in Table G to the nearest 10 meters will provide a more accurate CAS, however, if speed is more important to the FDO, he may direct the VCO to use chart range to the nearest 500 meters as the entry argument for Table G to avoid interpolation. This technique should be used in special situations and not as a general practice for an FDC.	
3b	Multiply the CSF by the absolute value of the angle of site (step 2), and express the result to the nearest 0.1 mil. This is the complementary angle of site; it will always have the same sign as the CSF.
4	Determine the value of site. Site is the algebraic sum of the angle of site and the complementary angle of site and is expressed to the nearest mil. **∡SI (±)** **+ CAS (±)** **SI (±) ≈ NEAREST 1 MIL**
Legend: ALT – altitude CAS – complementary angle of site CSF – complementary site factor FDC – fire direction center FDO – fire direction officer RG – range SI – site TFT – tabular firing table TGT – target VI – vertical interval	

SAMPLE PROBLEMS

8-26. The examples in tables 8-7 through 8-10 (pages 8-11 through 8-13) use data for the firing unit location, known point, and observer (T03) from Chapter 6. The following additional data is given:

- Weapon System: M109A6
- Charge: M232A1 4H
- Chart range from1/A to Target: 13,590 meters
- Distance from T03 to Target: 720 meters
- 1/A Altitude: 820
- T03 Altitude: 1084
- Target Altitude: 1019

8-27. Determination of Site (Manual Computations Requiring Interpolation). Table 8-7 shows an example of manually determining site.

Table 8-7. Sample Manual Computation of Site.

STEP	***ACTION***
1	Determine the vertical interval. **TGT ALT 1019** **- UNIT ALT 820** **VI +199M**

Table 8-7. Sample Manual Computation of Site (continued).

STEP	*ACTION*
2	Determine the angle of site. **$\frac{+199}{13.59}$ × 1.0186 = +14.9m̸ (∡SI)**
3	Determine the value for complementary angle of site. **|14.9| × +0.068 = +0.998 ≈ +1.0m̸ (CAS)**
4	Determine the value of site. **∡SI +14.9** **<u>+ CAS +(+1.0)</u>** **SI +15.9 ≈ +16m̸ (SI)**
Legend: ALT – altitude CAS – complementary angle of site m̸ - mils SI – site TGT – target VI – vertical interval	

8-28. Determination of Vertical Angle (Manual Computations). Table 8-8 shows an example of manually computing vertical angle.

Table 8-8. Sample Manual Computation of VA.

STEP	*ACTION*
1	Determine the vertical interval. **TGT ALT 1019** **<u>- UNIT ALT 1084</u>** **VI -65M**
2	Determine the vertical angle. **$\frac{-65}{0.72}$ × 1.0186 = -91.9 ~ -92m̸ (VA)**
Legend: ALT – altitude M – meters m̸ - mils SI – site TGT – target VA – vertical angle VI – vertical interval	

8-29. Determination of Angle of Site Using the GST. Table 8-9 shows an example of determining angle of site and vertical angle with the GST. Figure 8-6 on page 8-13 demonstrates angle of site and vertical angle on the GST.

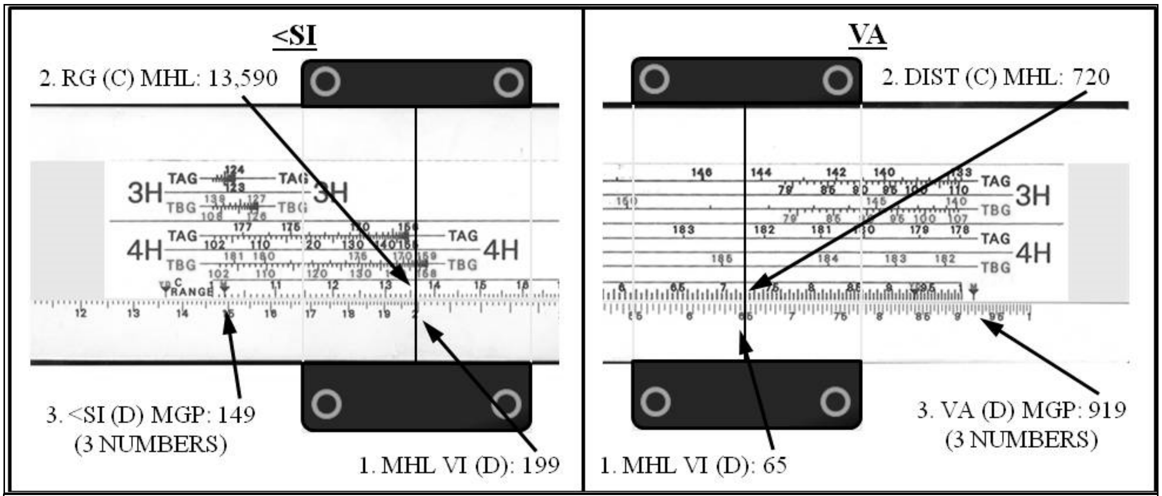
Note: The values in parentheses in table 8-9 pertain to the observer and the determination of VA.

Table 8-9. Sample Determination of Angle of Site and VA Using the GST.

STEP	*ACTION*
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. (In the case of determining VA, substitute the observer altitude for the unit altitude.) **TGT ALT 1019** **<u>- UNIT ALT (OBS ALT) 0820 (1084)</u>** **VI +199 (-65)**
2	Move the MHL until it is over the value of the VI on the D scale.
3	Without moving the cursor, slide the C scale until the range (distance) is directly beneath the MHL.
4	Determine the angle of site (VA) from beneath the meters gauge point on the D scale.
4a	Extract three numbers. **∡SI = 149 (VA = 919)**

Table 8-9. Sample Determination of Angle of Site and VA Using the GST (continued).

STEP	*ACTION*
4b	Perform rough math. ∡SI VA **+199 / 13.59 = 14.6 (APPROX ∡SI)** **-65 / 0.72 = 90.3 (APPROX VA)**
	Note: In the case of angle of site, rough math shows us that the decimal point should be placed in-between the second and third integers in the extracted value in order to obtain the correct magnitude for ∡SI. In the case of VA, rough math shows us that the decimal point must also be placed between the second and third integers of that extracted value to obtain the correct magnitude.
4c	Place decimal point and express to appropriate accuracy. ∡SI and VA carry the same sign as their respective VI. ∡SI = 14.9 ≈ +14.9 mils (VA = 91.9 ≈ -92 mils)
Note: The similarities between the angle of site and vertical angle determined with the GST as compared to manual computations in tables 8-6 and 8-7 (pages 8-10 and 8-11).	
Legend: ALT – altitude MHL – manufacturer's hair line OBS – observer SI – site TGT – target VA – vertical angle VI – vertical interval	



Legend: DIST – distance MGP – meter gauge point MHL – manufacturer's hair line RG – range <SI – angle of site TAG – target above gun TBG – target below gun VA – vertical angle VI – vertical interval

Figure 8-6. ∡SI and VA using the GST.

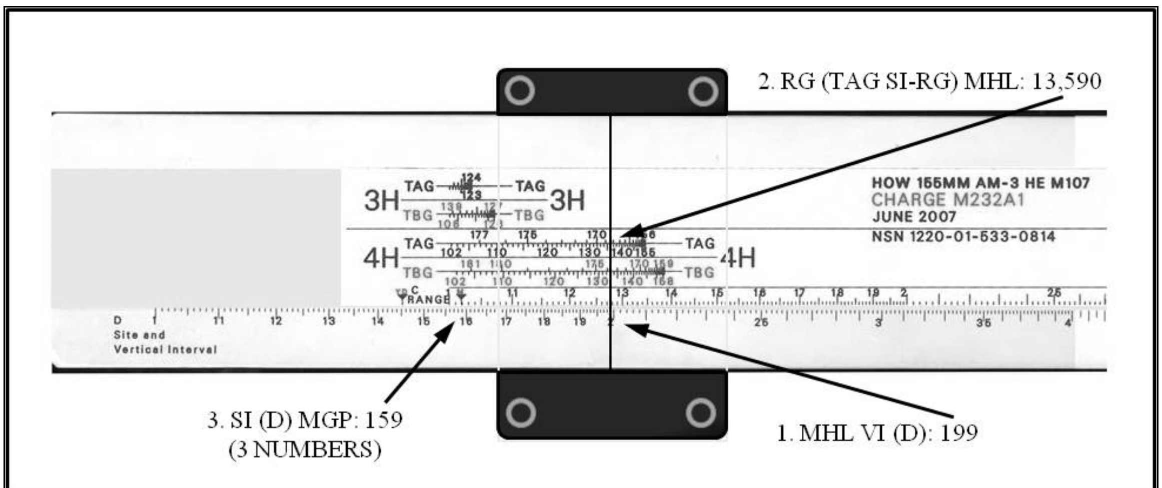
8-30. Determination of Site Using the GST. Table 8-10 shows an example of determining site with a GST (see figure 8-7 on page 8-14 for illustration).

Table 8-10. Sample Determination of Site Using the GST.

STEP	*ACTION*
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. **TGT ALT 1019** **- UNIT ALT 0820** **VI +199M**
2	Move the MHL until it is over the value of the VI on the D scale.

Table 8-10. Sample Determination of Site Using the GST (continued).

STEP	*ACTION*
3	Without moving the cursor, move the slide until the range is directly beneath the MHL on the appropriate site-range scale for the charge being fired.
4	Determine the site from beneath the meters gauge point on the D scale.
4a	Extract three numbers. **159**
4b	Perform rough math $\frac{+199}{13.59}$ **= 14.6 (APPROX SI)**
	NOTE: In the case, rough math shows us that the decimal point should be placed in-between the second and third integers in the extracted value in order to obtain the correct magnitude for SI.
4c	Place decimal point and express to the nearest whole mil. SI carries the same sign as the VI. **SI = 15.9 ≈ +16 mils**
Note: Note the similarity between SI determined with the GST as compared to manual computations in table 8-6 on page 8-10.	
Legend: ALT – altitude GST – graphical site table MHL – manufacturer's hair line SI – site TGT – target VI – vertical interval	



Legend: MGP – meter gauge point MHL – manufacturer's hair line RG – range SI – site TAG – target above gun TBG – target below gun VI – vertical interval

Figure 8-7. SI using the GST.

8-31. Determination of High-Angle Site Using the 10-mil Site Factor. Table 8-11 shows an example of determining high-angle site with the 10-mil site factor.

Table 8-11. Sample Determination of High-Angle Site Using the 10-Mil Site Factor.

STEP	*ACTION*
1	Determine the vertical interval by subtracting the unit altitude from the target altitude. **TGT ALT 1019** **- UNIT ALT 0820** **VI +199M**
2	Determine the value for <SI/10.
2a	Determine angle of site with the GST (table 8-3 on page 8-8) or manual procedures (table 8-1 on page 8-3, step 2.) $\frac{+199}{13.59}$ **× 1.0186 = +14.9m̸ (∡SI)**

Table 8-11. Sample Determination of High-Angle Site Using the 10-Mil Site Factor (continued).

STEP	*ACTION*
2b	Divide the resulting angle of site by 10. ∡SI/10 is expressed to the nearest 0.1 mil and will have the same sign as the VI. **+14.9/10 = +1.5₥**
3	Determine the 10-mil site factor. The 10-mil site factor is expressed to the nearest 0.1 mil and is always a negative value. **-1.2 ₥** (As per order of preference, listed value on high-angle GFT.)
4	Determine high-angle site by multiplying the ∡SI/10 by the 10-mil site factor. High-angle site is expressed to the nearest 1 mil and is a signed value. The sign should be the opposite than that of the VI. Use the following equation: **+1.5₥ × -1.2₥ = -1.8 ≈ -2₥**
Legend: ALT – altitude GFT – graphical firing table GST – graphical site table M – meters ₥ - mils SI – site TGT – target VI – vertical interval	

AVERAGE SITE

8-32. A considerable amount of time can be saved in mission processing if average site is pre-computed for the area of operations. As time permits after occupation, the VCO should develop a color-coded average site map (figure 8-8 on page 8-16). The average sites and altitudes would be listed within each color-coded area. Site is computed for vertical interval segments on the basis of ranges and charges to be used most frequently. The error in site will normally be small and is an acceptable tradeoff of accuracy for speed. When a target is plotted on the average site map, the VCO can read and announce site. This technique may not be practical in certain situations, for example, in mountainous terrain or in fast-moving situations. Here the VCO could use the altitude of the nearest pre-plotted target to compute site.

8-33. The VCO creates and improves his average site map by taking the following actions.

- Plotting of contour intervals. The VCO color-codes his map along with selected contour intervals, creating zones with little variation in altitude. VI is based on the mean altitude in each zone. Compute site for each color-coded zone by using the range to the center of the zone and the appropriate charge. This will result in an average site to use for all targets plotted within a color-coded zone.
- As time permits, average site values can be refined by computing additional values for variations in range within a color-coded zone. This will determine if there are significant changes in site caused by changes in range. For example, site would be computed for a zone between the 300 and 320 contour intervals by using ranges throughout that zone (that is, 5,000, 6,000, 7,000.) If site changes by more than 1 mil, the VCO would announce the refined site.

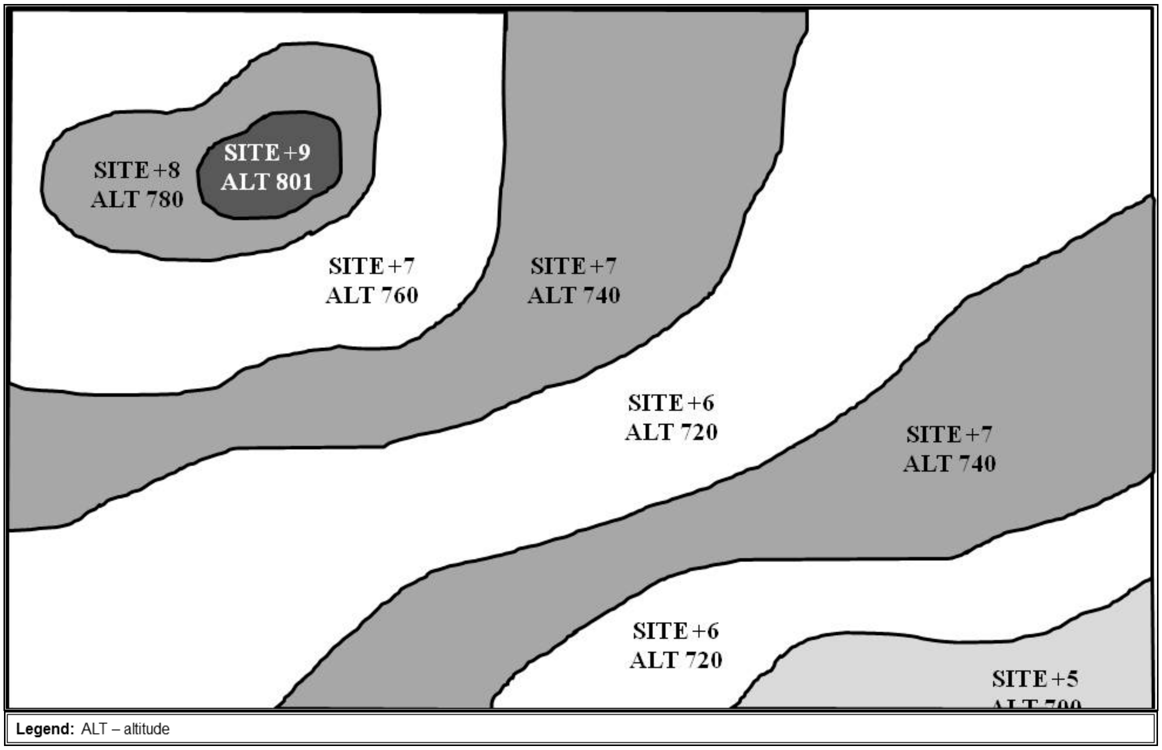


Figure 8-8. Average Site.

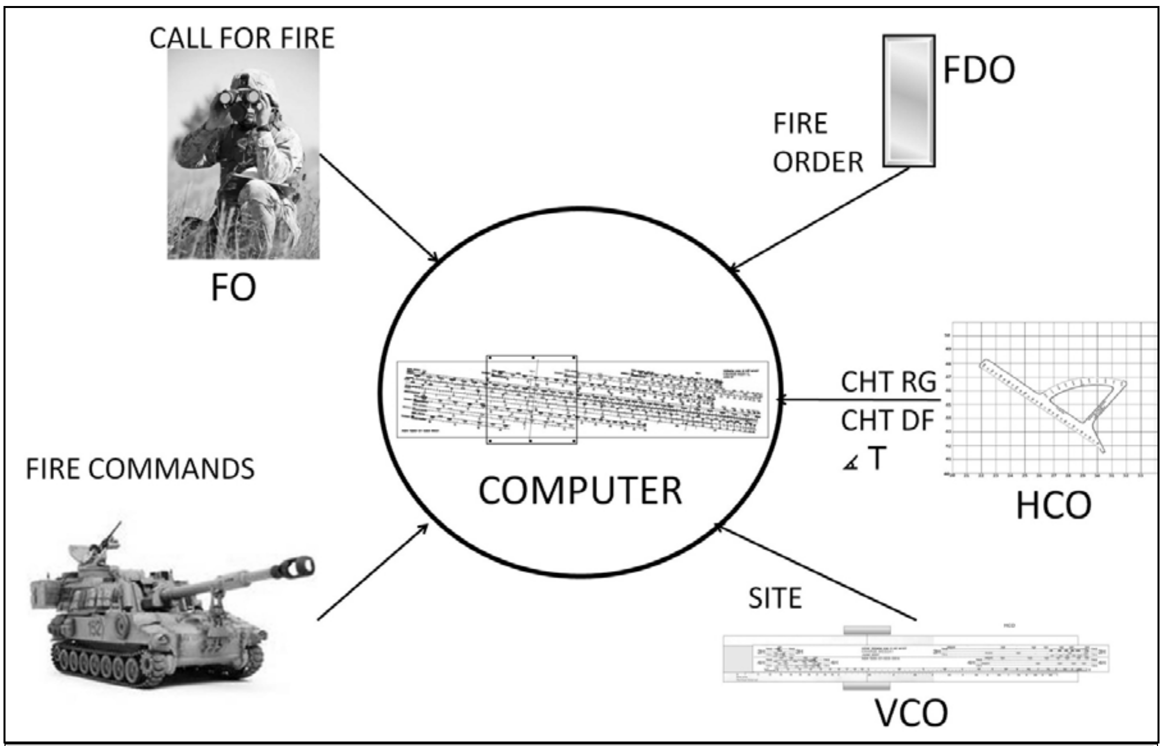
Chapter 9

Fire Mission Processing

In the battery or platoon FDC, all actions are oriented toward timely and accurate fire mission processing. All actions must provide the best possible flow of information between FDC personnel. The battery or platoon FDC must be trained to determine responsive and accurate firing data. Upon receipt of a call for fire, FDC personnel must work as a team to accomplish many tasks at the same time. (See figure 9-1.)

SECTION I: DUTIES AND THE RECORD OF FIRE

9-1. Understanding the duties within the FDC is imperative. All activity supports the computer. He determines and records firing data on the record of fire. He is also the link to the howitzers, because he transmits the fire commands.



Legend: CHT – chart DF – deflection FDO – fire direction officer FO – forward observer HCO – horizontal control operator RG – range VCO – vertical control operator

Figure 9-1. Flow of Information between the Gunnery Team.

CREW DUTIES FOR THE FDC

9-2. The procedures in table 9-1 (on page 9-2) should be used to facilitate mission processing and ensure responsiveness. (For automated FDC crew duties, see Appendix E.) The focus of mission processing is on a clear, consistent flow of information. This will facilitate the many concurrent actions required to process a mission in a timely and accurate fashion. Concurrent actions by FDC personnel are denoted as sub-steps in table 9-1.

Table 9-1. Mission Processing.

STEP	***ACTION***
1	**RTO** receives and records the Call for Fire (CFF), authenticates if necessary, and announces **"Fire Mission"** to the FDC. All FDC personnel announce **"Fire Mission"**.
2	**RTO** announces the CFF to the FDC in the three transmission format. The **Computer** or **RTO** reads back each transmission and records information on the record of fire (ROF), ensuring all personnel within the FDC can hear the information.
2a	**HCO** and **VCO** record target location and plot target. Determines chart range and deflection.
2b	**FDO** plots the target on the situation map and verifies it is safe and does not violate any fire support coordination measures (FSCMs) and extracts target altitude (if necessary). **Computer** or **RTO** reads back the announced target altitude and records it on the ROF. **VCO** records target altitude and determines site. **FDO** decides how to attack the target and issues the fire order to the FDC. **Computer** or **RTO** reads back the announced fire order and records it on the ROF.
3	**Computer** or **RTO** records initial fire commands on record of fire up to and including fuze. This is based on the CFF and fire order (**Chief** monitors).
3a	**RTO** composes and transmits Message to Observer (MTO) according to the CFF and fire order (**FDO** monitors). **Computer** or **RTO** records MTO on the record of fire.
4	Computer requests chart data from HCO, beginning with chart range, for example, **"Range Alpha."**
4a	**HCO** announces chart range to the computer, for example, **"Alpha Range, 5890."**
4b	**VCO** announces **"Check"** or **"Hold"** (± 30 meters).
4c	If "**Check**" is announced, **Computer** places announced range under the MHL of the appropriate GFT, and reads back the range that is set on the GFT, for example **"Range 5890"**, and records range on the ROF (**Chief** monitors). If **"Hold"** is announced, **Chief** verifies charts and determines which range to use.
4d	**HCO** announces chart deflection, for example, **"Deflection 3286."**
4e	**VCO** announces **"Check"** or **"Hold"** (± 3 mils).
4f	If **"Check"** is announced, **Computer** or **RTO** records chart deflection on ROF (**Chief** monitors). If **"Hold"** is announced, Chief verifies charts and determines which deflection to use.
5	**Computer** determines the remaining fire commands (**Chief** monitors): • Determines and records elevation on ROF. (Refer to Appendix F for assistance when determining data with or without a GFT setting). • If firing fuze time, determines and records Fuze Setting (FS) on ROF. • If firing fuze VT, determines and records FS on ROF. • Determines and records deflection correction on ROF. • Determines and records deflection to fire on ROF. • Requests site from **VCO**, for example, **"Alpha Site."** **VCO** announces site, for example, **"Site Alpha, Positive 4."** Computer records site on ROF. • Determines and records Quadrant Elevation (QE) on ROF. • Determines and records Method of Fire In Effect on ROF (if applicable).

Table 9-1. Mission Processing (continued).

STEP	*ACTION*
6	Computer verifies fire commands with FDO or Chief: • Ensures fire commands accurately reflect the fire order. ▪ If element of the fire command reflects the fire order, then **"Check"** is announced. ▪ If element of the fire command does not reflect the fire order, then **"Hold"** is announced. • Ensures the data are safe according to the safety T (if applicable) ▪ If data is safe, announce **"Safe."** ▪ If data is unsafe, announce **"Unsafe"** and state the reason why; for example, **"Unsafe, violates min QE."**
7	If fire commands accurately reflect the fire order, and the data are safe, **Chief** or **Computer** announces fire commands to howitzer(s).
8	**Computer** or **RTO** polices the ROF.
8a	**HCO** and **VCO** orient target grid on firing charts, determine Angle T (if able) and await any subsequent corrections from the observer.
Legend: CFF – call for fire FDC – fire direction center FDO – fire direction officer FS – fuze setting FSCM – fire support coordination measure GFT – graphical firing table HCO – horizontal control operator MHL – manufacturer's hair line MTO – message to observer QE – quadrant elevation ROF – record of fire RTO – radio telephone operator VCO – vertical control operator VT – variable time	

ELEMENTS OF FIRING DATA

9-3. The data determined from the firing chart must be converted to firing data that can be placed on the weapon and ammunition. These data consist of the shell, charge, fuze, fuze setting (when applicable), deflection, and quadrant elevation to be fired.

9-4. Shell. Shell is the projectile to be fired. The projectile will have a direct impact on determining the remaining elements since firing tables are based on the projectile.

9-5. Charge. The amount of propellant to be fired with artillery ammunition is varied by the number of propellant increments. The charge selected is based on the range to the target and the tactical situation.

9-6. Fuze. Fuze is the fuze to be fired. The fuze will have a direct impact on determining the quadrant elevation when firing mechanical time fuzes.

9-7. Fuze Setting. When a projectile with a mechanical time or proximity fuze is fired, the computer determines a fuze setting to be set on the fuze that should cause it to function at the desired point along the trajectory. Fuze setting is a function of elevation. This fuze setting is determined from the TFT or GFT. Some projectiles may also be fired with a point-detonating fuze, which can be set for delay action.

9-8. Deflection. The deflection to fire is the deflection announced to the howitzer. To compute deflection to fire, apply the deflection correction to the announced chart deflection by using the LARS rule (left, add; right, subtract). Determine the deflection correction by adding the GFT deflection correction to the drift corresponding to the initial elevation. (GFT deflection correction is discussed in Chapter 10.)

9-9. Quadrant Elevation. Quadrant elevation is the algebraic sum of site and the angle of elevation. Quadrant elevation is the angle through which the tube of the howitzer must be elevated from the base of the trajectory to cause the trajectory to pass through the target.

- Elevation. The angle of elevation is the vertical angle between the base of the trajectory and the axis of the bore required for a projectile to achieve a prescribed range under standard conditions.
- Site. If the target and the howitzer are not at the same altitude, site will be determined. Site is combined with elevation to cause the trajectory to pass through the target. If the target and howitzer are at the same altitude, site is announced as zero.

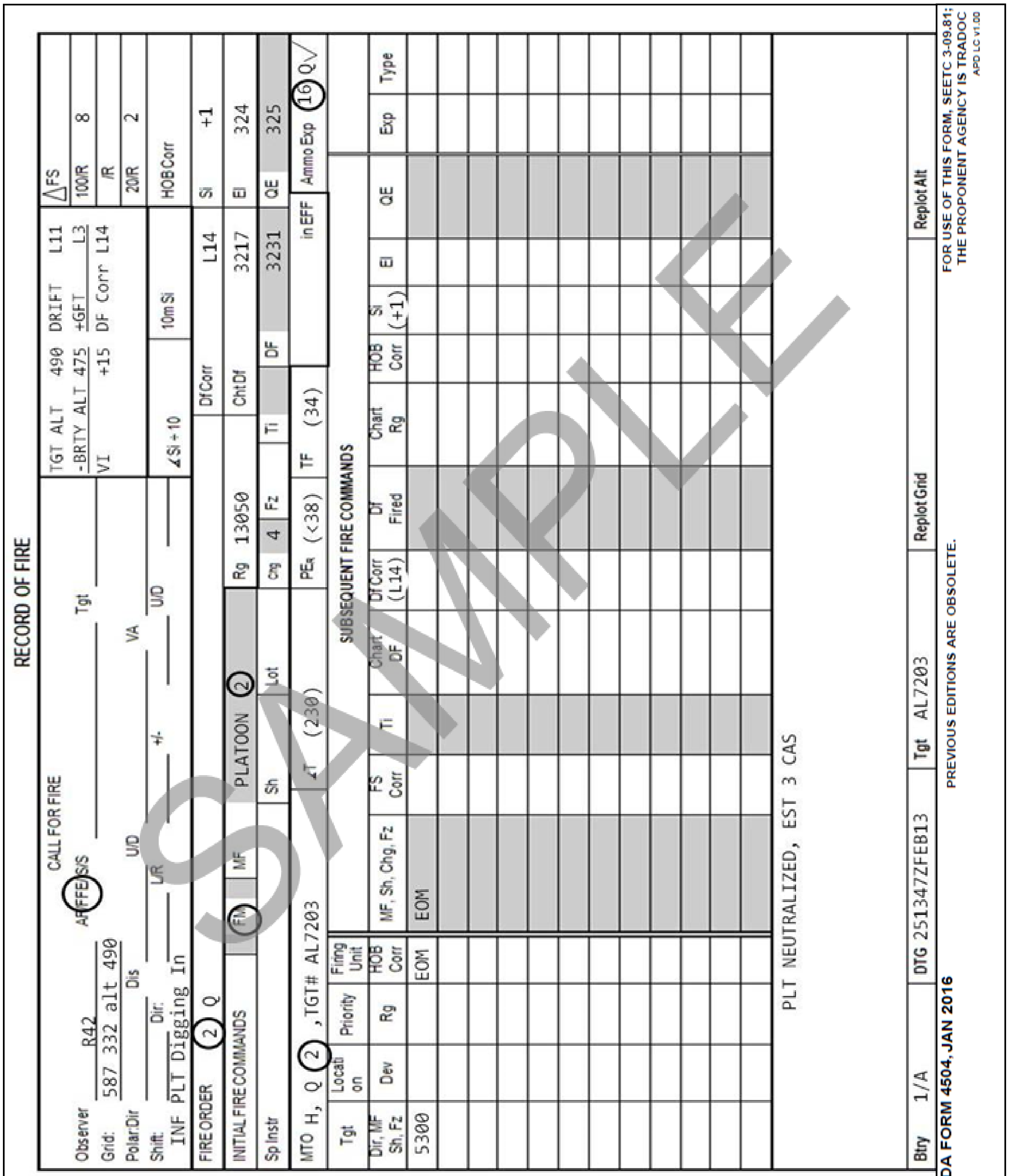
RECORDING FIRING DATA

9-10. DA Form 4504 (Record of Fire) is a legal document used for determining and recording firing data. It is organized to allow a smooth flow in determining and processing a fire mission. It is used for the following:

- Recording the call for fire.
- Computing and recording firing data for all types of fire missions.
- Keeping a permanent record of a fire mission, to include the type and amount of ammo expended during the mission.

Note: The Record of Fire is a legal document. All entries must be accurately recorded legibly in black ink.

9-11. On DA Form 4504 (figure 9-2 on page 9-5), the heavy black lines indicate major sections of the form. Shaded portions denote items that must be announced to the howitzer sections. The use of each block on the record of fire is explained below.



RECORD OF FIRE

CALL FOR FIRE	
Observer	R42
AF / FFE (circled) / S/S	Tgt
Grid:	587 332 alt 490
Polar:Dir / Dis / U/D / VA	
Shift: Dir: / L/R / +/- / U/D	
	INF PLT Digging In

TGT ALT 490	DRIFT L11	△FS	
-BRTY ALT 475	+GFT L3	100/R	8
VI +15	DF Corr L14	/R	
		20/R	2
∠Si + 10	10m Si	HOB Corr	

FIRE ORDER	(2) Q	Df Corr L14	Si	+1
INITIAL FIRE COMMANDS	FM (circled) / MF / PLATOON (2)	Rg 13050	Cht Df 3217	El 324
Sp Instr	Sh / Lot	Chg 4 / Fz / Ti	DF 3231	QE 325
MTO H, Q (2) ,TGT# AL7203	∠T (230)	PE_R (<38) / TF (34)	in EFF	Ammo Exp (16) Q✓

SUBSEQUENT FIRE COMMANDS

Tgt Dir, MF Sh, Fz	Location Dev	Priority Rg	Firing Unit HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L14)	Df Fired	Chart Rg	HOB Corr	Si (+1)	El	QE	Exp	Type
5300			EOM	EOM												

PLT NEUTRALIZED, EST 3 CAS

Btry 1/A	DTG 251347ZFEB13	Tgt AL7203	Replot Grid	Replot Alt

DA FORM 4504, JAN 2016

PREVIOUS EDITIONS ARE OBSOLETE.

FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC

APD LC v1.00

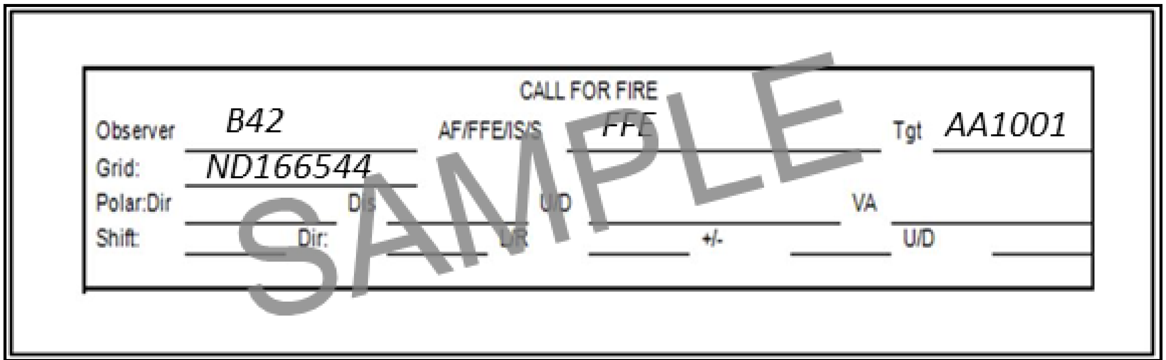
SAMPLE

Legend:

AF – adjust fire
ALT - altitude
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
INF – infantry
IS – immediate suppression
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VI – vertical interval

Figure 9-2. DA Form 4504 Record of Fire.

9-12. **Call for fire block**. The CFF announced by the observer is recorded in this block (see figure 9-3). Table 9-2 explains each item and its use.



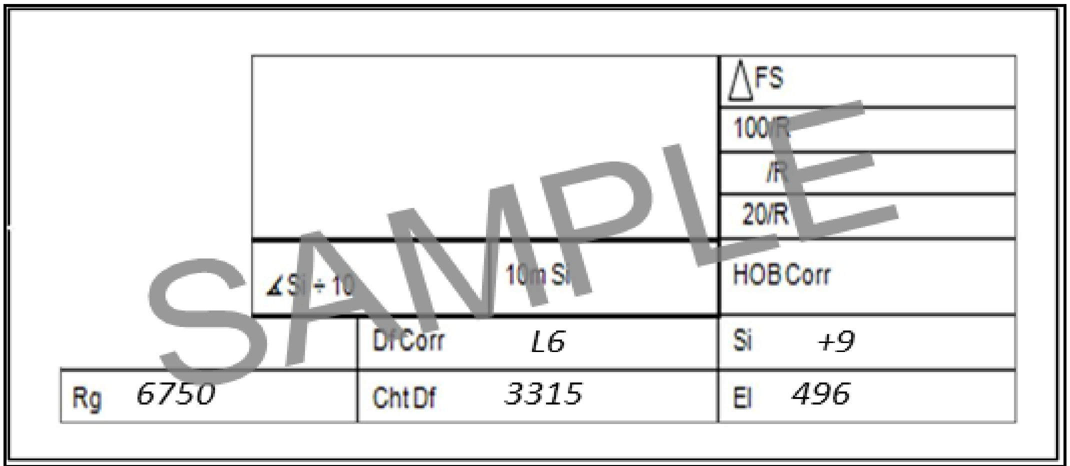
Legend: AF – adjust fire DIR – direction DIS – distance FFE – fire for effect IS – immediate suppression L/R – left/right S – smoke TGT – target U/D – up/down VA – vertical angle VI – vertical interval

Figure 9-3. Call for Fire Block.

Table 9-2. Call for Fire Block Items.

ITEM	***ACTION***
Observer ___	Used to record the **call sign** of the observer.
AF/FFE/IS/S__	Used to record the **mission type**. Choices are AF (adjust fire), FFE (fire for effect), IS (immediate suppression), and S (suppression). The blank line is used for other types; for example, immediate smoke, SEAD (Suppression of Enemy Air Defenses), etc.
Tgt ___	Used to record the **target number** sent by the observer in suppression missions, or for executing preplanned targets.
Grid ___	Used to record the **grid and altitude** for the grid method of target location.
Polar: Dir ___	Used to record the **observer direction** to the target, in mils, for the polar method of target location.
Dis ___	Used to record the **observer distance** to the target, in meters, for the polar method of target location.
U/D ___	Used to record the **vertical shift correction**, in meters, for the polar method of target location. Circle U (up) or D (down).
VA ___	Used to record the **vertical angle**, in mils, for the polar method of target location. VA is a signed (±) value.
Shift ___:	Used to record the **known point or target number** from which the observer is shifting for the shift from a known point method of target location.
Dir ___	Used to record the **direction** to the known point or target, in mils, for the shift from a known point method of target location.
L/R ___	Used to record the **lateral shift** to the target, in meters, for the shift from a known point method of target location. Circle L (left) or R (right).
+/- ___	Used to record the **range correction** to the target, in meters, for the shift from a known point method of target location. Circle + (add) or – (drop).
U/D ___	Used to record the **vertical shift correction** to the target, in meters, for the shift from a known point method of target location. Circle U (up) or D (down).
Blank Space	The blank space underneath the shift line is used to record the target description and/or method of fire/control transmitted by the observer in the call for fire third transmission.
Legend: AF – adjust fire D – down DIR – direction DIS – distance FFE – fire for effect IS – immediate suppression L – left R – right S – suppress SEAD – suppress enemy air defense TGT – target U – up	

9-13. **Upper Computational space and related data blocks**. These blocks are used to compute and record data used in determining firing data (see figure 9-4). Table 9-3 explains each item and its use.



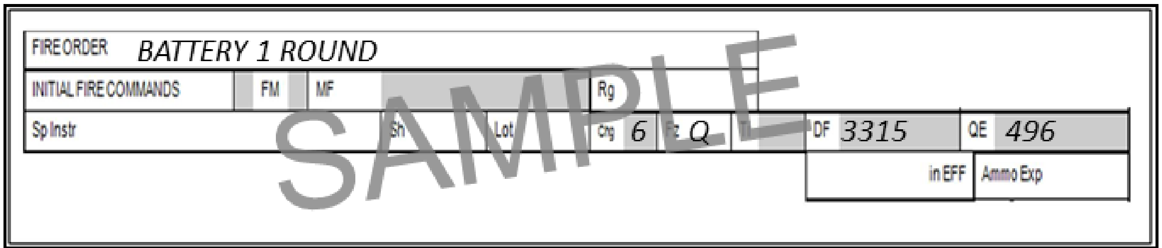
Legend: CHT DF – chart deflection DF CORR – deflection correction EL – elevation FS – fuze setting HOB CORR – height of burst correction RG – range SI - site

Figure 9-4. Upper Computational Space and Related Data Blocks.

Table 9-3. Upper Computational Space and Related Data Blocks Items.

ITEM	***ACTION***
Computational Space	Used to record computational data, such as determining VI and deflection correction.
∡ Si÷10	Used to record **∡Si÷10** when computing site for high-angle fire missions.
10mSi	Used to record the **10-mil site factor** when computing site for high-angle fire missions.
Df Corr	Used to record the **deflection correction** to be used for a fire mission.
Rg	Used to record the **chart range** for a fire mission.
Chart Df	Used to record the **chart deflection** for a fire mission.
ΔFS	Used to record **▲FS/▲10MHOB**. This is used to compute a change in FS for a 10-meter change in HOB and is recorded after the first time the fuze is fired.
100/R	Used to record **100/R**. This is used to move the burst 100 meters laterally or vertically.
/R	Used to record **/R**. This is used to move a burst other than 100 or 20 meters laterally or vertically.
20/R	Used to record **20/R**. This is used to move the burst 20 meters laterally or vertically. 20/R is determined by dividing 100/R by 5 and expressing to the nearest whole mil.
HOB Corr	Used to record the **height of burst correction** if a time fuze is used in the initial volley.
SI	Used to record the **site** for a fire mission. Site is a signed (±) value.
El	Used to record the initial **elevation** for a fire mission.
Legend: CORR – correction DF – deflection EL – elevation FS – fuze setting HOB – height of burst M – meter RG – range SI – site VI – vertical interval	

9-14. **Fire order and initial fire commands block**. The fire order announced by the FDO and the initial fire commands transmitted to the howitzers are recorded in this block. (See figure 9-5.) Table 9-4 explains each item and its use.



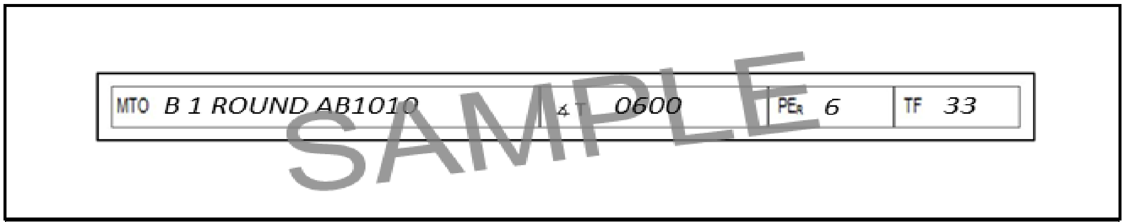
Legend: CHG – charge DF – deflection EFF – effect EXP – expended FM – fire mission FZ – fuze MF – method of fire RG – range SH – shell SP INSTR – special instructions TI – time QE – quadrant elevation

Figure 9-5. Fire Order and Initial Fire Commands Block.

Table 9-4. Fire Order and Initial Fire Commands Block Items.

ITEM	***ACTION***
FIRE ORDER	Used to record the **fire order**.
INITIAL FIRE COMMANDS	
FM	Used to circle the warning order **FIRE MISSION** transmitted the howitzer(s).
MF	Used to record the **pieces to follow, pieces to fire, and method of fire**.
Sp Instr	Used to record any **special instructions** transmitted to the howitzer(s).
Sh	Used to record the **shell**, if other than standard, transmitted to the howitzers.
Lot	Used to record the **ammunition lot**, if other than standard, transmitted to the howitzers. There are two lot designators (projectile and propellant) for separate-loading ammunition and one lot designator for projectile for semi-fixed ammunition.
Chg	Used to record the **charge** fired in a fire mission.
Fz	Used to record the **fuze**, if other than standard, transmitted to the howitzer(s).
Ti	Used to record the **fuze setting** for mechanical time or variable time fuzes sent to the howitzer(s).
Df	Used to record the initial **deflection to fire** transmitted to the howitzer(s).
QE	Used to record the initial **quadrant elevation** transmitted to the howitzer(s).
in Eff	Used to record the **method of fire for effect**. This is the number and shell fuze combination in effect.
Ammo Exp	Used to record the **ammunition expenditure**. This is the number of rounds fired with initial fire commands. The number of rounds is recorded when computed and circled when fired.
Legend: AMMO – ammunition CHG – charge DF – deflection EFF – effect EXP – expenditure FM – fire mission FZ – fuze MF – method of fire QE – quadrant elevation SH – shell SP INSTR – special instructions TI – time	

9-15. **Message to observer block**. The message to observer, angle T, probable error in range, and time of flight are recorded in this block. (See figure 9-6 on page 9-9.) Data determined but not transmitted are recorded in parentheses. Table 9-5 on page 9-9 explains each item and its use.


MTO	∡T	PE$_R$	TF
B 1 ROUND AB1010	0600	6	33

SAMPLE

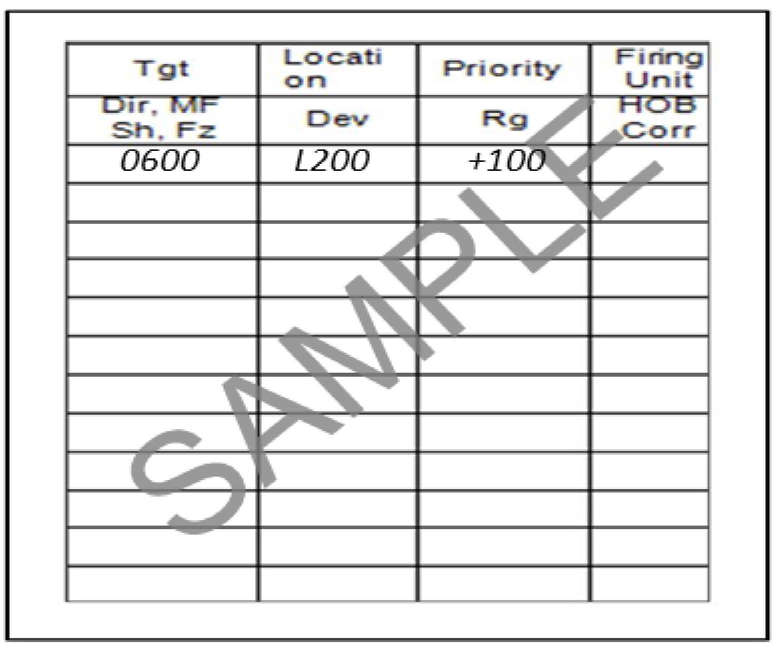
Legend: MTO – message to observer PE$_R$ – probable error in range TF – time of flight

Figure 9-6. Message to Observer Block.

Table 9-5. Message to Observer Block Items.

ITEM	***ACTION***
MTO	Used to record the message to observer transmitted to the observer for a fire mission.
∡T	Used to record the **angle T** for a fire mission. Angle T is transmitted to the observer if it is greater than or equal to 500m̸. The actual value is recorded and then expressed to the nearest 100m̸ before being transmitted.
PE$_R$	Used to record the **probable error in range** for a fire mission. Probable error in range is transmitted to the observer when it is greater than or equal to 38 meters for an area fire mission or 25 meters for a registration, destruction mission, or FPF.
TF	Used to record the **time of flight** of the projectile for a fire mission.
Legend: FPF – final protective fire m̸ - mil MTO – message to observer PE$_R$ – probable errors in range TF – time fuze	

9-16. **Fire planning and observer subsequent corrections block**. Fire plans or subsequent corrections transmitted by the observer are recorded in this block. (See figure 9-7.) Table 9-6 on page 9-10 explains each item and its use.


Tgt	Location	Priority	Firing Unit
Dir, MF Sh, Fz	Dev	Rg	HOB Corr
0600	L200	+100	

SAMPLE

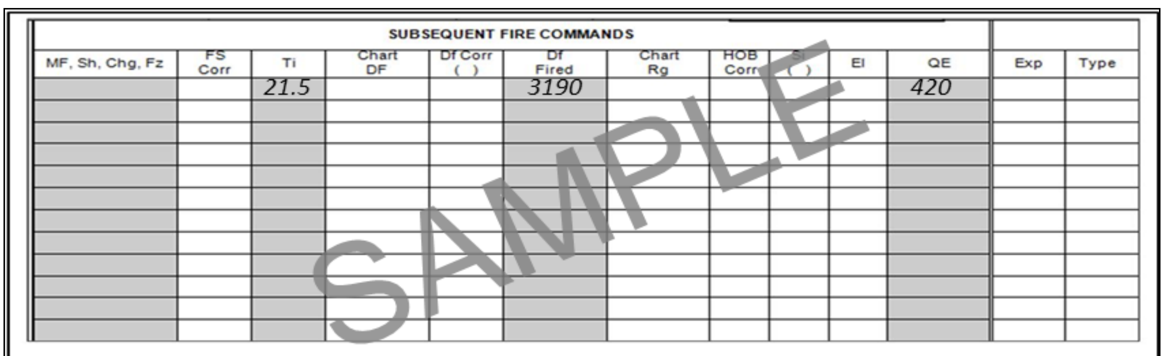
Legend: DEV – deviation DIR – direction FZ – fuze HOB CORR – height of burst correction MF – method of fire RG – range SH – shell TGT – target

Figure 9-7. Fire Planning and Observer Subsequent Corrections Block.

Table 9-6. Fire Planning and Observer Subsequent Corrections Block Items.

ITEM	***ACTION***
Tgt	Used to record the **target number** for fire plan targets.
Location	Used to record the **grid location** for a fire plan target.
Priority	Used to record a check mark to indicate a **priority target**.
Firing Unit	Used to record the **unit to fire** for fire plan targets.
Dir, MF, Sh, Fz	Used to record the **direction, method of fire, shell, or fuze** transmitted by the observer.
Dev	Used to record the **deviation correction** transmitted by the observer.
Rg	Used to record the **range correction** transmitted by the observer.
HOB Corr	Used to record the **height of burst correction** transmitted by the observer. Other items may be recorded in this block, such as FFE, EOM, and so on.
Legend: CORR – correction DEV – deviation DIR – direction EOM – end of mission FFE – fire for effect FZ – fuze HOB – height of burst MF – method of fire RG – range SH – shell TGT – target	

9-17. **Subsequent fire commands block**. Fire commands are recorded in this block. (See figure 9-8.) Data placed in parentheses indicate data that were determined but not transmitted because of no change. Table 9-7 explains each item and its use.



Legend: CHG – charge CORR – correction DF – deflection EL – elevation EXP – expended FS – fuze setting FZ – fuze HOB – height of burst MF – method of fire QE – quadrant elevation RG – range SH – shell Si – site TI – time

Figure 9-8. Subsequent Fire Commands Block.

Table 9-7. Subsequent Fire Commands Block Item.

ITEM	***ACTION***
MF, Sh, Chg, Fz	Used to record the **method of fire, shell, charge, or fuze** if changed from the initial fire commands.
FS Corr	Used to record the **fuze setting correction** for Time (TI) or Variable Time (VT) fuzes.
Ti	Used to record the **fuze setting** for TI or VT fuzes.
Chart Df	Used to record the subsequent **chart deflection** as announced by the HCO once the observer's corrections have been applied.
Df Corr ( )	Used to record the **deflection correction** for a fire mission. In low-angle fire, this will normally be the same as the initial deflection correction. In high-angle fire, drift is determined for each adjustment and added to the GFT Deflection Correction. If no GFT deflection correction is available for high angle, the deflection correction will be the same as drift.

Table 9-7. Subsequent Fire Commands Block Item (continued).

Chart Rg	Used to record the subsequent **chart range** and is announced by the HCO once the observer's corrections have been applied.
HOB Corr	Used to record the **height of burst correction** determined for a fire mission.
SI ( )	Used to record the **site** for a fire mission. This will normally be the same as the initial site unless it is recomputed.
El	Used to record the **elevation** determined by the computer for subsequent rounds.
QE	Used to record the **quadrant elevation** transmitted to the howitzer(s) for subsequent rounds.
Exp and Type	Used to record the **ammunition expenditure and shell-fuze type**. This portion of the record of fire is used to indicate the total number of rounds fired of a particular shell and fuze up to that point in the mission. When the shell and/or fuze changes, the count is restarted and the previous shell or fuze is recorded in the type column. Upon completion of the mission, the computer uses this total, by type, to subtract from the ammo count. Place a check mark after the type when this number is subtracted from the unit's ammo count. The number of rounds is recorded when computed and circled when fired.
Legend: CHG – charge CORR – correction DF – deflection EL – elevation EXP – expenditure FS – fuze setting FZ – fuze GFT – graphical firing table HCO – horizontal control operator HOB – height of burst MF – method of fire QE – quadrant elevation RG – range SH – shell SI – site TI – time VT – variable time	

9-18. **Lower Computational space and administrative blocks.** These are the lower computational areas used to record required data or conduct computations. (See figure 9-9.) Table 9-8 explains each item and its use.

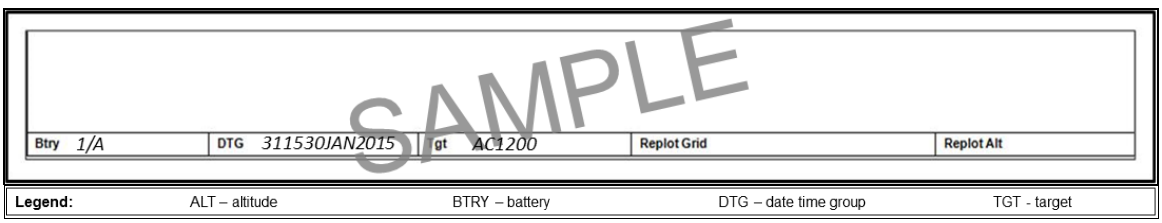


Figure 9-9. Lower Computational Space and Administrative Blocks.

Table 9-8. Lower Computational Space and Administrative Blocks Items.

ITEM	***ACTION***
Btry	Used to record the **firing unit** who fired the mission.
DTG	Used to record the **13 April 2016-time group** the unit entered the FFE phase of the mission.
Tgt	Used to record the **target number** assigned to the mission.
Replot Grid	Used to record the **replot grid** when replot is conducted.
Replot Alt	Used to record the **replot altitude** when replot is conducted.
Legend: ALT – altitude BTRY – battery DTG – 13 April 2016 time group FFE – fire for effect TGT – target	

SECTION II: HIGH EXPLOSIVE

9-19. High Explosive (HE) projectiles are typically the most common projectile found in used in both training and combat environments. The HE projectile is available in all cannon weapon systems (105 mm, 155 mm).

OVERVIEW

9-20. HE projectiles are hollow steel cases filled with explosives (trinitrotoluene [TNT] or composition B). They can be fuzed for air, surface, or subsurface burst. HE projectiles are used against personnel and material objects because of blast and fragmentation effects.

9-21. Determination of firing data for a point-detonating (Q), mechanical time (MT), mechanical time super quick (MTSQ), electronic time (ET), or variable time (VT) fuze mated to an HE projectile is almost identical. Only minor procedural differences exist. Data are determined from the GFT, GST, and TFT.

9-22. The HE-quick shell-fuze combination is the ammunition used for the basic fire mission. Chart data are determined to the target. The computer determines data with the GFT (see table 9-9).

Note: All remaining examples of the Record of Fire throughout the chapter utilize the following GFT setting:

GFT 1/A, Chg 4, Lot A/H, Rg 14000, EL 372, TI 38.1 TOT DF Corr L16, GFT Df Corr L3

For determination and application of a GFT Setting see Chapter 10. For determining data with or without a GFT setting see Appendix F.

Table 9-9. Computation of Data Without a GFT Setting.

ITEM	***ACTION***
Range	**Range is the base scale**. The Manufacture's Hairline (MHL) is placed over the range, and all elements that are a function of range can be determined.
100/R	**100/R is a function of range**. (To determine 100/R the MHL is placed directly over the range.) It is determined from the 100/R scale and expressed to the nearest mil. It can be determined manually by dividing 100 by the ranged expressed in thousandths multiplied by 1.0186.
El	**Elevation is a function of range**. (To determine elevation, the MHL is placed directly over the range.) It is determined from the elevation scale and is expressed to the nearest mil.
Drift	**Drift is a function of elevation**. (To determine drift, the MHL is placed directly over the elevation.) It is determined from the drift scale and expressed to the nearest mil. Drift is always recorded as a left (L) correction.
M582/M564 FS	**Fuze Setting is a function of elevation**. (To determine FS, the MHL is placed directly over that elevation.) It is determined from the appropriate fuze setting scale (TF/FS MTSQ/ET scale for MTSQ and ET fuzes or M564 scale for MT Fuzes) and is expressed to the nearest tenth (0.1) of a FS increment.
TOF	**Time of flight is a function of elevation**. (To determine TOF, the MHL is placed directly over the elevation). It is determined from the TF/FS MTSQ/ET scale and expressed to the nearest whole second.
VT FS	**Variable Time fuze setting is a function of elevation**. (To determine VT FS, the MHL is placed directly over the elevation). It is determined from the TF/FS MTSQ/ET scale and expressed by vanishing the tenths and applying a .0 (express down). If the value extracted from the TF/M582 scale is already determined to the whole second, there is no need to express down.
▲FS/▲10MHOB	**Change in fuze setting for a change in 10 meters in HOB is a function of FS**. (To determine delta FS, the MHL is placed directly over the FS). It is determined from the ▲FS/▲10MHOB scale and expressed to the nearest hundredth (0.01).
Legend: EL – elevation ET – electronic time FS – fuze setting HOB – height of burst M – meter MHL – manufacturer's hair line MT – mechanical time MTSQ – mechanical time super quick TOF – time of flight VT – variable time	

Note: The fire order SOP and fire command standards in figure 9-10 are used for all the examples found in this chapter.

FIRE ORDER SOP		
FIRE ORDER ELEMENT		***SOP***
1	UNIT TO FIRE	PLATOON
2	ADJUSTING ELEMENT AND/OR MOF Projectile in adjustment Lot and charge in adjustment Fuze in adjustment	#3 1 round HE LOT A/H, Chg 4 Q
3	BASIS FOR CORRECTIONS	USE GFT
4	DISTRIBUTION	PARALLEL
5	SPECIAL INSTRUCTIONS	
6	METHOD OF FIRE FOR EFFECT	FDO ANNOUNCE
7	PROJECTILE IN EFFECT	OBS/FDO SELECT
8	AMMUNITION LOT AND CHARGE IN EFFECT	FDO or COMPUTER SELECT
9	FUZE IN EFFECT	OBS/FDO SELECT
10	TARGET NUMBER	NEXT AVAILABLE
FIRE COMMAND STANDARDS		
ELEMENT		***STANDARD***
1	WARNING ORDER	
2	PIECES TO FOLLOW/PIECES TO FIRE/METHOD OF FIRE	
3	SPECIAL INSTRUCTIONS	
4	PROJECTILE	HE
5	AMMUNITION LOT	LOT A/H
6	CHARGE	
7	FUZE	Q
8	FUZE SETTING	
9	DEFLECTION	
10	QUADRANT	
11	METHOD OF FFE	
Legend: CHG – charge FDO – fire direction officer FFE – fire for effect GFT – graphical firing table HE – high explosive MOF – method of fire OBS – observer Q – quick SOP – standard operating procedures		

Figure 9-10. Fire Order SOP and Fire Command Standards.

EXAMPLES OF COMPLETING THE RECORD OF FIRE FOR HE FIRE MISSIONS

9-23. HE/Q Adjust-Fire Mission. Use the steps in table 9-10 (on page 9-14) to process an HE/Q adjust-fire mission. Figure 9-11 on page 9-17 shows an example record of fire (ROF) for this type of mission.

Table 9-10. HE/Q Adjust-Fire Mission.

STEP	***REFERENCE***	***ACTION***
1	CFF	Computer/RTO reads back and records the CFF.
2	Fire Order	Computer/RTO reads back and records fire order announced by the FDO.
3	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Computer/RTO circles warning order.
	MF	Computer determines and records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records as directed by the fire order.
	Sh	Computer/RTO records **if other than standard**, as directed by the fire order.
	Lot	Computer/RTO records **if other than standard**, as directed by the fire order.
	Chg	Computer/RTO records charge. If not announced in the fire order, and no standard is in effect, computer will determine charge after receiving chart range.
	Fz	Computer/RTO records **if other than standard**, as directed by the fire order.
4	MTO	Computer/RTO records the MTO announced by the RTO.
5	Rg	HCO determines and announces chart range. Computer places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
6	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
7	El	Computer/RTO determines and records elevation.
8	Drift	Computer/RTO determines and records drift in the upper computational space
9	Df Corr	Computer/RTO records deflection correction. This is the sum of drift plus the GFT deflection correction **(DRIFT + GFT DF CORR = DF CORR).** If no GFT deflection correction is available, the deflection correction will be the same as drift.
10	Df	Computer/RTO determines and records the deflection to fire **(CHT DF + DF CORR = DF TO FIRE).**
11	SI	VCO determines and announces site. Computer/RTO records it.
12	QE	Computer/RTO determines and records quadrant elevation. **(SI+EL=QE).**
13	In Eff	Computer/RTO records method of fire for effect as directed by the fire order.
14	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
15	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
16	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations. (See Table 9-11 on page 9-15).
Legend: CFF – call for fire CHG – charge CHT – chart CORR – correction DF – deflection FDC – fire direction center FDO – fire direction officer FM – fire mission FS – fuze setting FSCM – fire support coordination measure GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line MTO – message to observer QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions VCO – vertical control operator VT – variable time		

9-24. Police of Record of Fire. Use the steps in table 9-11 to police the record of fire.

Table 9-11. Police of the Record of Fire.

STEP	***REFERENCE***	***ACTION***
1	Delta FS (▲FS)	Determine after the first time fuze is fired. ▲FS is not determined for Fuze VT.
2	100/R	Determined after the first round is fired, or after significant changes in range.
3	20/R	Determined after the first round is fired, or after significant changes in range.
4	Computational Space	Computer/RTO records the VCO's math steps used to determine VI.
5	Ammo Exp	Computer/RTO records when computed and circles the number of rounds when the howitzer(s) have fired. This is a running count of a particular shell-fuze combination fired in the mission up to this point.
6	Type	Computer/RTO records shell and/or fuze type corresponding to the ammunition fired. This is done when shell and/or fuze have changed or EOM is received.
7	TF	Computer/RTO determines and records the TOF. If not sent to the observer during the mission, it is placed in parentheses.
8	PER	Computer/RTO determines and records the PE_R. If PER is less than 38 meters, the <38 is recorded in parentheses. If it is equal to or greater than 38 meters, then the actual value is recorded and transmitted to the observer by the RTO. If PE_R is equal to or greater than 25 meters for a registration, destruction mission, or FPF the actual value is recorded and transmitted to the observer by the RTO.
9	∡T	When direction is received, the HCO determines and announces angle T. Computer/RTO records it to the nearest 10 mils and places it in parentheses. If it is equal to or greater than 500 mils, it is recorded again to the nearest 100 mils and is transmitted to the observer by the RTO.
10	SI ( )	Computer/RTO records the site in parentheses at the top of the SI column. During subsequent corrections, record this value on each line used to compute fire commands.
11	Df Corr ( )	Computer/RTO records the deflection correction in parentheses at the top of the Df Corr column. During subsequent corrections, record this value on each line used to compute fire commands.
12	Exp	Computer/RTO records when the data for a round(s) is computed and circles the number of rounds when the howitzer(s) have fired. This is a running count of a particular shell-fuze combination fired in the mission up to this point.
13	Type	Computer/RTO records shell and/or fuze type corresponding to the ammunition fired. This is done when shell and/or fuze have changed or EOM is received.
14	Surveillance	Computer/RTO records end of mission surveillance in the lower computation space if sent by the observer.
15	Tgt	Computer/RTO records the target number assigned to the mission.
16	DTG	Computer/RTO records the 13 April 2016 and time group the unit entered the FFE phase of the mission. If FFE is never entered, the Computer/RTO records the DTG the unit received end of mission. (Format for the DTG is DDHHMMTZMTHYY, for example **152305ZFEB13**).
17	Btry	Computer/RTO records the battery or platoon designation.

Legend: BTRY – battery CORR – correction DF – deflection DTG – 13 April 2016 time group EOM – end of mission EXP – expenditure FFE – fire for effect FPF – final protective fire FS – fuze setting HCO – horizontal control operator PER – probable error in range RTO – radio telephone operator SI – site TOF – time of flight TGT – target VCO – vertical control operator VT – variable time

9-25. HE/Q Fire Mission. Use the steps in table 9-12 for a subsequent adjustment of an HE/Q fire mission. An example ROF for this entire mission is shown in figure 9-ll on page 9-17.

Table 9-12. Subsequent Adjustment of an HE/Q Fire Mission.

STEP	***REFERENCE***	***ACTION***
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
3	Chart Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
4	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
5	El	Computer/RTO determines and records elevation.
6	Df	Computer/RTO determines and records deflection to fire **(CHT DF + DF CORR = DF TO FIRE).**
7	QE	Computer/RTO determines and records QE **(EL + SI = QE).**
8	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
9	Transmit Fire Commands	Computer/RTO transmits fire commands to the howitzer(s).
10	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations. (See table 9-11 on page 9-15.)
	Note: Repeat steps 1 through 10 as necessary to complete the observer's corrections. These steps are valid until the observer changes fuze or projectile. Site and deflection corrections are not recomputed; the observer will correct for inaccuracies or changes through adjustments. An example ROF for this entire mission is shown in figure 9-11 on page 9-17.	
Legend: CHG – charge CHT – chart CORR – correction DEV – deviation DF – deflection DIR – direction EL – elevation EXP – expenditure FS – fuze setting FZ – fuze GFT – graphical firing table HCO – horizontal control operator HOB – height of burst MF – method of fire MHL – manufacturer's hair line QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site TI – time VT – variable time		

RECORD OF FIRE

CALL FOR FIRE

Observer: B34 — (AF) FFE/IS/S — Tgt: ____
Grid: 593 372alt 375
Polar: Dir ____ Dis ____ U/D ____ VA ____
Shift: Dir: ____ L/R ____ +/- ____ U/D ____
COMMAND POST, Q I/E

TGT ALT 475	DRIFT L10	ΔFS
-BRTY ALT 475	+GFT L3	100/R 8
VI -100	DF Corr L13	/R
		20/R 2
∠Si ÷ 10	10m Si	HOB Corr

FIRE ORDER: (2) I/E — Df Corr: L13 — Si: -8

INITIAL FIRE COMMANDS: (FM) MF: PLT ADJ, # 3 (1) — Rg: 12400 — Cht Df: 3364 — El: 293

Sp Instr: ____ Sh: ____ Lot: ____ — Chg: 4 — Fz: ____ — Ti: ____ — DF: 3377 — QE: 285

MTO: H, (2) I/E, TGT# AL7215 — ∠T (670) 700 — PE_R (<38) — TF (32) — (2) in EFF — Ammo Exp (1)

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L13)	Df Fired	Chart Rg	HOB Corr	Si (-8)	El	QE	Exp	Type
5300	R40	+100					3323	L13	3336	12490		-8	297	289	(2)	
		-50	FFE	PLT (2)			3321	L13	3334	12460		-8	296	288	(10)	Q ✓
	L20	+20	EOM	EOM												

CMD POST DEST, EST 7 CAS

Btry	DTG	Tgt	Replot Grid	Replot Alt
1/A	261347ZFEB13	AL7215		

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Legend:
ADJ - adjust
AF – adjust fire
ALT - altitude
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CMD – command
CORR – correction
DEST – destroyed
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
INF – infantry
IS – immediate suppression
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-11. Example Record of Fire for an HE/Q Adjust-Fire Mission.

HIGH-EXPLOSIVE WITH TIME FUZE.

9-26. Determining data for an HE/Ti round is exactly the same as HE/Q except for the HOB correction and the fuze setting correction.

9-27. A time fuze achieves the best effects on the target when it functions at a 20-meter HOB. To achieve the 20-meter HOB, the trajectory of the projectile must be altered to cause the projectile to pass 20 meters above the target. By applying the mil-relation formula in a vertical plane, the amount of mils the trajectory needs to be altered at any range is 20/R. When the value of 20/R is used as the HOB correction, it will always be a positive value. The HOB correction is included in the computation of QE. The HOB correction is added to the site (ground site), and a total site is determined (HOB CORR + GROUND SITE = TOTAL SITE). This total site is applied to elevation to determine QE. The HOB correction is applied only to the initial time QE. (See figure 9-12.)

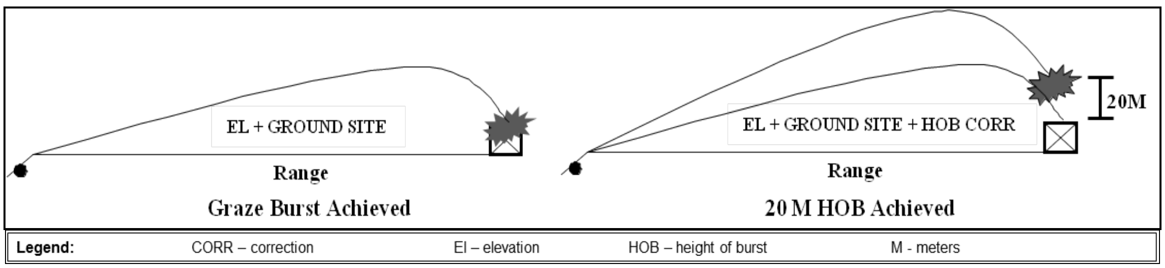


Figure 9-12. Determination of a 20 Meter Height of Burst for Time Fuze.

9-28. If subsequent adjustments for the HOB are necessary, then the FS is the only element of firing data that is recomputed. The trajectory, deflection and quadrant elevation, will remain the same. A FS correction will be applied to the previous fuze setting. The FS correction will be a multiple of ▲FS/▲10M HOB. The ▲FS moves the functioning of the fuze along the trajectory by increments of 10 meters (See figure 9-13). The observer will adjust the HOB by transmitting HOB corrections (up or down) to the nearest 5 meters. The observer's corrections in meters must be converted to corrections in FS. The observer's HOB correction is divided by 10 and then multiplied by ▲FS/▲l0M HOB. This value is expressed to the nearest tenth (0.1) of a FS increment. Before this can be applied as a FS correction, it must have a sign (±). The sign is based on the direction (up or down) of the observer's correction. If the correction is up, then the fuze functioned late and the FS correction must be subtracted. If the correction is down, then the fuze functioned early and the FS correction must be added. Simply stated, for an up correction, the FS corrections negative; for a down correction, the FS correction is positive. An easy rule to remember is USDA (up, subtract; down, add). Figure 9-14 on page 9-19 shows an example of the USDA Rule.

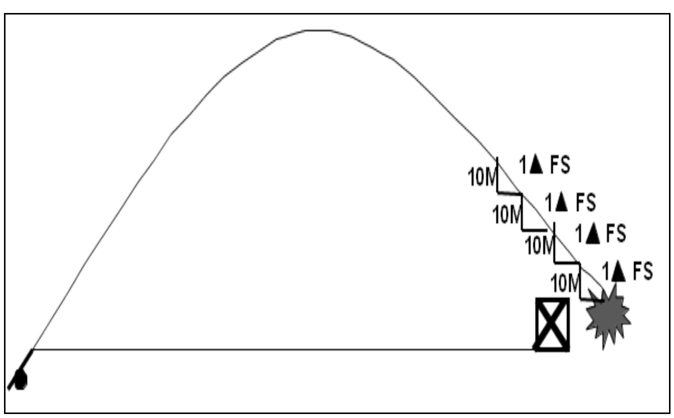


Figure 9-13. Effect of ▲FS on Achieved HOB.

Where ▲FS = 0.10

U: U40 ÷ 10 = 4 x 0.10 = 0.4

S: ~ - 0.4

D: D25 ÷ 10 = 2.5 x 0.10 = 0.25

A: ~ + 0.2

Figure 9-14. Example of USDA Rule.

HE/TI FIRE MISSION WITH HE/Q IN ADJUSTMENT.

9-29. Process the HE/Q adjustment as outlined in paragraph 9-5. Once the observer has requested a change in fuze type to a mechanical time fuze, process the request as described in table 9-13. Figure 9-15 on page 9-21 shows an example ROF for this type of mission.

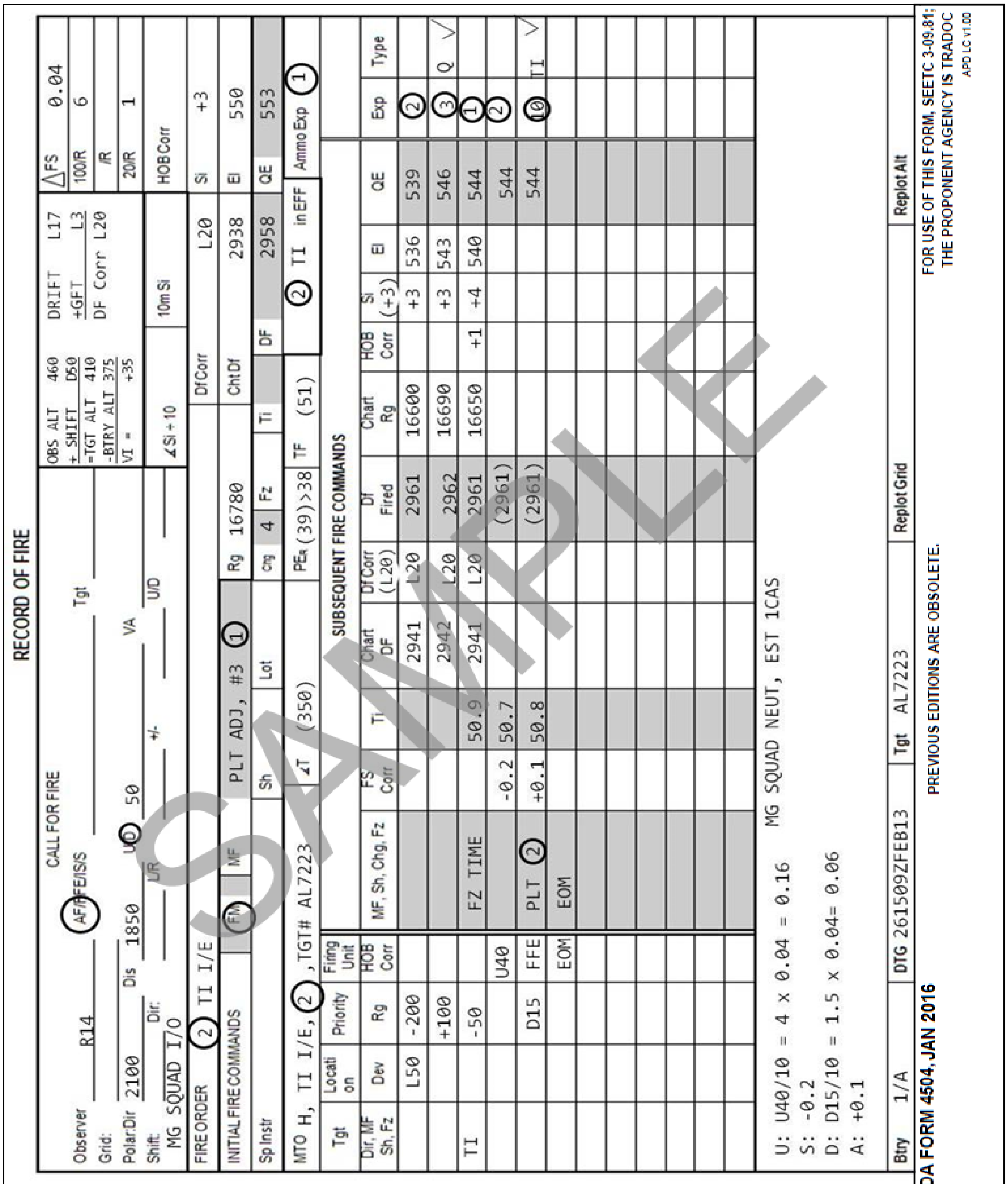
Table 9-13. HE/TI Fire Mission with HE/Q in Adjustment.

STEP	***REFERENCE***	***ACTION***
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze. Computer/RTO records **FUZE TIME**.
3	Chart Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the GFT over the announced range, reads back the range, and records it.
4	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
5	El	Computer/RTO determines and records elevation.
6	Ti	Computer/RTO determines and records time fuze setting.
7	Df	Computer/RTO determines and records deflection to fire **(CHT DF + DF CORR = DF TO FIRE).**
8	HOB Corr	Computer/RTO determines and records HOB Corr. 20/R is the HOB correction, and it is a positive signed value (+).
9	SI	Computer/RTO determines and records total site. The HOB correction (step 8) is algebraically added to previously determined ground site. The result is total site **(HOB CORR + GROUND SITE = TOTAL SITE)**.
10	QE	Computer/RTO determines and records **QE (EL + TOTAL SITE = QE).**
11	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
12	Transmit	Chief/Computer transmits fire commands to the howitzer(s).
13	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data used in subsequent corrections.
Note: Ensure ▲FS is determined during policing of the ROF. If the observer adjusts the HOB, the FS will need to be recomputed. The FS determined in step 6 is used to determine ▲FS.		
Legend: CHG – charge CHT – chart CORR – correction DEV – deviation DF – deflection DIR – direction EL – elevation EXP – expenditure FS – fuze setting FZ – fuze GFT – graphical firing table HCO – horizontal control operator HOB – height of burst MF – method of fire MHL – manufacturer's hair line QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site TI – time VT – variable time		

9-30. If a 20-meter HOB was not achieved, the fuze setting must be adjusted. At this point in the mission, the observer does not make any range or deviation corrections. The only corrections are for HOB. Therefore, the only firing data that will change are the fuze setting. Use the steps in table 9-14 to adjust the fuze setting, figure 9-15 on page 9-21 shows an example ROF for this type of mission.

Table 9-14. Adjustment of Time Fuze.

STEP	***REFERENCE***	***ACTION***
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
3	FS Corr	Computer/RTO determines and records FS correction. The FS correction is determined by dividing the HOB correction by 10 and multiplying the value by ▲FS. The result is expressed to the nearest tenth and is a signed value (See Figure 9-14 for example of USDA). The computations are placed in the lower computational space of the ROF **[(HOB CORR ÷ 10) x ▲FS = FS CORR ~ 0.1 FSI (±)].** Up correction = negative FS CORR/ Down Correction = positive FS CORR.
4	Ti	Computer/RTO determines and records the fuze setting. The fuze setting is determined by applying the FS correction to the previous fuze setting fired **(FS CORR + PREVIOUS FS = Ti).**
5	Df	Computer/RTO records the deflection in parentheses (it does not change).
6	QE	Computer/RTO records the quadrant (QE does not change but must be announced in the subsequent fire commands).
7	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
8	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
9	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
Note: Repeat Steps 1 through 9 as necessary to process the observer's HOB correction. An example mission is shown in figure 9-15 on page 9-21.		
Legend: CHG – charge CORR – correction DEV – deviation DF – deflection DIR – direction FS – fuze setting FZ – fuze HOB – height of burst MF – method of fire QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site TI – time		



RECORD OF FIRE

CALL FOR FIRE
Observer R14 (AF)/FFE/IS/S Tgt
Grid:
Polar:Dir 2100 Dis 1850 (U/D) 50 VA
Shift: Dir: L/R +/- U/D
MG SQUAD I/O

OBS ALT 460
+ SHIFT D50
=TGT ALT 410
-BTRY ALT 375
VI = +35
∠Si ÷ 10
10m Si

DRIFT L17
+GFT L3
DF Corr L20

ΔFS 0.04
100/R 6
/R
20/R 1
HOB Corr

FIRE ORDER (2) TI I/E
Df Corr L20
Si +3

INITIAL FIRE COMMANDS (FM) MF PLT ADJ, #3 (1)
Rg 16780
Cht Df 2938
El 550

Sp Instr Sh Lot Chg 4 Fz Ti
DF 2958
QE 553

MTO H, TI I/E, (2) ,TGT# AL7223 ∠T (350) PER (39)>38 TF (51)
(2) TI in EFF
Ammo Exp (1)

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L20)	Df Fired	Chart Rg	HOB Corr	Si (+3)	El	QE	Exp	Type
	L50	-200					2941	L20	2961	16600		+3	536	539	(2)	
		+100					2942	L20	2962	16690		+3	543	546	(3)	Q √
TI		-50		FZ TIME		50.9	2941	L20	2961	16650	+1	+4	540	544	(1)	
			U40		-0.2	50.7			(2961)					544	(2)	
		D15	FFE	PLT (2)	+0.1	50.8			(2961)					544	(10)	TI √
			EOM	EOM												

U: U40/10 = 4 x 0.04 = 0.16
S: -0.2
D: D15/10 = 1.5 x 0.04= 0.06
A: +0.1

MG SQUAD NEUT, EST 1CAS

Btry 1/A | DTG 261509ZFEB13 | Tgt AL7223 | Replot Grid | Replot Alt

DA FORM 4504, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC
APD LC v1.00

SAMPLE

Legend:

ADJ - adjust
AF – adjust fire
ALT - altitude
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L/R – left/right
MF – method of fire
MG – machine gun
NEUT – neutralized
OBS – observer
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-15. Example Record of Fire for an HE/TI (M767) Adjust-Fire Mission.

9-31. HE/Time (TI) FFE Mission. Use table 9-15 for processing an HE/TI FFE fire mission. Figure 9-16 on page 9-24 shows an example for this type of mission.

Table 9-15. HE/TI FFE Fire Mission Process.

STEP	***REFERENCE***	***ACTION***
1	CFF	Computer/RTO reads back and records the CFF announced by the RTO.
2	Fire Order	Computer/RTO reads back and records the fire order announced by the FDO.
3	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Computer/RTO circles warning order.
	MF	Computer/RTO determines and records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records as directed by the fire order.
	Sh	Computer/RTO records **if other than standard**, as directed by the fire order.
	Lot	Computer/RTO records **if other than standard**, as directed by the fire order.
	Chg	Computer/RTO records charge. If not announced in the fire order, and no standard is in effect, computer will determine charge after receiving chart range.
	Fz	Computer/RTO records **FUZE TIME**.
4	MTO	Computer/RTO records the MTO announced by the RTO.
5	Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
6	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
7	El	Computer/RTO determines and records elevation.
8	Ti	Computer/RTO determines and records the time setting
9	Drift	Computer/RTO determines and records drift in the upper computational space
10	Df Corr	Computer/RTO records deflection correction. This is the sum of drift plus the GFT deflection correction **(Drift + GFT DF CORR = DF CORR)**. If no GFT deflection correction is available, the deflection correction will be the same as drift.
11	Df	Computer/RTO determines and records the deflection to fire **(CHT DF + DF CORR = DF TO FIRE).**
12	100/R	Computer/RTO determines 100/R and records it.
13	20/R	Computer/RTO determines 20/R and records it to the nearest whole mil. 20/R is determined by dividing 100/R by 5 and expressing to the nearest whole mil.
14	HOB Corr	Computer/RTO determines and records HOB Correction. 20/R is the HOB Correction, and it is a positive signed value (+).
15	Ground SI	VCO determines and announces site. Computer/RTO records it in parentheses in the SI block of the upper computational space. This is ground site.
16	SI	Computer/RTO determines and records total site in the SI block of the upper computational space. Total site is determined by the algebraic sum of HOB correction and ground site. **(HOB CORR + GROUND SITE = TOTAL SITE).**
17	QE	Computer/RTO determines and records quadrant elevation. **(TOTAL SI+EL=QE).**

Table 9-15. HE/TI FFE Fire Mission Process (continued).

STEP	REFERENCE	ACTION
18	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
19	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
20	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
Legend: CFF – call for fire CHG – charge CHT – chart CORR – correction DF – deflection FDC – fire direction center FDO – fire direction officer FM – fire mission FS – fuze setting FSCM – fire support coordination measure GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line MTO – message to observer QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions VCO – vertical control operator		

HIGH-EXPLOSIVE WITH VARIABLE TIME (M732/M728).

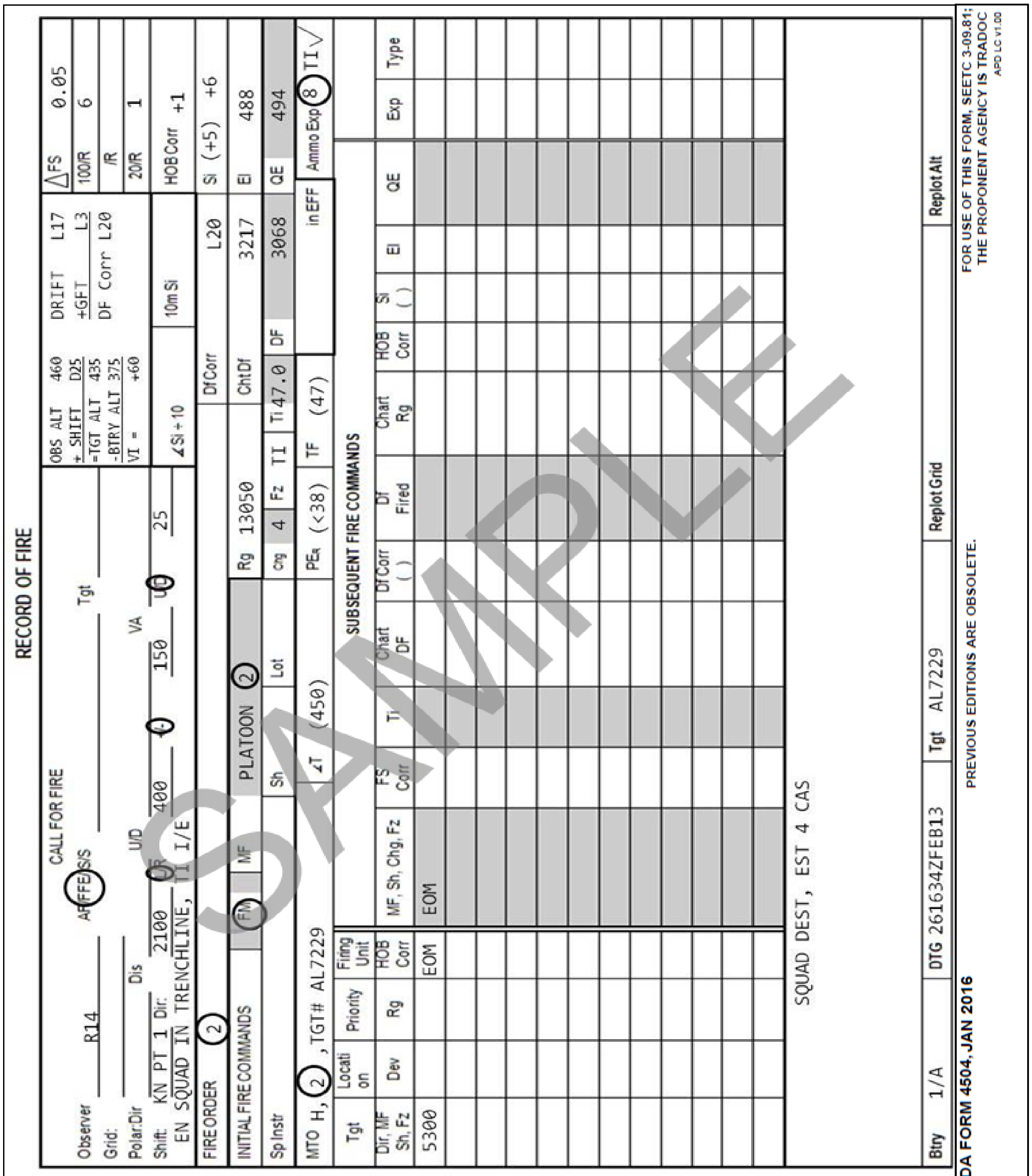
9-32. The variable time, or proximity fuze, is designed to function at a predetermined HOB (7 meters for M728/732). No HOB correction is needed because of the low HOB. The VT has a built-in radio transmitter-receiver. The fuze transmits a signal. When the reflected signal reaches a certain wave length, the fuze will determine it is 7 meters above the ground and function.

9-33. The VT fuze setting is determined from the time of flight of the projectile. The TOF is determined to the nearest tenth of a second (0.1). However, a VT fuze cannot physically be set to the nearest tenth. The scales are graduated in whole seconds; therefore, the TOF must be expressed down to the whole second. If the TOF extracted is already determined to the whole second, there is no need to express down. The VT memory aid "vanish tenths" will help in the determination of the VT FS. Expressing down provides a greater assurance of an airburst. About 3 seconds before the fuze setting, the fuze is armed and the radio transmitter is activated. Whenever a VT FS is determined, recorded, or announced, it will always end in point zero.

9-34. Fuze M732A2 is graduated only in even, whole seconds. The only fuze settings that may be physically set on the M732A2 fuze is even, whole second. Therefore, the TOF must be expressed down the next even whole second.

Note: If the observer transmits a graze repeat, the automatic correction to the VT FS is to subtract 1.0 seconds.

9-35. HE/VT Fire Mission with HE/Q in Adjustment. Process the HE/Q adjustment as outlined in paragraph 9-21. Once the observer has requested a change in fuze type to a variable time fire, process the request as described in table 9-16 on page 9-25. Figure 9-17 (on page 9-26) shows an example ROF for this type of mission.



RECORD OF FIRE

CALL FOR FIRE

Observer R14 | AF (FFE) S/S | Tgt

Grid:

Polar:Dir | Dis | U/D | VA

Shift: KN PT 1 Dir: 2100 L/R 400 + 150 U/D 25

EN SQUAD IN TRENCHLINE, TI I/E

OBS ALT 460 | + SHIFT D25 | =TGT ALT 435 | -BTRY ALT 375 | VI = +60

DRIFT L17 | +GFT L3 | DF Corr L20

ΔFS 0.05 | 100/R 6 | /R | 20/R 1

∠Si + 10 | 10m Si | HOB Corr +1

FIRE ORDER (2) | Df Corr L20 | Si (+5) +6

INITIAL FIRE COMMANDS | FM | MF | PLATOON (2) | Rg 13050 | Cht Df 3217 | El 488

Sp Instr | Sh | Lot | Chg 4 | Fz TI | Ti 47.0 | DF 3068 | QE 494

MTO H, (2), TGT# AL7229 | ∠T (450) | PE_R (<38) | TF (47) | in EFF | Ammo Exp (8) TI ✓

SUBSEQUENT FIRE COMMANDS

Tgt	Location	Priority	Firing Unit																	
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
5300			EOM	EOM												

SQUAD DEST, EST 4 CAS

Btry 1/A | DTG 261634ZFEB13 | Tgt AL7229 | Replot Grid | Replot Alt

SAMPLE

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Legend:
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEST - destroyed
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EN – enemy
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
IS – immediate suppression
KN PT – known point
L/R – left/right
MF – method of fire
PER – probable error in range
PT – point
Q – quick
QE – quadrant elevation
REC – record
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-16. Example Record of Fire for an HE/TI (M767) FFE Mission.

Table 9-16. HE/VT Fire Mission with HE/Q in Adjustment Process.

STEP	***REFERENCE***	***ACTION***
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze. Computer/RTO records **FUZE VT**.
3	Chart Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
4	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
5	El	Computer/RTO determines and records elevation.
6.	Ti	Computer/RTO determines and records the variable time FS. The Computer/RTO first determines TOF to the nearest tenth (from the TF/FS MTSQ/ET scale), then vanishes the tenths, and applies a point zero.
5	Df	Computer/RTO determines and records the deflection. **(CHT DF + DF CORR = DF TO FIRE).**
6	QE	Computer/RTO determines and records the quadrant. **(EL + SI = QE).**
7	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
8	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
9	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
Legend: CHG – charge CHT – chart CORR – correction DEV – deviation DF – deflection DIR – direction EL – elevation FS – fuze setting FZ – fuze GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line MTSQ – mechanical time super quick QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site TI – time TF – time fuze TOF – time of flight VT – variable time		

RECORD OF FIRE

CALL FOR FIRE			
Observer: R14	(AF)/FFE/IS/S	Tgt	
Grid: 6137 3925 alt 335			
Polar:Dir	Dis	U/D	VA
Shift: Dir:	L/R	+/-	U/D
MORTAR TEAM I/O			

TGT ALT 335	DRIFT L14	△FS	
-BRTY ALT 375	+GFT L3	100/R	7
VI -40	DF Corr L17	/R	
		20/R	1
∠Si ÷ 10	10m Si	HOB Corr	

FIRE ORDER	(2) VT I/E				Df Corr	L17	Si	-3
INITIAL FIRE COMMANDS	(FM)	MF	PLT ADJ, #3 (1)	Rg 14550	Cht Df	3201	El	402
Sp Instr	Sh	Lot	Chg 4	Fz	Ti	DF 3218	QE	399
MTO H, VT I/E, (2) ,TGT# AL7231	∠T (170)		PER (<38)	TF (40)	(2) VT in EFF		Ammo Exp	(1)

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L17)	Df Fired	Chart Rg	HOB Corr	Si (-3)	El	QE	Exp	Type
	R80	+200					3207	L17	3224	14630		-3	407	404	(2)	
		-100					3205	L17	3222	14580		-3	404	401	(3)	Q ✓
		+50	FFE	PLT (2) FZ VT		40.0	3206	L17	3223	14600		-3	405	402	(8)	
		GRZ	RPT		-1.0	39.0			(3223)					402	(16)	VT ✓
			EOM	EOM												

MORTAR TEAM DEST, EST 4 CAS

Btry 1/A	DTG 270026ZFEB13	Tgt AL7231	Replot Grid	Replot Alt

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SAMPLE

Legend:

- AF – adjust fire
- ALT - altitude
- AMC – at my command
- BTRY – battery
- CHG – charge
- CHT – chart
- CORR – correction
- DEST - destroyed
- DEV – deviation
- DF – deflection
- DIR – direction
- DIS – distance
- DTG – date time group
- EFF – effect
- EL – elevation
- EN – enemy
- EOM – end of mission
- EST – estimate
- EXP – expended
- FFE – fire for effect
- FM – fire mission
- FS – fuze setting
- FZ – fuze
- GFT – graphical firing table
- GRZ – graze
- HOB – height of burst
- I/O – in the open
- IS – immediate suppression
- KN PT – known point
- L/R – left/right
- MF – method of fire
- PER – probable error in range
- PLT – platoon
- PT – point
- Q – quick
- QE – quadrant elevation
- REC – record
- RG – range
- RPT – repeat
- S – smoke
- SH – shell
- Si – site
- SP INSTR – special instructions
- TF – time of flight
- TGT – target
- TI – time
- U/D – up/down
- VA – vertical angle
- VI – vertical interval
- VT – variable time

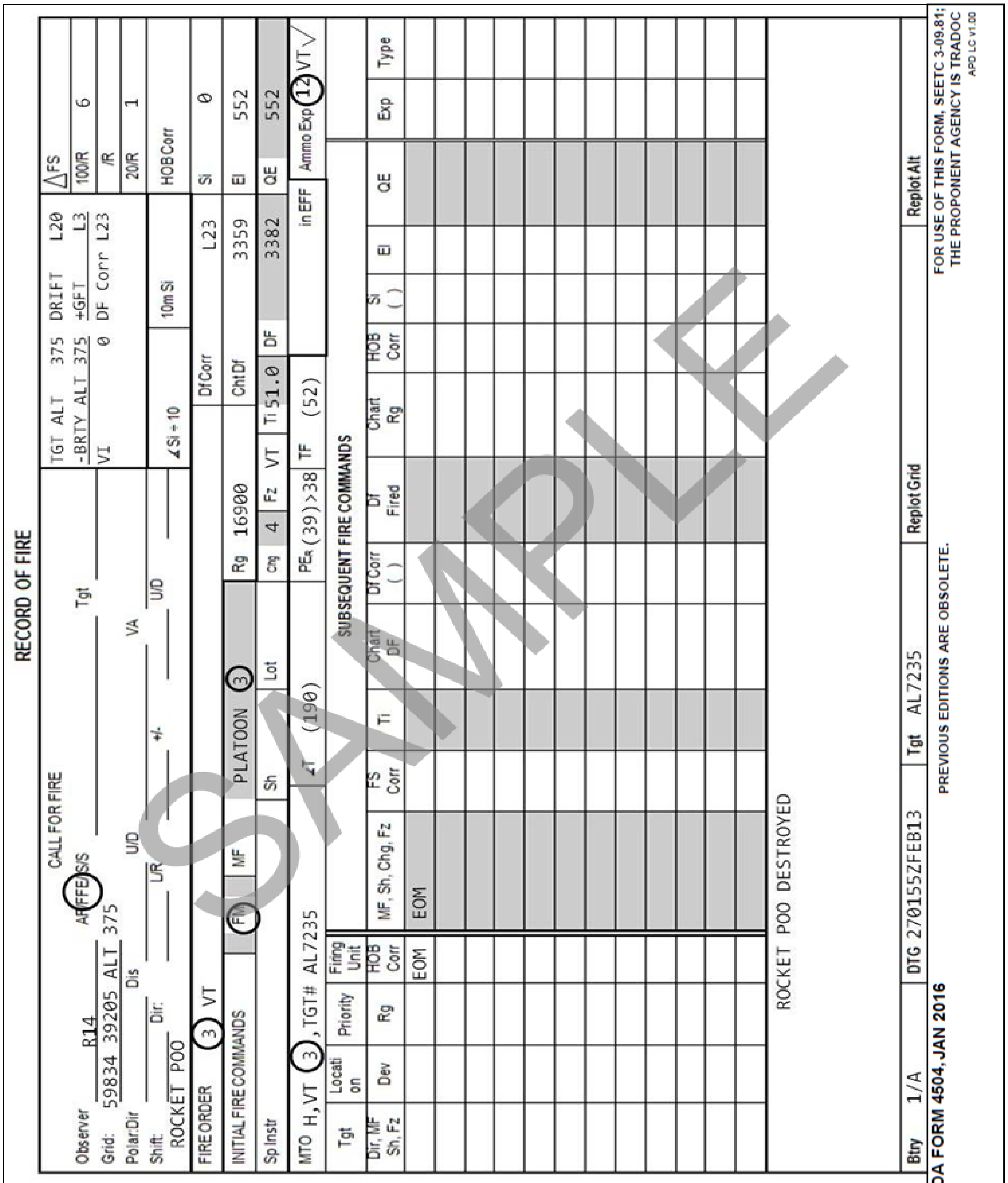
Figure 9-17. Example Record of Fire for an HE/VT Adjust-Fire Mission.

9-36. HE/VT FFE Fire Mission. Use table 9-17 for processing an HE/VT FFE fire mission. Figure 9-18 on page 9-28 shows an example record of fire for this type of mission.

Table 9-17. HE/VT FFE Fire Mission Process.

STEP	***REFERENCE***	***ACTION***
1	CFF	Computer/RTO reads back and records the CFF announced by the RTO.
2	Fire Order	Computer/RTO reads back and records the fire order announced by the FDO.
3	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Computer/RTO circles warning order.
	MF	Computer/RTO determines and records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records as directed by the fire order.
	Sh	Computer/RTO records **if other than standard**, as directed by the fire order.
	Lot	Computer/RTO records **if other than standard**, as directed by the fire order.
	Chg	Computer/RTO records charge. If not announced in the FO, and no standard is in effect, computer will determine charge after receiving chart range.
	Fz	Computer/RTO records **FUZE VT**.
4	MTO	Computer/RTO records the MTO announced by the RTO.
5	Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
6	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
7	El	Computer/RTO determines and records elevation.
8	Ti	Computer/RTO determines and records time setting for fuze VT.
9	Drift	Computer/RTO determines and records drift in the upper computational space
10	Df Corr	Computer/RTO records deflection correction. This is the sum of drift plus the GFT deflection correction **(Drift + GFT DF CORR = DF CORR).** If no GFT deflection correction is available, the deflection correction will be the same as drift.
11	Df	Computer/RTO determines and records the deflection to fire. **(CHT DF + DF CORR = DF TO FIRE).**
12	SI	VCO determines and announces site. Computer/RTO records it.
13	QE	Computer/RTO determines and records quadrant elevation. **(SI+EL=QE).**
14	In Eff	Computer/RTO records the method of fire for effect as directed by the fire order.
15	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
16	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
17	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.

Legend: CFF – call for fire CHG – charge CHT – chart CORR – correction DF – deflection FDC – fire direction center
FDO – fire direction officer FM – fire mission FS – fuze setting GFT – graphical firing table
HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line MTO – message to observer
QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site
SP INSTR – special instructions VCO – vertical control operator VT – variable time



RECORD OF FIRE

CALL FOR FIRE

Observer R14 AF FFE S/S Tgt

Grid: 59834 39205 ALT 375

Polar: Dir Dis U/D VA

Shift: Dir: L/R +/- U/D

ROCKET POO

TGT ALT 375 DRIFT L20 | -BRTY ALT 375 +GFT L3 | VI 0 DF Corr L23 | ∠Si ÷ 10 | 10m Si | ΔFS | 100/R 6 | /R | 20/R 1 | HOB Corr

FIRE ORDER (3) VT | Df Corr L23 | Si 0

INITIAL FIRE COMMANDS | FM | MF | PLATOON (3) | Rg 16900 | Cht Df 3359 | El 552

Sp Instr | Sh | Lot | Chg 4 | Fz VT | Ti 51.0 | DF 3382 | QE 552

MTO H,VT (3), TGT# AL7235 | ∠T (190) | PER (39)>38 | TF (52) | in EFF | Ammo Exp (12) VT ✓

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
			EOM	EOM												

ROCKET POO DESTROYED

Btry 1/A | DTG 270155ZFEB13 | Tgt AL7235 | Replot Grid | Replot Alt

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SAMPLE

Legend:
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEST - destroyed
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
IS – immediate suppression
KN PT – known point
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
POO – point of origin
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure 9-18. Example Record of Fire for an HE/VT FFE Fire Mission.

EXAMPLE OF COMPLETING THE RECORD OF FIRE FOR A NONSTANDARD SQUARE WEIGHT WP OR HE PROJECTILE

9-37. Some projectiles may require corrections to firing data because of variations in square weight. The determination of firing data incorporates the use of the GFT and the TFT. The basic HE mission procedures must be altered to compensate for a deviation from the standard square weight from which the firing tables were developed. The TFTs have tables that correct for nonstandard conditions, one of which is projectile square weight. The computer must enter the appropriate TFT with the chart range to the target and the difference in square weight (increase or decrease). The difference in weight is determined by subtracting the standard square weight (or registration square weight) from the actual square weight of the projectile to be fired. The range correction factor is extracted and multiplied by the change in square weight. The result is expressed to the nearest 10 meters and is a signed value (±). This value is algebraically added to the chart range. This new range is known as the adjusted range and is used to compute elevation and all elements that are a function of elevation. The following steps apply to nonstandard square weight WP and HE projectiles.

Note: Normal HE procedures are followed until the observer requests a projectile with a nonstandard square weight.

9-38. Table 9-18 lists the procedures for processing a WP/Q FFE mission following HE adjustment. Figure 9-19 on page 9-31 shows an example ROF for this type of mission.

Table 9-18. WP/Q FFE Mission Following HE Adjustment Process.

STEP	*REFERENCE*	*ACTION*
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
3	Chart Rg	HCO determines and announces chart range. Computer/RTO reads back the range, and records it
4	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
5	Determine Difference in Square Weight	Computer/RTO determines difference in square weight. Subtract the standard weight from the square weight of the projectile to be fired. The difference is recorded as an increase (I) or decrease (D). Record computations in the lower computational space **(STD SQ WT – PROJ SQ WT = ▲SQ WT).**
6	Determine Unit Correction Factor	Computer/RTO determines unit correction factor. Enter Table F with the chart range to the nearest 100 meters (from step 3). Extract the range correction factor for a decrease or increase (column 18 or 19) for 1 square. Record this **signed value** in the lower computational space.
7	Rg Corr	Multiply the ▲SQ WT (step 5) by the unit correction factor (step 6). Express this value to the nearest 10 meters. This is the range correction.
8	Adjusted Rg	Add the range correction (step 7) to the chart range (step 3). Record this adjusted range in the right side of the range block. This value is used to determine elevation and all data that are a function of elevation.
9	El	Computer/RTO places the MHL of the appropriate GFT over the adjusted range (Step 8). Computer/RTO determines and records elevation.

Table 9-18. WP/Q FFE Mission Following HE Adjustment Process (continued).

STEP	***REFERENCE***	***ACTION***
10	Df	Computer/RTO determines and records deflection to fire **(CHT DF + DF CORR = DF).**
11	QE	Computer/RTO determines and records **QE (EL + SI = QE).**
12	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
13	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
14	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
Note: The range correction is determined for the initial nonstandard square weight projectile, and it is applied to all subsequent corrections for that particular projectile.		
Legend: CHG – charge CHT – chart CORR – correction DEV – deviation DF – deflection DIR – direction EL – elevation FS – fuze setting FZ – fuze GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line PROJ – projectile QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SQ – square STD – standard WT – weight		

RECORD OF FIRE

CALL FOR FIRE

Observer: R14 Tgt: ____ AF/FFE/IS/S (AF circled)
Grid: 6685 3765 ALT 350
Polar: Dir ____ Dis ____ U/D ____ VA ____
Shift: Dir: ____ L/R ____ +/- ____ U/D ____
REFUEL SITE I/O, WP I/E

TGT ALT 350 DRIFT L9
-BRTY ALT 375 +GFT L3
VI -25 DF Corr L12

ΔFS	
100/R	9
/R	
20/R	2
∠Si ÷ 10	10m Si
HOB Corr	

FIRE ORDER: (3), LOT W/H I/E
Df Corr: L12 Si: -2

INITIAL FIRE COMMANDS: FM (circled) MF ____ PLT ADJ, #3 (1) Rg 11700 Cht Df 2850 El 262
Sp Instr ____ Sh ____ Lot ____ Chg 4 Fz ____ Ti ____ DF 2862 QE 260
MTO H, (3) I/E, TGT# AL7244 ∠T (470) PEᴿ (<38) TF (29) (2) WP in EFF Ammo Exp (1)

SUBSEQUENT FIRE COMMANDS

Tgt	Location	Priority	Firing Unit													
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L12)	Df Fired	Chart Rg	HOB Corr	Si (-2)	El	QE	Exp	Type
1300	R80	+100					2872	L12	2884	11780		-2	265	263	(2)	Q
		+50	FFE	PLT (3) SH WP LOT W/H			2873	L12	2885	11790/11760		-2	264	262	(12)	WP
			EOM	EOM												

WP ØWT 7Ø UNIT CORR FAC -11 M CHT RG 11790 REFUEL SITE BURNING, EST 2 CAS
-STD ØWT 4Ø X I3Ø + RF CORR -30
ΔØWT I3Ø RG CORR -33 ≈ -30M ADJ RG 11760

Btry 1/A | DTG 270344ZFEB13 | Tgt AL7244 | Replot Grid | Replot Alt

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SAMPLE

Legend:
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FAC – factor
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
IS – immediate suppression
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
STD – standard
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time
WP – white phosphorous
WT – weight

Figure 9-19. Example Record of Fire for an HE Adjust-Fire Mission with WP/Q in Effect.

SECTION III: HIGH ANGLE FIRE

9-39. High-angle fire is used for firing into or out of deep defilade such as that found in heavily wooded, mountainous, and urban areas. It is also used to fire over high terrain features near friendly troops (figure 9-20). The observer may request high-angle fire on the basis of terrain in the target area. The FDO also may order high-angle fire on the basis of a terrain analysis from the firing unit position to the target area (i.e. intervening crests, see Chapter 15). The primary characteristic of high-angle fire is that an increase in elevation causes a decrease in range. Because high-angle fire involves large quadrant elevations and long times of flight, it will not be as responsive as low-angle fire to the immediate needs of a maneuver force. Trajectories are vulnerable to enemy detection. The long time of flight makes it more difficult for the observer to identify his round, and corrections may change drastically from round to round. To help the observer, FDC personnel will announce **SPLASH** 5 seconds before each round impacts. To further help the observer, the FDC announces time of flight in the MTO.

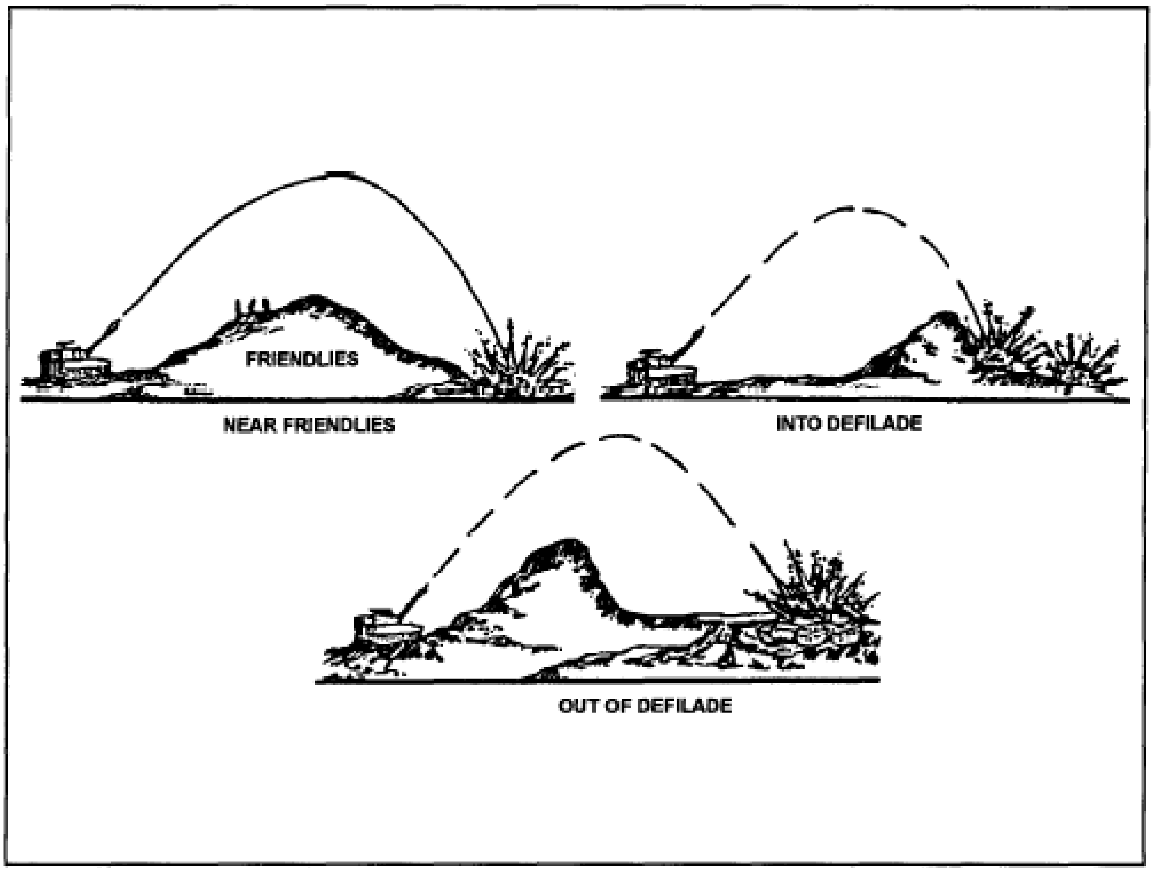


Figure 9-20. High Angle Fire.

DUTIES OF PERSONNEL IN HIGH-ANGLE FIRE

9-40. Except for differences noted in this section, the procedures for high-angle fire are the same as low-angle fire. Duties of FDC personnel in high-angle fire differ in several ways as described below.

9-41. The FDO does the following:

- Includes the command HIGH ANGLE in his fire order.
- Considers high-angle fire characteristics in selecting the shell and fuze to fire.
  - Antipersonnel improved conventional munitions (APICM) and DPICM can be used in high-angle fire for the same types of targets as in low-angle fire.

- The high-angle trajectory has two inherent characteristics that affect munitions selection: a steep angle of fall and large probable errors. The steep angle of fall means the projectile is almost vertical as it approaches the ground. When the HE projectile bursts, the side spray contains most of the fragmentation. Since the projectile is nearly vertical, side spray is in all directions and nearly parallel to the ground, providing a more consistent fragmentation saturation to a larger area (figure 9-21). Thus, shell HE with fuze quick or fuze VT is very effective when fired high angle.

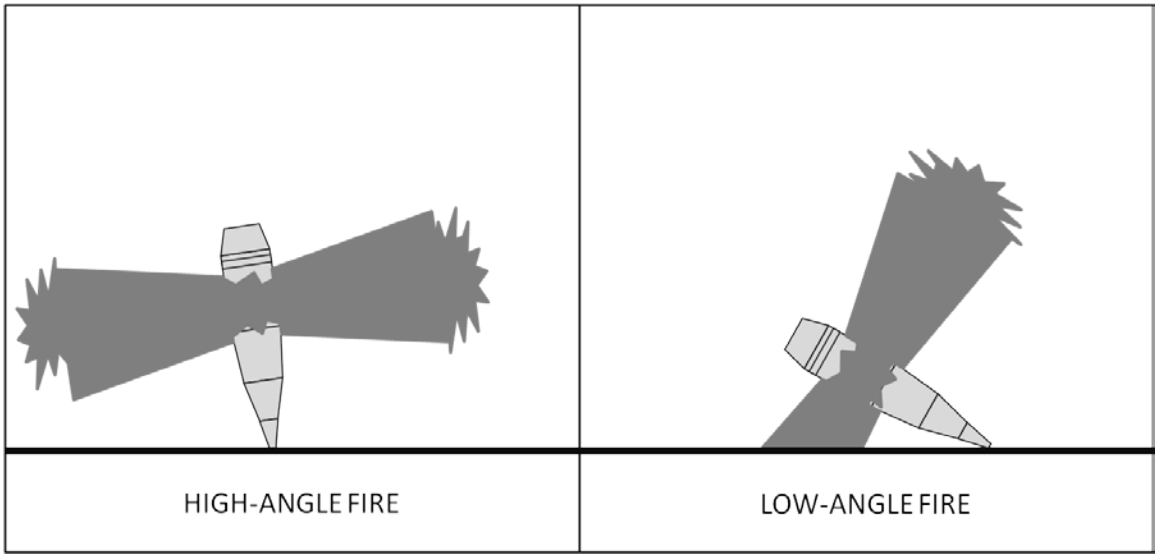


Figure 9-21. High-Angle Side Spray Compared to Low-Angle Side Spray.

Note: The large probable errors in height of burst makes the use of time fuzes impractical in high-angle fire and SHOULD BE AVOIDED.

9-42. The VCO computes and announces angle of site rather than site.

9-43. The Computer does the following:

- Selects the charge to be fired (if it is not announced in the fire order). High-angle fire has two characteristics that affect the selection of charge: a shorter range span for each charge and a range overlap between charges. The range span within which accurate fire can be delivered by a particular charge is less for high-angle fire than for low-angle fire. This may cause a problem during a high-angle fire mission, because a large observer correction may move the round outside the capabilities of the initial charge fired. This, in turn, will necessitate changing charges. Changing charges in a high-angle fire mission is sometimes unavoidable, although it is not desirable. For this reason, the computer initially selects the charge that is least likely to require changing. As a guideline, he selects the lowest charge that allows for a range shift of at least 500 meters short of and 500 meters beyond the initial chart range.
- Includes drift correction. Drift is appreciably greater in high-angle fire than in low-angle fire. Because drift changes a great amount for a relatively small elevation change, the computer determines drift (recorded as the deflection correction) for each elevation. The correction is always applied to the left. If a GFT setting is available for the high-angle GFT, the computer will determine drift and algebraically add it to the GFT deflection correction. The sum is the deflection correction to be applied to the chart deflection.
- Includes site in the computation of QE unless the FDO directs otherwise. Site is included when the angle of site is large or when a high-angle registration or a mass mission is being fired. If site is to be ignored, the FDO announces IGNORE SITE in the fire order. Since one of the criteria for ignoring site is a small angle of site, the FDO may have to wait for the VCO to compute and

announce angle of site. In this situation, the FDO issues a fire order and later supplements it with the command IGNORE SITE.

- Announces HIGH ANGLE as a special instruction when sending initial fire commands to the howitzers.
- The RTO announces the time of flight in the message to observer and announces SPLASH for each round.

EXAMPLE OF COMPLETING THE ROF FOR AN HE HIGH-ANGLE ADJUST-FIRE MISSION

9-44. The steps in table 9-19 are used to process a HE high-angle adjust-fire mission. Figure 9-22 on page 9-36 shows an example ROF for this type of mission.

Table 9-19. HE High-Angle Adjust-Fire Mission.

STEP	*REFERENCE*	*ACTION*
1	CFF	Computer/RTO reads back and records the CFF announced by the RTO.
2	Fire Order	Computer/RTO reads back and records the fire order announced by the FDO.
3	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Computer/RTO circles warning order.
	MF	Computer/RTO determines and records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records HIGH-ANGLE as directed by the fire order.
	Sh	Computer/RTO records **if other than standard**, as directed by the fire order.
	Lot	Computer/RTO records **if other than standard**, as directed by the fire order.
	Fz	Computer/RTO records **if other than standard**, as directed by the fire order.
4	MTO	Computer/RTO records the MTO announced by the RTO.
5	Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate high-angle GFT over the announced range, reads back the range, and records it.
6	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
7	Chg	Computer/RTO determines and records charge, if not announced in the fire order.
8	El	Computer/RTO determines and records elevation.
9	Drift	Computer/RTO determines and records drift in the upper computational space
10	Df Corr	Computer/RTO records deflection correction. This is the sum of drift plus the GFT deflection correction **(Drift + GFT DF CORR = DF CORR)**. If no GFT deflection correction is available, the deflection correction will be the same as drift.
11	Df	Computer/RTO determines and records the deflection to fire. **(CHT DF + DF CORR = DF TO FIRE).**
12	∡Si÷10	VCO determines and announces angle of site. Computer/RTO divides the angle of site by 10 and records it to the nearest tenth (0.1). This is a signed (±) value.
13	10mSi	Computer/RTO determines the 10-mil site factor from the GFT or TFT and records it to the nearest tenth (0.1). . **This value is always negative**.
14	SI	Computer/RTO determines and records site **(∡Si÷10 x 10mSi = SI).**
		NOTE: High-Angle site will always have the opposite sign of VI.

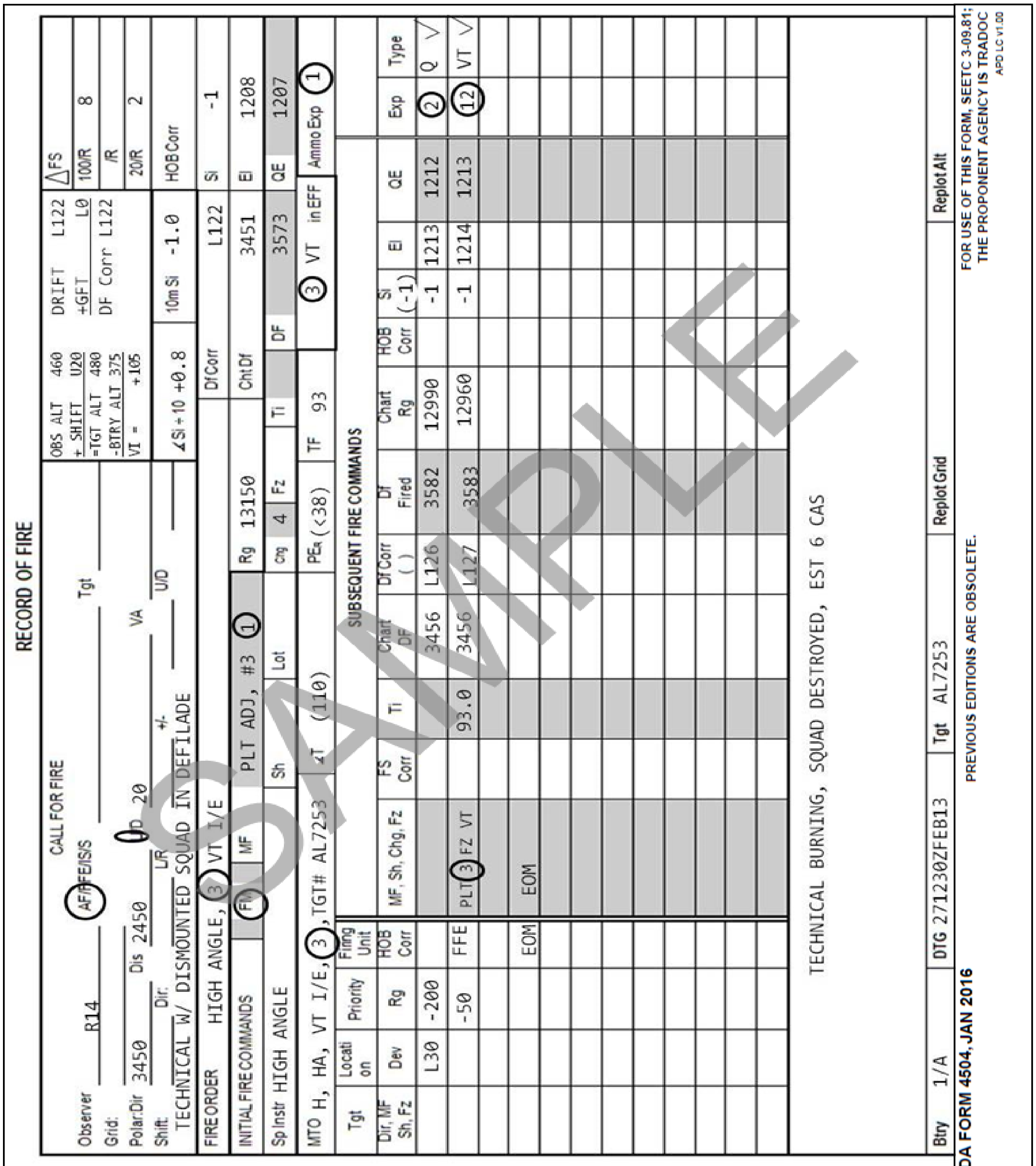
Table 9-19. HE High-Angle Adjust-Fire Mission (continued).

STEP	REFERENCE	ACTION
15	QE	Computer/RTO determines and records quadrant elevation. **(SI+EL=QE).**
16	In Eff	Computer/RTO records the method of fire for effect as directed by the fire order.
17	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
18	Transmit	Chief/Computer transmits fire commands to the howitzer(s).
19	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations. The deflection correction is not carried down. Drift is determined for each subsequent adjustment and added to GFT DF correction.
Legend: CFF – call for fire CHG – charge CHT – chart CORR – correction DF – deflection FDC – fire direction center FDO – fire direction officer FM – fire mission FS – fuze setting GFT – graphical firing table HCO – horizontal control operator M – mil MF – method of fire MHL – manufacturer's hair line MTO – message to observer QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions TFT – tabular firing table VCO – vertical control operator		

9-45. The steps in table 9-20 are used to process a high-angle subsequent adjustment. An example ROF for this entire mission is shown in figure 9-22 on page 9-36.

Table 9-20. High-Angle Subsequent Adjustment.

STEP	REFERENCE	ACTION
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
3	Chart Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate high-angle GFT over the announced range, reads back the range, and records it.
4	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
5	El	Computer/RTO determines and records elevation.
6	Ti	Computer/RTO determines and records VT fuze setting (if required).
7	Df Corr	Computer/RTO records deflection correction. This is the sum of drift plus the GFT deflection correction (**Drift + GFT DF CORR = DF CORR).** If no GFT deflection correction is available, the deflection correction will be the same as drift.
9	Df	Computer/RTO determines and records the deflection. **(CHT DF + DF CORR = DF TO FIRE).**
10	QE	Computer/RTO determines and records the quadrant**. (EL + SI = QE).**
11	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
12	Transmit	Chief/Computer transmits fire commands to the howitzer(s).
13	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
Legend: CHG – charge CHT – chart CORR – correction DEV – deviation DF – deflection DIR – direction EL – elevation FDO – fire direction officer FS – fuze setting FZ – fuze GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site TI – time VT – variable time		



RECORD OF FIRE

CALL FOR FIRE

Observer R14 AF/FFE/IS/S Tgt

Grid:

Polar:Dir 3450 Dis 2450 U/D 20 VA

Shift: Dir: L/R +/- U/D

TECHNICAL W/ DISMOUNTED SQUAD IN DEFILADE

OBS ALT 460
+ SHIFT U20
=TGT ALT 480
-BTRY ALT 375
VI = +105

DRIFT L122
+GFT L0
DF Corr L122

∆FS | 100/R 8 | /R | 20/R 2

∠Si ÷ 10 +0.8 | 10m Si -1.0 | HOB Corr

FIRE ORDER HIGH ANGLE, 3 VT I/E | Df Corr L122 | Si -1

INITIAL FIRE COMMANDS FM | MF PLT ADJ, #3 1 | Rg 13150 | Cht Df 3451 | El 1208

Sp Instr HIGH ANGLE | Sh | Lot | Chg 4 | Fz | Ti | DF 3573 | QE 1207

MTO H, HA, VT I/E, 3 ,TGT# AL7253 | ∠T (110) | PE_R (<38) | TF 93 | 3 VT in EFF | Ammo Exp 1

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si (-1)	El	QE	Exp	Type
	L30	-200					3456	L126	3582	12990		-1	1213	1212	2	Q √
		-50	FFE	PLT 3 FZ VT		93.0	3456	L127	3583	12960		-1	1214	1213	12	VT √
			EOM	EOM												

TECHNICAL BURNING, SQUAD DESTROYED, EST 6 CAS

Btry 1/A | DTG 271230ZFEB13 | Tgt AL7253 | Replot Grid | Replot Alt

DA FORM 4504, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC APD LC v1.00

SAMPLE

Legend:

AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
IS – immediate suppression
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure 9-22. Example Record of Fire for an HE High-Angle Adjust-Fire Mission.

SECTION IV: ILLUMINATION

9-46. Illuminating projectiles are available for the 105-mm and the 155-mm howitzers in both visible light and Infrared (IR). They are used to illuminate a designated area for observing enemy night operations, for adjusting artillery fires at night, for marking locations, for friendly direction, or in laser locator missions.

9-47. Illuminating projectiles are base-ejection projectiles fired with time fuzes. The filler consists of an illuminating canister and a parachute assembly. The FDO should select the lowest practical charge to prevent a malfunction caused by the parachute ripping when the flare is ejected from the projectile.

OVERVIEW

9-48. Illumination is conducted by using one of the following techniques: one-gun, two-gun, and four-gun illumination patterns.

9-49. The one-gun illumination pattern is used when effective illumination can be achieved by firing one round at a time.

9-50. The two-gun illumination pattern is used when an area requires more illumination than one gun can furnish.

- The two-gun illumination pattern is used when the area to be illuminated requires more illumination than one projectile can furnish. This pattern provides two separate illumination rounds be fired 50 meters apart from the target location, perpendicular to the GTL.
- The two-gun illumination range spread pattern is used when the area to be illuminated has greater depth than width. This pattern provides two separate illumination rounds fired one effective burst width apart from the target location, parallel to the observer-target (OT) line.
- The two-gun illumination lateral spread pattern is used when the area to be illuminated has greater width than depth. This pattern provides two separate illumination rounds fired one effective burst width apart from the target location, perpendicular to the OT line.

9-51. The four-gun illumination pattern is used to illuminate a large area. Four rounds are fired at the same time by using both the lateral and range spread patterns. This is more commonly referred to as the four-gun illumination range and lateral spread.

ILLUMINATION FIRING DATA

9-52. The illumination projectile is not weight-zoned. It is designed to illuminate a large area (figure 9-23 on page 9-38). The minimum corrections from the observer are 200 meters for range and deviation and 50 meters for HOB. All subsequent HOB corrections are always given in multiples of 50 meters. Because of these characteristics, the determination of firing data is significantly different from HE. Drift, site, and elevation are not determined. However, an illumination HOB is determined. The HOB is used in conjunction with range to determine QE and FS. Therefore, any HOB correction sent by the observer will cause both the FS and QE to change.

9-53. The HCO determines chart data in the same manner as in an HE mission. The VCO determines VI in the same manner as in an HE mission. The computer will express the VI determined by the VCO to the nearest 50 meters.

CANNON	PROJECTILE	ILLUM TYPE	OPTIMAL HEIGHT OF BURST (METERS)	EFFECTIVE ILLUM DIAMETER (SPREAD)	BURNING TIME (SECONDS)	RATE OF CONTINUOUS ILLUMINATION (PER MINUTE)	RATE OF FALL (M/S)
105 mm	M314A2	VL	750	800	60	2	10
	M1064	IR	750	800	60	2	10
155 mm	M485A2	VL	600	1000	120	1	5
	M1066	IR	600	2400	120	1	5
	M1123	IR	600	2400	120	1	5
	M1124	VL	600	1000	120	1	5
Legend: IR – infrared VL – visible light							

Figure 9-23. Employment Factors for Illuminating Projectiles.

DETERMINATION OF ILLUMINATION FIRING DATA WITH THE GFT

9-54. The appropriate HOB scale is determined by applying the VI determined by the computer to the optimum HOB for the illuminating projectile being fired. During subsequent adjustments, the observer's HOB correction is applied to the previous HOB determined.

9-55. QE is determined by placing the MHL over the chart range. The QE is determined by visually interpolating the point of intersection of the MHL and the appropriate HOB scale. Determine QE to the nearest mil.

9-56. Fuze setting is determined in the same manner as QE; that is, by placing the MHL over the chart range. Fuze setting is determined by visually interpolating between the red fuze setting arcs along the selected HOB scale. To determine the value of the arcs, follow the arcs to the bottom of the GFT. This fuze setting is for the M762 ET fuze. To determine a fuze setting for MT M565, enter Table B, Part 2, of the TFT and apply the FS correction to the ET M762 value. Determine FS to the nearest tenth (0.1).

DETERMINATION OF ILLUMINATION FIRING DATA WITH THE TFT

9-57. Part 2 of the TFT deals exclusively with illum data. Each charge has three tables, Tables A, B, and C. Table A lists basic data, Table B lists corrections to fuze setting, and Table C list trajectory information for graze burst data (typically used for illum safety computations).

9-58. FS and QE are determined by entering Table A with the chart range (expressed to the nearest 100 meters). QE is extracted from Column 2 (QUAD ELEV) and M762 FS from Column 3 (FS). These values are for the optimum HOB and must be corrected for VI.

9-59. HOB corrections are made in 50-meter increments. Columns 4 and 5 of Table A list the corrections to QE and FS for an increase of 50 meters in HOB. The VI is expressed to the nearest 50 meters. Once the VI is expressed, it is divided by 50 to determine the number of 50-meter increments that are needed. The number of 50-meter increments are multiplied by the value in Column 4 (QE) and Column 5 (FS). These values are applied to QE and FS. For a positive VI, the values are added; for a negative VI, the values are subtracted. These corrected values are the FS and QE that should be fired. The corrections in columns 4 and 5 must be applied together.

9-60. To process HOB corrections, divide the observer's HOB correction by 50. This will provide the number of 50-meter increments. Multiply the number of 50-meter increments by the values in Columns 4 and 5. Apply this correction value as described above.

9-61. 100/R can be determined manually by using the mil relation formula by dividing 100 by the range in thousands and multiplying that value by 1.0186. The result is expressed to the nearest mil.

Note: The FS determined from the illumination GFT or from Table A, Part 2, Column 3 of the TFT is for the M762 fuze. A correction value must be applied to determine a fuze setting for the M565 fuze. Table B of the TFT lists the correction values. To determine a correction value, enter Table B with the FS for the M762 fuze. Apply this FS correction to the FS for the M762 fuze. The resulting value is a FS for the M565 fuze.

PROCESSING A ONE-GUN ILLUMINATION FIRE MISSION

9-62. The steps in table 9-21 are used to process a one-gun illumination mission. Figure 9-24 on page 9-41 shows an example ROF for this type of mission. The time fuze being fired is M762.

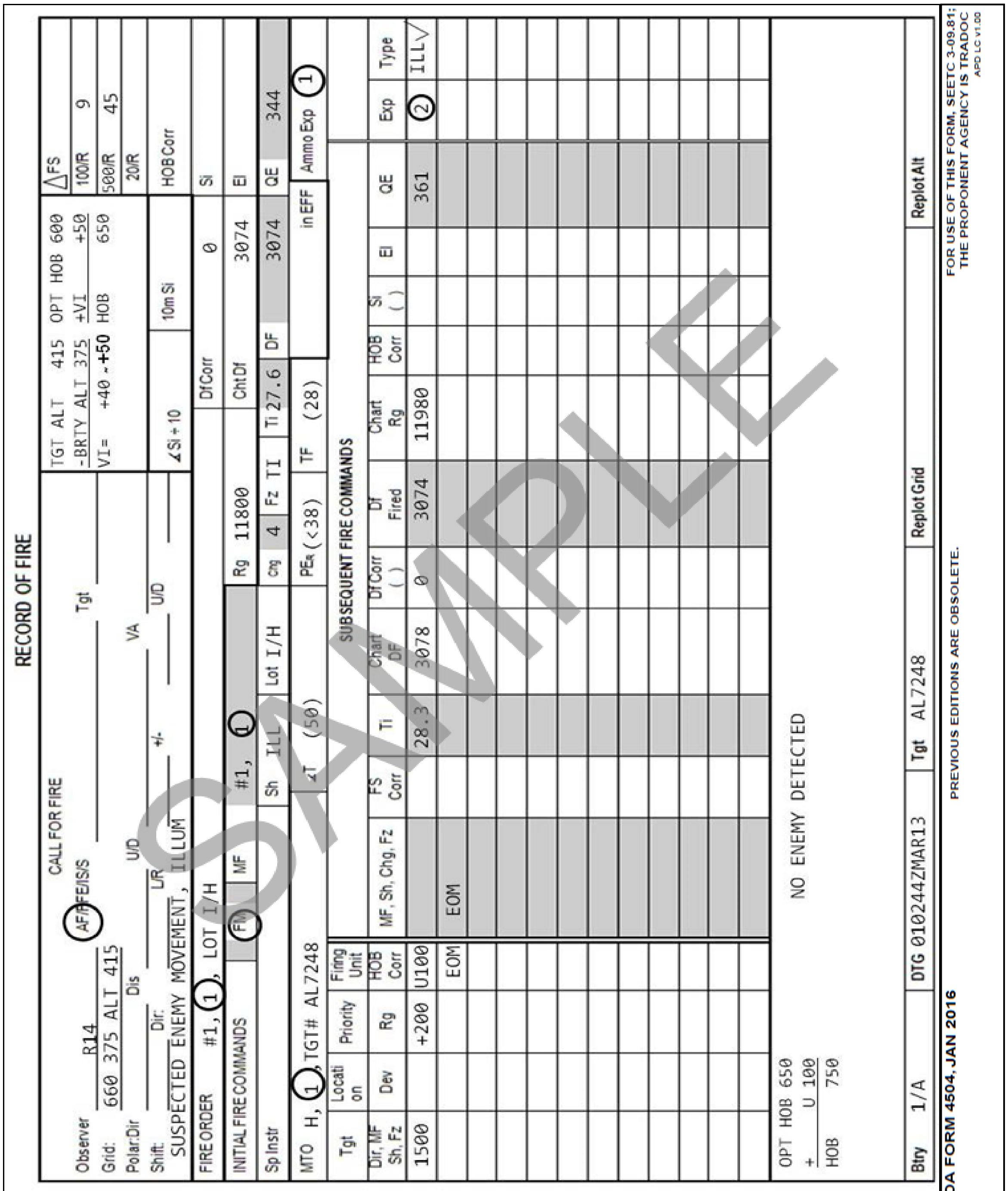
Table 9-21. One-Gun Illumination Fire Mission Process.

STEP	***REFERENCE***	***ACTION***
1	CFF	Computer/RTO reads back and records the CFF announced by the RTO.
2	Fire Order	Computer/RTO reads back and records the fire order announced by the FDO.
3	Fire Cmds	Computer/RTO determines and records the fire commands.
	FM	Computer/RTO circles warning order.
	MF	Computer/RTO records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records as directed by the fire order.
	Sh	Computer/RTO records shell illumination.
	Lot	Computer/RTO records lot for shell illumination.
	Chg	Computer/RTO records charge. If not announced in the FO, and no standard is in effect, computer will determine charge after receiving chart range.
	Fz	Computer/RTO records fuze time.
4	MTO	Computer/RTO records the MTO announced by the RTO.
5	Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, & records.
6	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
7	VI	VCO determines and announces VI. Computer/RTO records in the upper computational space and expresses VI to the nearest 50 meters.
8	Illumination HOB	Computer/RTO determines the HOB by modifying the optimum HOB. The VI is applied to the optimum HOB and recorded in the upper computational space. This value determines the HOB scale to be used on the GFT.
9	Ti (M762)	Computer/RTO determines and records time setting for fuze time.
10	Df	Computer/RTO records the chart deflection, this is the deflection to fire
11	QE	Computer/RTO determines and records the quadrant elevation directly from the GFT using the appropriate HOB scale.
12	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
13	Transmit	Chief/Computer transmits fire commands to the howitzer(s).
14	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded; also determines and records data that could be used in subsequent computations.
	Note: During the police of the ROF for an illumination mission, the value for __/R is determined. This value is a multiple of 100/R. It is either 400/R (for 105mm) or 500/R (for 155mm) determined at the initial chart range.	
Legend: CFF – call for fire CHG – charge DF – deflection FDO – fire direction officer FM – fire mission FO – forward observer GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line MTO – message to observer QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions TI – time VCO – vertical control operator VI – vertical interval		

9-63. The steps in table 9-22 are used to process an illumination subsequent adjustment. An example ROF for this entire mission is shown in figure 9-24 on page 9-41. The time fuze being fired is the M762.

Table 9-22. Illumination Subsequent Adjustment.

STEP	***REFERENCE***	***A CTION***
1	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO records the observer's direction and subsequent corrections.
2	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
3	Chart Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the illumination GFT over the announced range, reads back the range, and records it.
4	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
5	HOB	Computer/RTO determines the HOB by applying the observer's up or down correction to the previous HOB. The computations are performed in the lower computational space. This value determines the HOB scale to be used on the GFT.
6	Ti (M762)	Computer/RTO determines and records the time setting for fuze time.
5	Df	Computer/RTO records the chart deflection as the deflection to fire.
6	QE	Computer/RTO determines and records the quadrant elevation directly from the GFT using the appropriate HOB scale.
7	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
8	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
9	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
Legend: CHG – charge CORR – correction DEV – deviation DF – deflection DIR – direction EL – elevation FDO – fire direction officer FZ – fuze GFT – graphical firing table HCO – horizontal control operator HOB – height of burst MF – method of fire MHL – manufacturer's hair line QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell TI – time		



Legend:

AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
ILL – illumination
IS – immediate suppression
L/R – left/right
MF – method of fire
OPT – optimum
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-24. Example Record of Fire for a One-Gun Illumination Fire Mission.

TWO-GUN ILLUMINATION RANGE SPREAD.

9-64. A two-gun range spread requires two illuminating projectiles to function parallel in relation to the OT line to provide the maximum range coverage. The projectiles are fired one effective illumination diameter apart (refer to figure 9-23 on page 9-38). To determine the aimpoints, the HCO will place two separate plotting pins one-half the illumination diameter over and short of the target location, along the OT line, announced in the CFF. The HCO will then determine and announce chart data (chart range and chart deflection) to both aimpoints. The computer will in turn determine firing data to both sets of chart data.

9-65. Use table 9-23 to process a two-gun illumination range spread fire mission. An example ROF for this entire mission is shown in figure 9-25 on page 9-44. The time fuze being fired is fuze M762.

TWO-GUN ILLUMINATION LATERAL SPREAD

9-66. A two-gun lateral spread requires two illuminating projectiles to function perpendicular in relation to the OTL to allow for the maximum lateral coverage. The projectiles are fired one effective illumination diameter apart (refer to figure 9-23 on page 9-38). To determine the aimpoints, the HCO will place two separate plotting pins one-half the illumination diameter left and right of the target location, along the OT line, announced in the CFF. The HCO will then determine and announce chart data (chart range and chart deflection) to both aimpoints. The computer will in turn determine firing data to both sets of chart data.

9-67. Use table 9-23 to process a two-gun illumination lateral spread fire mission. The time fuze being fired is fuze M762.

Table 9-23. Two-Gun Illumination Pattern Fire Mission Process.

STEP	*REFERENCE*	*ACTION*
1	CFF	Computer/RTO reads back and records the CFF announced by the RTO.
2	Fire Order	Computer/RTO reads back and records the FO announced by the FDO.
3	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Computer/RTO circles warning order.
	MF	Computer/RTO determines and records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records as directed by the fire order.
	Sh	Computer/RTO records shell illumination.
	Lot	Computer/RTO records lot for shell illumination.
	Chg	Computer/RTO records charge. If not announced in the fire order, and no standard is in effect, computer will determine charge after receiving chart range.
	Fz	Computer/RTO records fuze time.
4	MTO	Computer/RTO records the MTO announced by the RTO.
5	Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the illumination GFT over the announced range, reads back the range, and records it.
6	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
	Note: Steps 5 and 6 are completed for both sets of chart data the HCO determined for the two separate aimpoints. The data are recorded on the corresponding line for each aimpoint in the subsequent fire commands block.	
7	VI	VCO determines and announces VI. Computer/RTO records in the upper computational space and expresses VI to the nearest 50 meters.

Table 9-23. Two-Gun Illumination Pattern Fire Mission Process (continued).

STEP	***REFERENCE***	***ACTION***
8	Illumination HOB	Computer/RTO determines the HOB by modifying the optimum HOB. The VI is applied to the optimum HOB. This value determines the HOB scale to be used on the GFT.
9	Ti (M762)	Computer/RTO determines and records time setting for fuze time.
10	Df	Computer/RTO records the chart deflection, this is the deflection to fire
11	QE	Computer/RTO determines and records the quadrant elevation directly from the GFT using the appropriate HOB scale.
	Note: Steps 9 through 11 are completed for both sets of chart data the HCO determined for the two separate aimpoints. The data are recorded on the corresponding line for each aimpoint in the subsequent fire commands block.	
12	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
13	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
14	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
	Note: During the police of the ROF for an illum mission, the value for __/R is determined. This value is a multiple of 100/R. It is either 400/R (for 105mm) or 500/R (for 155mm) determined at the initial chart range.	
Legend: CFF – call for fire CHG – charge DF – deflection FDO – fire direction officer FM – fire mission GFT – graphical firing table HCO – horizontal control operator HOB – height of burst MF – method of fire MHL – manufacturer's hair line MTO – message to observer QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions TI – time VCO – vertical control operator VI – vertical interval		

RECORD OF FIRE

CALL FOR FIRE

Observer: R14 — AF / FFE (circled) / S/S — Tgt

Grid: 690 344 ALT 395

Polar: Dir — Dis — U/D — VA

Shift: Dir: — L/R — +/- — U/D

SUSPECTED ENEMY MOVEMENT, ILLUM

FIRE ORDER: #2, #3, AMC, (1), LOT I/H

INITIAL FIRE COMMANDS: FM (circled) — MF: #2, #3, (1) — Rg

Sp Instr: AMC, SPEC CORR — Sh: ILL — Lot: I/H — Chg: 4 — Fz: TI — Ti — DF — QE

MTO: H, (1), TGT# AL7250 — ∠T (150) — PE_R (<38) — TF (24) — in EFF — Ammo Exp

TGT ALT 395 OPT HOB 600
-BRTY ALT 375 ±VI 0
VI= +20 ∠ 0 HOB 600

ΔFS	
100/R	9
500/R	45
20/R	

∠Si ÷ 10 — 10m Si — HOB Corr

Df Corr — Si

Cht Df — El

DF — QE

SUBSEQUENT FIRE COMMANDS

Tgt: Dir, MF Sh, Fz	Location: Dev	Priority: Rg	Firing Unit: HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
1700					#2	24.2	2858	0	2858	10880				307		
					#3	27.4	2861	0	2861	11750				338	(2)	ILL✓
			EOM	EOM												

NO ENEMY DETECTED

Btry 1/A	DTG 010354ZMAR13	Tgt AL7250	Replot Grid	Replot Alt

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FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC

APD LC v1.00

SAMPLE

Legend:

AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
ILL – illumination
IS – immediate suppression
L/R – left/right
MF – method of fire
OPT – optimum
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
SPEC CORR – special corrections
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-25. Example Record of Fire for a Two-Gun Illumination Range Spread Fire Mission.

FOUR-GUN ILLUMINATION–RANGE AND LATERAL SPREAD

9-68. The four-gun illumination pattern is used to illuminate a large area in width and depth. Four rounds are fired at the same time by using the range and lateral spread patterns. The observer may request a range and lateral spread in the initial CFF or may request this pattern during a subsequent correction as part of a one-gun or two-gun (range or lateral spread) illumination mission.

9-69. To process a four-gun illumination mission, combine the procedures for the two-gun range spread and the two-gun lateral spread illumination missions (see table 9-23 on page 9-42). The flank howitzers will fire the two-gun lateral spread while the interior howitzers will fire the two-gun range spread.

9-70. If the four-gun illumination mission is requested during a subsequent correction, the FDO must initiate a new fire order and the computer will announce new initial fire commands.

9-71. An example ROF for this type of mission is shown in figure 9-26 on page 9-46. The time fuze being fired is the M762.

COORDINATED ILLUMINATION

9-72. A coordinated illumination mission is a combination of an illum mission (one-gun, two-gun, two-gun range or lateral spread, or four-gun range and lateral spread) and another fire mission (normally HE). The illumination is adjusted by the observer until the target is illuminated. When the best target illumination is achieved, the observer will transmit ILLUMINATION MARK. Once the observer has marked the illumination round, he will request coordinated illumination and transmit another call for fire. The FDC will process both missions following normal procedures. The rounds will be fired at a predetermined interval that will ensure the rounds of the second mission function when the target is best illuminated. This allows the observer to make the needed corrections and observe the effects. The firing interval may be controlled by either the FDC or observer. The preferred method is for the FDC to control the firing interval.

9-73. Every time an illumination round is fired, the FDC will start a stopwatch. When the target receives the best illumination, the observer will announce ILLUMINATION MARK. The FDC will stop the stopwatch. This time interval is known as the illumination mark time and this value is recorded. When the second call for fire is received, the FDC must compute the TOF for the second mission. This TOF plus a five-second reaction time is subtracted from the illumination mark time and the difference is the firing interval (ILLUM MARK TIME – (TOF + 5 SECONDS) = FIRING INTERVAL). At this point, the FDC must ensure both missions are at my command (AMC). The FDC commands the howitzer(s) firing the illumination mission to fire. The stopwatch is started as the illumination mission is fired. When the firing interval is reached, the FDC commands the howitzer(s) firing the second mission to fire.

9-74. The observer may request by round at my command. In this situation, the observer wishes to control the firing of both missions. The FDC will compute data, ensuring both missions are at my command. The FDC must also transmit the TOF of the second mission to the observer. When the howitzers for both missions report READY, the FDC will relay this information to the observer. The observer commands the firing of the illum mission. After determining the firing interval, the observer commands the firing of the second mission at the appropriate time.

9-75. Use the steps in table 9-24 on page 9-47 to determine the firing interval. Example ROFs for this type of mission are shown in figures 9-28 (page 9-48) and 9-29 (page 9-49). The illumination time fuze being fired is the M762.

9-76. An example of determining the firing interval is shown in figure 9-27 on page 9-47.

9-77. When coordinated illumination is requested, the FDO must initiate a new fire order for the second mission and the computer will announce new initial fire commands. If the howitzers that are firing the illumination are also included in the second mission, the FDC must ensure those howitzer sections understand they are firing both missions and inform them of the firing interval between missions.

RECORD OF FIRE

CALL FOR FIRE		TGT ALT 460 / -BRTY ALT 375 / VI=+85 - +100	OPT HOB 600 / +VI 100 / HOB 700	ΔFS
Observer R14	AF (FFE) S/S ___ Tgt ___			100/R 9
Grid: 701 364 ALT 460				500/R 45
Polar:Dir ___ Dis ___ U/D ___ VA ___				20/R
Shift: ___ Dir: ___ L/R ___ +/- ___ U/D ___		∡Si ÷ 10	10m Si	HOB Corr
SUSPECTED ENEMY MOVEMENT, ILLUM				

FIRE ORDER	#1, (1), LOT I/H		Df Corr	0	Si
INITIAL FIRE COMMANDS	(FM)	MF #1, (1)	Rg 14560	Cht Df 2867	El
Sp Instr	Sh ILL	Lot I/H	Chg 4 Fz TI Ti 39.3	DF 2867	QE 480
MTO H, (1), TGT# AL7257	∡T (240)		PER (<38)	TF (39)	in EFF / Ammo Exp (1)

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
4300		-400	D100			38.1	2940	0	2940	14330				458	(2)	
RG + LAT SPREAD				(FO: AMC (1)												
				LOT I/H)												
				PLT (1) AMC	#1	37.5	2977	0	2977	14280				450		
				SPEC CORR,	#2	35.8	2942	0	2942	13800				430		
				SH ILL,	#3	44.4	2941	0	2941	14810				486		
				LOT I/H,	#4	37.9	2906	0	2906	14270				455	(6)	ILL ✓
				CHG 4, FZ TI												
			EOM	EOM												

OPT HOB 700
\+ D 100
HOB 600

NO ENEMY DETECTED

Btry 1/A	DTG 010623ZMAR13	Tgt AL7257	Replot Grid	Replot Alt

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SAMPLE

Legend:
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
ILL – illumination
IS – immediate suppression
L/R – left/right
LAT – lateral
MF – method of fire
OPT – optimum
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
SPEC CORR – special corrections
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-26. Example ROF for a Four-Gun Illumination Range and Lateral Spread Fire Mission.

Table 9-24. Determination of the Firing Interval.

STEP	***ACTION***
1	Record the number of seconds to the best illumination **(ILLUMINATION MARK),** as determined with the stopwatch.
2	Record the time of flight for the second mission plus 5 seconds.
3	Subtract step 2 from step 1 to determine the firing interval.

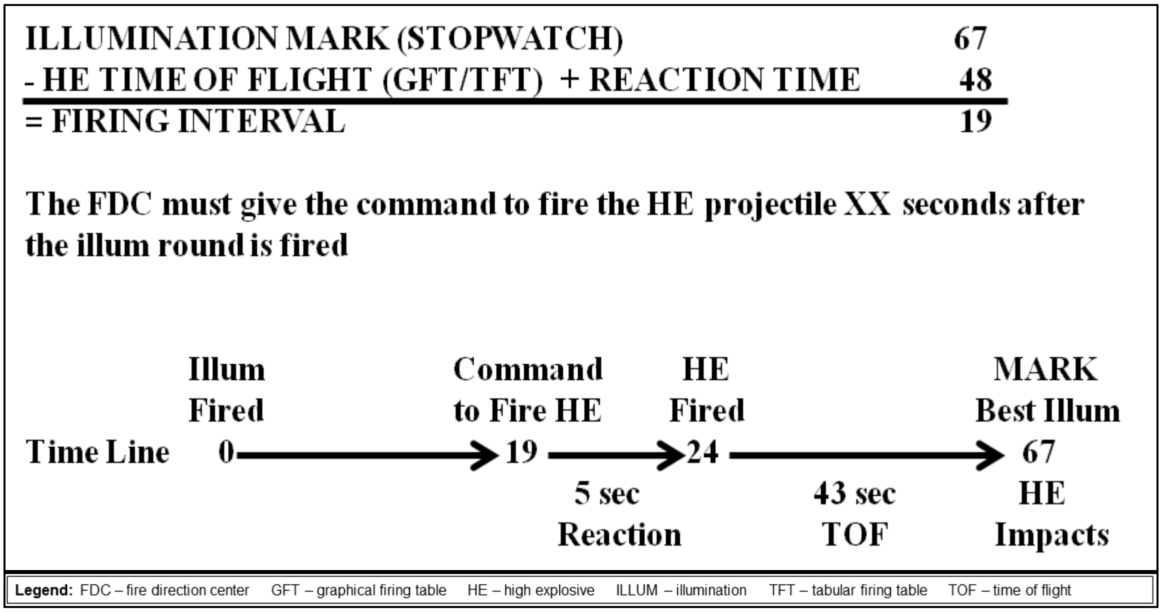
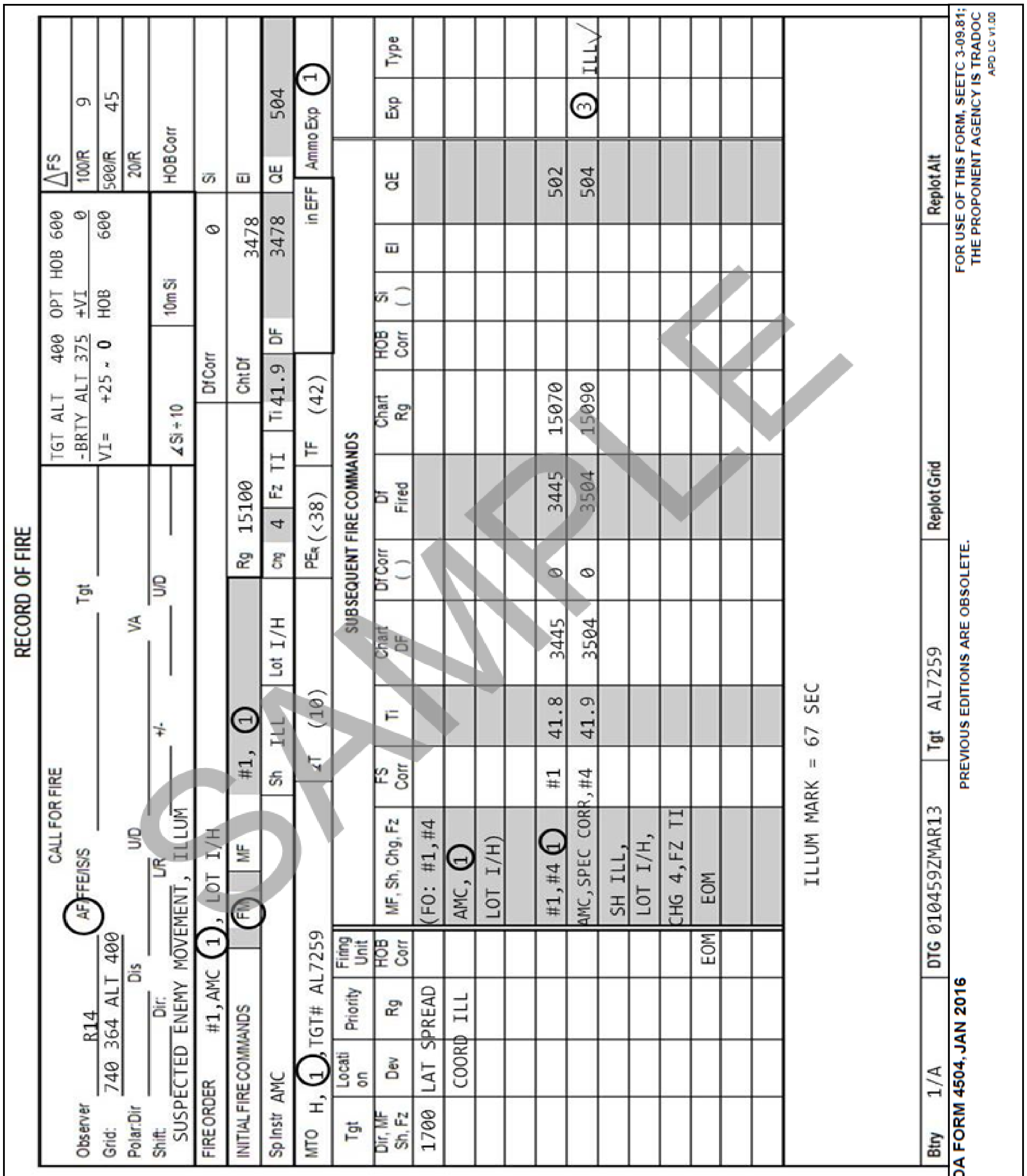


Figure 9-27. Determination of Firing Interval for a Coordinated Illumination Mission.


RECORD OF FIRE

CALL FOR FIRE

Observer R14 AF FFE/IS/S Tgt

Grid: 740 364 ALT 400

Polar:Dir Dis U/D VA

Shift: Dir: L/R +/- U/D

SUSPECTED ENEMY MOVEMENT, ILLUM

TGT ALT 400 OPT HOB 600

-BRTY ALT 375 +VI 0

VI= +25 ÷ 0 HOB 600

∆FS

100/R 9

500/R 45

20/R

∠Si ÷ 10 | 10m Si | HOB Corr

FIRE ORDER #1, AMC (1), LOT I/H | Df Corr 0 | Si

INITIAL FIRE COMMANDS FM MF #1, (1) | Rg 15100 | Cht Df 3478 | El

Sp Instr AMC | Sh ILL | Lot I/H | Chg 4 | Fz TI | Ti 41.9 | DF 3478 | QE 504

MTO H, (1), TGT# AL7259 | ∠T (10) | PE_R (<38) | TF (42) | in EFF | Ammo Exp (1)

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
1700	LAT SPREAD			(FO: #1,#4												
	COORD ILL			AMC, (1)												
				LOT I/H)												
				#1,#4 (1)	#1	41.8	3445	0	3445	15070				502		
				AMC, SPEC CORR, #4		41.9	3504	0	3504	15090				504	(3)	ILL✓
				SH ILL,												
				LOT I/H,												
				CHG 4, FZ TI												
			EOM	EOM												

ILLUM MARK = 67 SEC

Btry 1/A | DTG 010459ZMAR13 | Tgt AL7259 | Replot Grid | Replot Alt

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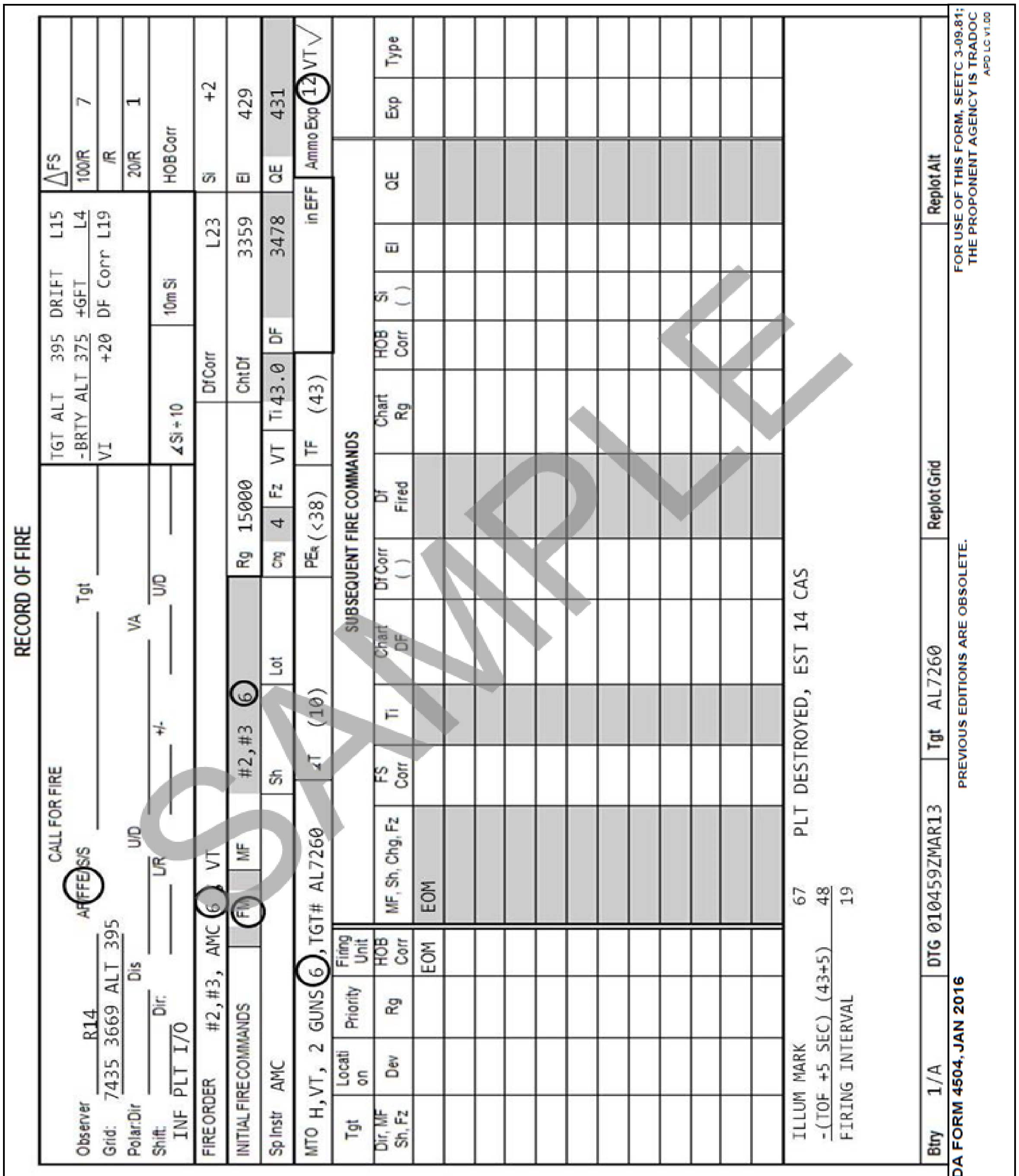
APD LC v1.00

Legend:

AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
COORD – coordinated
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
ILL – illumination
IS – immediate suppression
L/R – left/right
LAT – lateral
MF – method of fire
OPT – optimum
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-28. Example ROF for the Illumination Portion of a Coordinated Illumination Fire Mission.



RECORD OF FIRE

CALL FOR FIRE

Observer R14 AF/FFE/S/S (FFE circled) Tgt

Grid: 7435 3669 ALT 395

Polar:Dir Dis U/D VA

Shift: Dir: L/R +/- U/D

INF PLT I/O

TGT ALT 395 DRIFT L15
-BRTY ALT 375 +GFT L4
VI +20 DF Corr L19

∆FS | 100/R 7 | /R | 20/R 1

∠Si ÷ 10 | 10m Si | HOB Corr

FIRE ORDER #2,#3, AMC (6), VT | Df Corr L23 | Si +2

INITIAL FIRE COMMANDS (FM) MF #2,#3 (6) | Rg 15000 | Cht Df 3359 | El 429

Sp Instr AMC | Sh | Lot | Chg 4 | Fz VT | Ti 43.0 | DF 3478 | QE 431

MTO H,VT, 2 GUNS (6),TGT# AL7260 | ∠T (10) | PE_R (<38) | TF (43) | in EFF | Ammo Exp (12) VT ✓

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
			EOM	EOM												

ILLUM MARK 67
-(TOF +5 SEC) (43+5) 48
FIRING INTERVAL 19

PLT DESTROYED, EST 14 CAS

Btry 1/A | DTG 010459ZMAR13 | Tgt AL7260 | Replot Grid | Replot Alt

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SAMPLE

Legend:
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
I/O – in the open
ILL – illumination
INF – infantry
IS – immediate suppression
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TOF – time of flight
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure 9-29. Example ROF for the HE Portion of a Coordinated Illumination Fire Mission.

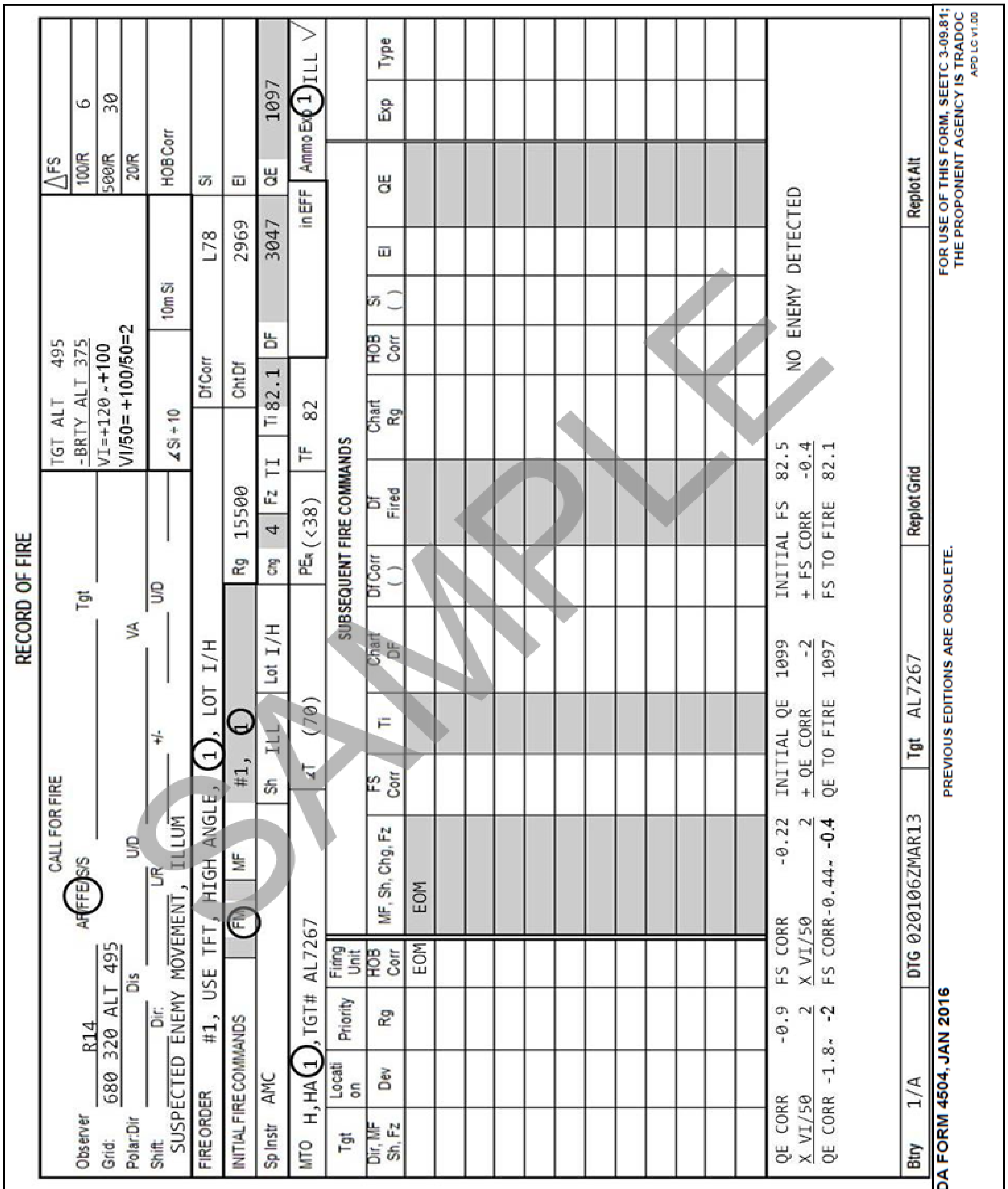
HIGH-ANGLE ILLUMINATION

9-78. Some impact areas are so small that firing low-angle illumination severely restricts or prohibits the firing of the round because of range-to-impact concerns with the projectile body. To compensate for this, fire high-angle illumination and use the TFT (Part 2, Illumination). This is not the preferred method of firing illumination.

9-79. Use table 9-25 to process a high-angle illumination mission. An example ROF for this type of mission is shown in figure 9-30 on page 9-51. The time fuze being fired is M762.

Table 9-25. High Angle Illumination Process.

STEP	***ACTION***
1	Determine and record the chart range and deflection.
2	Determine and record VI, and express to the nearest 50 meters in the upper computational space.
3	Determine and record the change in 50-meter increments from the value determined in step 2 in the upper computational space. **(VI~50m/50= NUMBER OF 50m INCREMENTS).**
4	Determine the QE at the chart range from Part II, Table A, Column 2 in the lower computational space. This is the initial QE.
5	Determine and record the M762 FS corresponding to the QE determined in step 4 from column 3 in the lower computational space. This is the initial FS.
6	Determine and record the correction factors for both QE (column 4) and FS (Column 5).
7	Determine and record the QE and FS corrections in the lower computational space. Multiply the value from step 3 by the QE correction factor determined in step 6 and express to the nearest whole mil. This is the QE Correction. Multiply the value from step 3 by the FS correction factor determined in step 6 and express to the nearest tenth (0.1) of a fuze setting increment. This is the FS Correction.
8	In the lower computational space, apply the QE correction to the initial QE. This will yield the QE to Fire.
9	In the lower computational space, apply the FS correction to the initial FS. This will yield the FS to Fire.
10	Determine, record, and apply drift to the chart deflection. This will yield the deflection to fire. Drift is extracted from Part I, Table F, Column 8 for the appropriate chart range. Drift is expressed to the nearest whole mil.
Note: If firing the M565 fuze, the FS must be converted by applying the correction factor to the M762 FS to fire determined in step 9. This factor is extracted from Part II, Table B of the appropriate TFT.	
Legend: FS – fuze setting m – meters QE – quadrant elevation VI – vertical interval	


RECORD OF FIRE

CALL FOR FIRE

Observer R14 — AF (FFE) S/S — Tgt

Grid: 680 320 ALT 495

Polar:Dir — Dis — U/D — VA

Shift: Dir: — L/R — +/- — U/D

SUSPECTED ENEMY MOVEMENT, ILLUM

TGT ALT 495
-BRTY ALT 375
VI=+120 ≈ +100
VI/50= +100/50=2

△FS | 100/R 6 | 500/R 30 | 20/R

∠Si ÷ 10 | 10m Si | HOB Corr

FIRE ORDER #1, USE TFT, HIGH ANGLE, (1), LOT I/H | Df Corr L78 | Si

INITIAL FIRE COMMANDS (FM) MF #1, (1) | Rg 15500 | Cht Df 2969 | El

Sp Instr AMC | Sh ILL | Lot I/H | Chg 4 | Fz TI | Ti 82.1 | DF 3047 | QE 1097

MTO H,HA (1), TGT# AL7267 | ∠T (70) | PE_R (<38) | TF 82 | in EFF | Ammo Exp (1) ILL ✓

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												Exp	Type
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE			
			EOM	EOM													

QE CORR -0.9 | FS CORR -0.22 | INITIAL QE 1099 | INITIAL FS 82.5
X VI/50 2 | X VI/50 2 | + QE CORR -2 | + FS CORR -0.4
QE CORR -1.8 ≈ -2 | FS CORR -0.44 ≈ -0.4 | QE TO FIRE 1097 | FS TO FIRE 82.1

NO ENEMY DETECTED

Btry 1/A | DTG 020106ZMAR13 | Tgt AL7267 | Replot Grid | Replot Alt

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SAMPLE

Legend:

AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
HA – high angle
HOB – height of burst
I/E – in effect
I/O – in the open
ILL – illumination
INF – infantry
IS – immediate suppression
L/R – left/right
MF – method of fire
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TFT – tabular firing table
TGT – target
TOF – time of flight
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 9-30. Example Record of Fire for a High-Angle Illumination Fire Mission.

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Chapter 10

Registration

Registration is a means of determining cumulative errors and the corrections for those errors. The purpose of this Chapter is to explain registrations and their application to the gunnery problem.

SECTION I: REASONS FOR REGISTRATION

10-1. Registrations should not be needed if the firing unit can meet their portion of the five requirements for accurate fire (minus target location). If the observer cannot provide an accurate target location, the battalion S-3 needs to consider providing a survey team to extend survey into the target area and providing common survey to the observers.

10-2. If all conditions of weather, position, and material were standard, a cannon firing at a particular elevation and deflection would cause the projectile to travel the range shown in the firing table corresponding to that elevation and charge. Since all standard conditions will never exist at the same time, firing table data must be corrected.

10-3. The purpose of a registration is to determine firing data corrections that will correct for the cumulative effects of all nonstandard conditions. All registrations yield total corrections. With these corrections applied to firing data, a unit can rapidly and successfully engage any accurately located target, subject to range transfer limits and the registration point, and have a first round FFE capability.

ACCURATE FIRING UNIT LOCATION

10-4. Accurate range and deflection from the firing unit to the target require that the weapons be located accurately and that the FDC knows this location. The battalion survey section survey equipment to provide accurate survey information on the unit location. Survey techniques available to the firing unit can also help in determining the location of each weapon. The FDC can determine the grid location of each piece by using the reported direction and distance from the aiming circle used to lay the battery or platoon.

ACCURATE WEAPON AND AMMUNITION INFORMATION

10-5. The actual performance of the weapon is measured by the weapon muzzle velocity for a projectile family-propellant combination. The firing unit can measure the muzzle velocity of a weapon and correct for nonstandard projectile weight and propellant temperature. This is performed by using a MVS and MVCT for each charge, propellant type, and projectile family. Calibration should be conducted continuously by using the MVS. Firing tables and technical gunnery procedures allow the unit to consider specific ammunition information (weight, fuze type, and propellant temperature); thus, accurate firing data are possible.

ACCURATE METEOROLOGICAL INFORMATION

10-6. The effects of weather on the projectile in flight must be considered, and firing data must compensate for those effects. Firing tables and technical gunnery procedures allow the unit to take into account specific met information (air temperature, air density, wind direction, and wind speed) in the determination of accurate firing data.

ACCURATE COMPUTATIONAL PROCEDURES

10-7. The computation of firing data must be accurate. If the five requirements for accurate fire (minus target location) cannot be met, registrations can be conducted to compute data that will compensate for nonstandard conditions. Applying these corrections to other fire missions will allow the unit to determine accurate firing data.

Note: If the unit is able to meet the five requirements for accurate fire, it will still be necessary to improve the firing data derived from the GFT. The unit will not be able to fire accurately (first round fire for effect capability) by firing "cold stick" data. Therefore, the use of a Met + VE technique will allow the unit to take all measurable nonstandard conditions into account, and derive a GFT setting. Met + VE techniques are discussed in Chapter 11.

WHEN TO CONDUCT REGISTRATIONS

10-8. The FDO must consider the following:

- Mission.
- Equipment.
- Troops.
- Time.
- Terrain and weather.
- Commander's guidance.
- Tactical situation.
- Enemy target acquisition assets.
- Availability and location of observers.
- Availability, location, and survey accuracy of known points.
- Type of registration.
- Assurance of registration validity.

10-9. A mission conducted only for the purpose of registering does not cause any damage to the enemy. It does, however, expose the firing unit to enemy TA devices. Also, missions conducted solely for the purpose of registering require additional ammunition and time. Therefore, when possible, registration missions should be integrated into other missions, especially when the observer is equipped with a laser.

10-10. Met + VE GFT settings should be used when accurate MVVs, met data, and survey are available. The amount of corrections needed to adjust onto a target will be minimal. Firing two check rounds from an inferred GFT setting can be an abbreviated registration. Any refinement sent by the observer should be used to adjust the GFT setting.

10-11. The flow chart shown in figure 10-1 on page 10-3 can be used to help you decide whether or not to conduct a registration.

TYPES OF REGISTRATIONS

10-12. There are two types of registrations: precision registration and high-burst and/or mean-point-of-impact (HB/MPI) registration. Within the two categories are alternate methods of registering that may be more suitable for use in a particular tactical situation.

- **Precision registration**. The precision registration is a technique for determining, by adjustment, firing data that will place the MPI of a group of rounds on a point of known location. This point is called a known point.
- **High-burst and/or mean point-of-impact registration**. The HB/MPI registration determines the mean burst location of a group of rounds fired with a single set of firing data. When the mean burst location (or MPI) has been determined, the chart data (should hit data) are determined and compared to the data that were fired (adjusted data or did hit data).

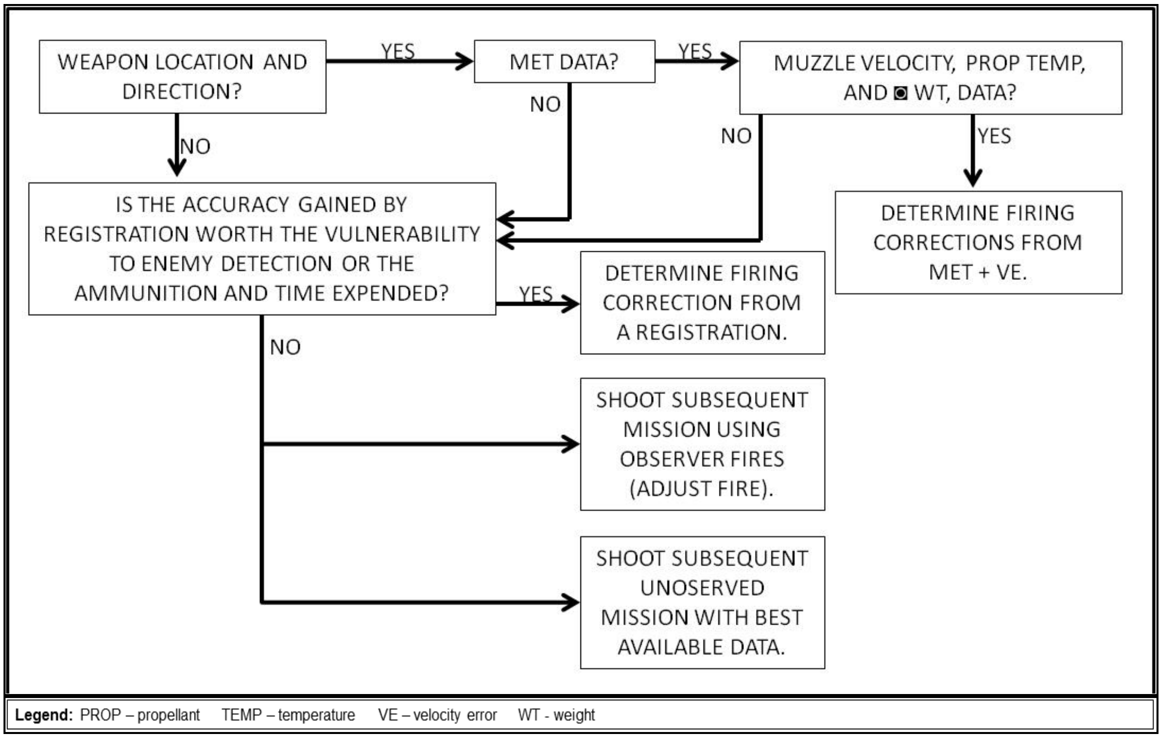

Figure 10-1. Registration Decision Diagram.

10-13. Alternate registration types are discussed below.

- **Radar-observed registration**. The radar-observed registration is a form of the HB/MPI registration and is thoroughly discussed later in this Chapter.
- **Abbreviated registration**. Any registration that is conducted by using fewer useable rounds than recommended for the precision or HB/MPI techniques is an abbreviated registration. The use of fewer rounds can degrade the results of total corrections. However, the use of fewer rounds to determine the mean burst location (MBL) or the use of a larger “acceptance box” (for example, 2 Pes rather than 1 PE from the MPI) is acceptable if the decreased assurance is acceptable to the commander.
  - **Abbreviated HB/MPI registration**. An abbreviated HB/MPI registration is conducted exactly like an HB/MPI registration, except fewer rounds are fired.
  - Met + VE and check round(s). This form of abbreviated registration requires the solution of a subsequent met to an accurately located target and determines adjusted data by adjusting a round(s) fired by use of the Met + VE firing data. Final corrections are determined on the basis of observer refinement.
  - **Abbreviated laser registration**. The abbreviated laser registration determines total corrections by comparing the data fired to the chart data determined to the burst location.
  - **Adjust-fire missions**. Any adjust-fire mission conducted on an accurately located target can be used to improve firing data by determining total corrections on the basis of the observer adjustments. In this case, refinement data must be sent by the observer. The validity of the GFT setting is directly proportional to the accuracy of the target location.

Note: Use of the laser with calibrated common directional control enables an observer to accurately locate a target to registration-required accuracy

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- **Offset registration**. A platoon or offset position as much as 1,000 to 2,000 meters away from the firing unit center can be used to conduct a registration. The GFT setting determined from the offset position is assumed to be valid for the primary position if common survey and common direction exist between the two positions. A registration from a flank platoon may reduce the vulnerability of the firing unit.

- **Registration to the rear**.
  - Registering to the rear (or at some azimuth significantly different from the primary azimuth of fire) results in a GFT setting that does not include the primary azimuth of fire within its deflection transfer limits.
  - To derive a GFT setting for the primary azimuth of lay, apply eight-direction met techniques as follows:
    - Determine position constants by calculating a solution for a concurrent met for the registration azimuth.
    - Using subsequent met applications, determine the total corrections (in the direction of the azimuth of lay) by re-determining the met.

Note: The eight-direction met technique is discussed later in this Chapter and in detail in Chapter 11

ASSURANCE TABLES

10-14. A registration conducted with fewer rounds than recommended will degrade the accuracy of the determined corrections. Table 10-1 lists the percentage of probability that the mean location of a particular number of rounds is within 1 or 2 probable errors of the actual mean point of impact achieved by firing an infinite number of rounds. As more rounds are fired, the assurance of validity of the MPI is increased. If the tactical situation dictates, the lesser assurance from an abbreviated registration may have to be accepted.

Table 10-1. Assurance of Registration Validity.

NUMBER OF ROUNDS FIRED	***1***	***2***	***3***	***4***	***5***	***6***
WITHIN 1 PROBABLE ERROR	50%	66%	76%	82%	87%	90%
WITHIN 2 PROBABLE ERRORS	82%	94%	98%	99%	99%	99%

REGISTRATION CORRECTIONS AND GFT SETTINGS

10-15. The final step in every registration is the determination and application of registration corrections. Registration corrections consist of total range, total fuze, and total deflection corrections. The total corrections are determined by comparing the chart data (should hit data) to the adjusted data (did hit data) resulting from a registration. When it is impractical to conduct a registration, corrections can be obtained mathematically by use of a met technique. (See Chapter 11)

10-16. The **total corrections** are then used as the basis for a GFT setting. This allows the FDC personnel to apply total corrections to the GFT. With the GFT setting properly applied, it is possible to fire for effect without an adjustment phase on accurately located targets within transfer limits. Total corrections, GFT settings, and transfer limits will be discussed in greater detail later in this Chapter. It is important to remember that no registration is complete until registration corrections-are determined and a GFT setting is applied.

Note: ***Should hit data*** **(SHD) are data fired under standard conditions that will cause the round to impact at a point of known location.** ***Did hit data*** **(DHD) are data fired under nonstandard conditions that will cause the round to impact at a point of known location.**

SECTION II: PRECISION REGISTRATIONS

10-17. ***Precision registration* is a technique that requires an observer to adjust a group of rounds fired from the same howitzer so that their mean point of impact occurs at a point of known location (that is, a known point).** The point of registration is accurately located (8-digit grid, 10-meter accuracy or 10-digit grid 1-meter accuracy). It can be determined from survey, can be an easily recognized map spotted terrain feature, or it can be any identifiable point located by a laser and should be on common survey with the firing unit. Corrections are determined by comparing the data that actually did hit the target (adjusted data) to the data that should have hit the target (chart data) if standard conditions had existed at the time of firing.

OBJECTIVE

10-18. The observer's objective in the impact phase of a precision registration is to obtain spottings of two **OVERS** and two **SHORTS** along the OT line from rounds fired with the same data or from rounds fired with data 25 meters apart (50 meters apart when PER is greater than or equal to 25 meters). This normally requires the spottings of four separate rounds. Four spottings achieved by firing projectiles with the same data or data 25 meters apart is critical. This critical bracket must be formed by the observer making only range corrections since a deviation correction will introduce a difference in firing data greater than the 25-meter requirement. The observer should not make any deviation corrections after establishing the 200-meter bracket. If he does, then any previous rounds cannot be used as part of the 25-meter bracket. However, a **TARGET HIT** or **RANGE CORRECT** will be spotted by the observer as an **OVER** and a **SHORT**. The objective of the time portion of the registration is to correct the mean height of burst of four rounds fired with the same data to 20 meters above the target point. The FDC's objective in a precision registration is to determine corrections to firing data on the basis of the observer's corrections and to determine whether or not the objectives were achieved.

INITIATION OF A PRECISION REGISTRATION

10-19. The decision to register is based on the considerations in Section I. After the decision to register has been made, the FDO announces a fire order. The FDO does not address fire order SOP items unless he feels that it is necessary to avoid confusion. When the FDO announces his fire order, he includes the following information:

- What are we going to perform? (for example, precision registration)
- Where are we going to perform it? (for example, known point 1)
- With whom? (for example, with T03)
- Registering howitzer. Use only one weapon to fire the registration. It is best to select the piece that is plotted on the firing chart and for which we have accurate MVV information for the registering charge (for example, the **BASE PIECE**).
- Method of fire. The FDO states the method of fire for the precision registration. (For example, 1 round)
- Lot. Register the largest calibrated lot of propellant. This lot is used for first-round FFE missions.
- Charge selection. Listed below are a few of the factors an FDO should consider when selecting the charge to register:
  - At what range will most targets be engaged?
  - If the enemy has a sophisticated sound ranging capability, a lower charge is preferred.
  - If the enemy has a sophisticated counter battery radar capability, a higher charge is preferred.
  - Which charge has the smallest PE_R for a given range (see the charge selection table in the TFT)?
  - Lower charges produce less tube wear, residue, and noise.

- Fuze. The FDO announces the fuze or fuzes to be fired during the precision registration. (for example, Q & TI)
- Special Instructions. The FDO announces any special instructions pertinent to the precision registration (for example, use gunner's quadrant).

10-20. When the RTO hears the fire order, he will announce a message to observer to alert the observer.

- **MTO**. The MTO includes the information from the fire order that pertains to the observer. For example, a MTO may include the following information:
  - Type of registration.
  - The known point.
  - Fuzes to be registered.

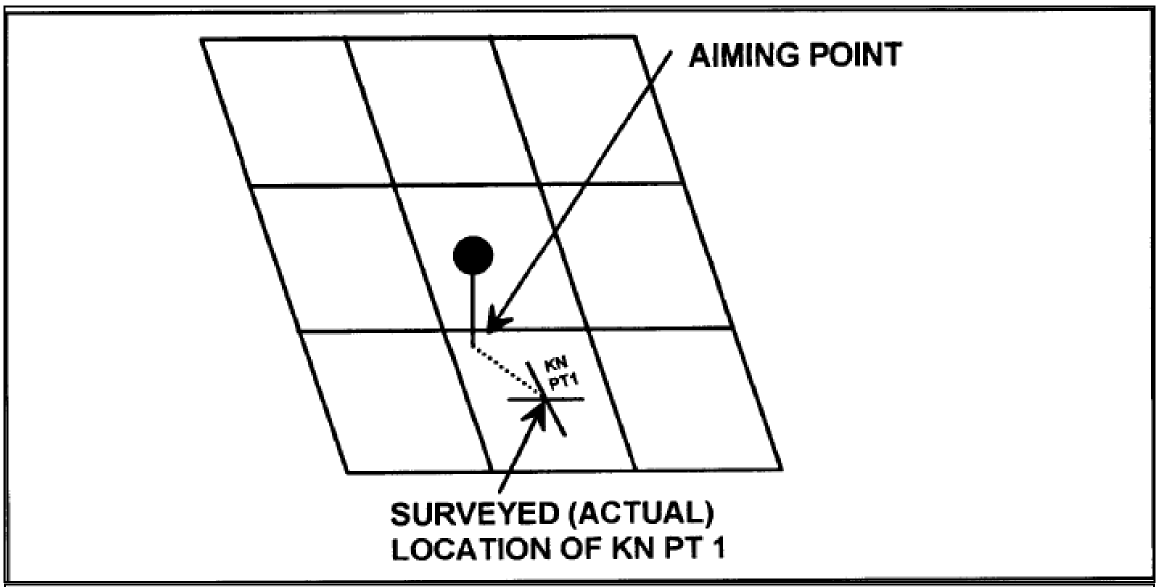
10-21. If there is no **known point**, the FDO will direct the observer to select one in a specified area, and the observer will send the location to that point. The FDO will then designate the number of the known point. Because of the possibility of introducing a target location error, this option is least preferred.

10-22. **Observer's response**. After the observer has received the MTO, he will report direction. If the observer is directed to select a known point, he will report the eight-digit grid location and direction. In either case, the report of direction indicates the observer is ready to conduct the registration.

CONDUCT OF THE IMPACT PHASE OF A PRECISION REGISTRATION

10-23. Fire direction procedures for an impact phase of a registration are identical to those used in the conduct of any adjust-fire mission. All observer corrections are plotted on the firing chart and chart data are announced. The computer sends fire commands to the registering piece. Although care should be taken during all computational steps, extraordinary measures should not be used for the conduct of a registration.

10-24. The final location of the plotting pin on the chart represents the point where the howitzer had to be aimed to have rounds impact on the known point (figure 10-2). It is not the actual location of the known point. The difference between these locations depicts the effects that all nonstandard conditions had during firing.



Legend: KN PT – known point

Figure 10-2. Difference between Aiming Point and Surveyed Location.

10-25. The data announced after the observer's final impact refinement shows the range and deflection to the point where the howitzers must aim to have rounds impact on the known point. At this point, no projectile is fired and the time phase of the registration begins. The deflection and elevation corresponding to the data measured to the final pin location is called the adjusted data–the data that did hit the known point. Adjusted data determined during a registration will be circled on the record of fire.

CONDUCT OF THE TIME PHASE OF A PRECISION REGISTRATION

10-26. When the impact phase of the registration is complete, the time phase can be started. The observer's refinement data moved the mean point of impact of the rounds to the known point. At this point, an adjusted deflection and elevation are determined. The adjusted deflection and elevation are did hit data for the known point and the most accurate data with which to begin the time portion.

10-27. The first fuze setting fired corresponds to the adjusted elevation. The initial fuze setting to fire is determined by placing the MHL over the adjusted elevation and reading a fuze setting corresponding to that adjusted elevation. At the same time, the computer determines ▲FS corresponding to the first fuze setting fired.

10-28. As with other fuze time missions, an HOB correction (20/R) is added to the ground site to determine a total site. The total site is added to the adjusted elevation to determine the quadrant to fire for the rest of the mission. The adjusted deflection is fired for the rest of the mission.

10-29. Normal procedures for application of ▲FS for up or down corrections are followed to meet the objective of the time phase of the mission, which is to correct the mean height of burst of four rounds fired with the same data to 20 meters above the known point.

10-30. The adjusted time is determined after the observer's HOB refinement is applied. The adjusted time is circled. With the observer's correction applied, the adjusted time will produce an airburst 20 meters above the known point. The adjusted time is not fired.

SECOND LOT REGISTRATIONS

10-31. The use of the second lot registration technique has become marginalized with the use of the MVS and the ability to account for muzzle velocity differences in propellant lots. However, if a MVS is not available, the second lot registration technique is an acceptable alternative method. The GFT settings for subsequent lots can be determined by using the subsequent met techniques if muzzle velocity information is available.

10-32. Conduct second lot registrations in the same manner as single lot registrations with the following exceptions:

- **Fire order**. The fire order informs the FDC that corrections are needed for two different lots (of the same charge and propellant type).
- **MTO**. The radio operator transmits the MTO notifying the FO to observe two lots by announcing **TWO LOTS** after the fuze or fuzes to be fired.

INITIATION OF THE SECOND LOT REGISTRATION

10-33. After completing the first lot time registration, begin firing the first round of the second lot registration with the adjusted deflection and the adjusted quadrant elevation (adjusted elevation plus ground site) determined for the first lot. **Fire fuze quick only**. To notify the observer that a second lot registration is going to be conducted, the FDC announces: **OBSERVE SECOND LOT, OVER**.

10-34. In the appropriate columns on the ROF, enter the firing data determined from the first lot registration. These data include the following:

- Adjusted deflection.
- Adjusted chart range.
- Value of ground site.
- Adjusted elevation.

10-35. The adjusting piece must be given commands to change the method of fire, lot and fuze. The objective of the second lot registration is the same as that of the first lot. Once the observer has met the objective, he will announce **(any refinement)** and **RECORD AS SECOND LOT REGISTRATION POINT, END OF MISSION.**

10-36. To determine the adjusted fuze setting, add the fuze correction from the first lot to the fuze setting corresponding to the subsequent lot adjusted elevation. To determine the adjusted fuze setting for the second lot registration, follow the steps in table 10-2.

Table 10-2. Determine Adjusted Fuze Setting (Second Lot).

STEP	***ACTION***
1	Align the MHL of the GFT over the adjusted elevation from the second lot registration.
2	Determine the fuze setting under the MHL.
3	Add the total fuze correction from the first lot precision registration to the fuze setting determined in step 2.
Legend: GFT – graphical firing table MHL – manufacturer's hair line	

10-37. The second lot GFT setting will be constructed in the same manner as the first lot GFT setting.

Note: To minimize confusion, the second lot GFT setting should be placed on a different cursor and labeled with the appropriate lot.

10-38. Determine the total deflection correction by using the following formula:

2D LOT ADJ DF – CHART DF = TOT DF CORR

10-39. Determine the GFT deflection correction by placing the MHL over the second lot adjusted elevation and reading the value under the MHL on the drift scale. This value is subtracted from the total deflection correction, and the LARS rule is used to determine whether the GFT deflection correction is a left (L) correction or a right I correction.

TOT DF CORR – DRIFT ~ 2D LOT ADJ EL = GFT DF CORR

10-40. 10-15. Example of a Completed Precision Registration. Use table 10-3 to process a precision registration with fuzes quick and time.

Table 10-3. Impact Phase of Precision Registration Example.

STEP	***REFERENCE***	***ACTION***
1	Fire Order	Computer/RTO reads back and records the fire order announced by the FDO.
2	MTO	Computer/RTO records the MTO announced by the RTO.
	Note: The observer will report direction once he has received the MTO and identified the known point. The Computer/RTO records the direction in the observer subsequent commands block on the record of fire.	
3	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Announced and circled or checked.
	MF	Computer/RTO determines and records the pieces to follow, pieces to fire, and method of fire.
	Sp Instr	Computer/RTO records as directed by the fire order.
	Sh	Computer/RTO records **if other than standard**, as directed by the fire order.
	Lot	Computer/RTO **records if other than standard**, as directed by the fire order.

Table 10-3. Impact Phase of Precision Registration Example (continued).

STEP	*REFERENCE*	*ACTION*
	Chg	Computer/RTO records charge. If not announced in the FO, and no standard is in effect, computer will determine charge after receiving chart range.
	Fz	Computer/RTO records **if other than standard**, as directed by the fire order.
4	Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
5	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
6	El	Computer/RTO determines and records elevation.
7	Drift	Computer/RTO determines and records drift in the upper computational space
8	Df Corr	Computer/RTO records deflection correction. This is the sum of drift plus the GFT deflection correction **(DRIFT + GFT DF CORR = DF CORR)**. If no GFT deflection correction is available, the deflection correction will be the same as drift.
9	Df	Computer/RTO determines and records the deflection to fire **(CHT DF + DF CORR = DF TO FIRE).**
10	SI	VCO determines and announces site. Computer/RTO records it.
11	QE	Computer/RTO determines and records quadrant elevation. **(SI+EL=QE).**
12	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
13	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
14	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
	Note: Normal procedures are followed as discussed in Chapter 9 with the exception of PE_R. PE_R for a precision registration is announced when it is ≥25 meters.	
15	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the subsequent corrections.
16	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
17	Chart Rg	HCO determines and announces chart range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
18	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
19	El	Computer/RTO determines and records elevation.
20	Df	Computer/RTO determines and records deflection to fire (CHT DF + DF CORR = DF TO FIRE).
21	QE	Computer/RTO determines and records QE (EL + SI = QE).
22	Verification	Computer/RTO verifies fire commands with either the FDO or chief.

Table 10-3. Impact Phase of Precision Registration Example (continued).

STEP	*REFERENCE*	*ACTION*
23	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
24	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
	Note: Repeat steps 14 through 23 as needed to complete the observer's corrections. These steps are valid until the observer ends the impact phase.	
Legend: CFF – call for fire CHG – charge CHT – chart CORR – correction DF – deflection FDC – fire direction center FDO – fire direction officer FM – fire mission FS – fuze setting GFT – graphical firing table HCO – horizontal control operator MF – method of fire MHL – manufacturer's hair line MTO – message to observer PE_R – probable errors in range QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions VCO – vertical control operator		

10-41. The observer ends the impact phase of the registration by providing refinement data and requesting **RECORD AS REGISTRATION POINT (announces the number of the registration point), TIME REPEAT**. Record this transmission on two lines of the ROF. The first line is used to determine the adjusted elevation and adjusted deflection. The adjusted data are determined by processing the refinement data. These adjusted data (adjusted time fuze setting, adjusted deflection and adjusted elevation) are referred to as **did-hit data** (**DHD)** and are circled on the record of fire for quick reference. **The adjusted data are not transmitted to the howitzer(s)**. For later use in the determination of total corrections, the chart range, chart deflection and initial time fuze setting may be labeled **should-hit data (SHD)** and the adjusted range, adjusted deflection and adjusted time fuze setting may be labeled DHD.

10-42. Once the refinement data have been processed, the time phase is initiated. The chart data, deflection to fire (adjusted deflection), and elevation (adjusted elevation) have already been determined. The only data that needs to be computed are the time fuze setting (should hit) and the quadrant elevation. Use the steps in table 10-4 to process the time phase of the registration.

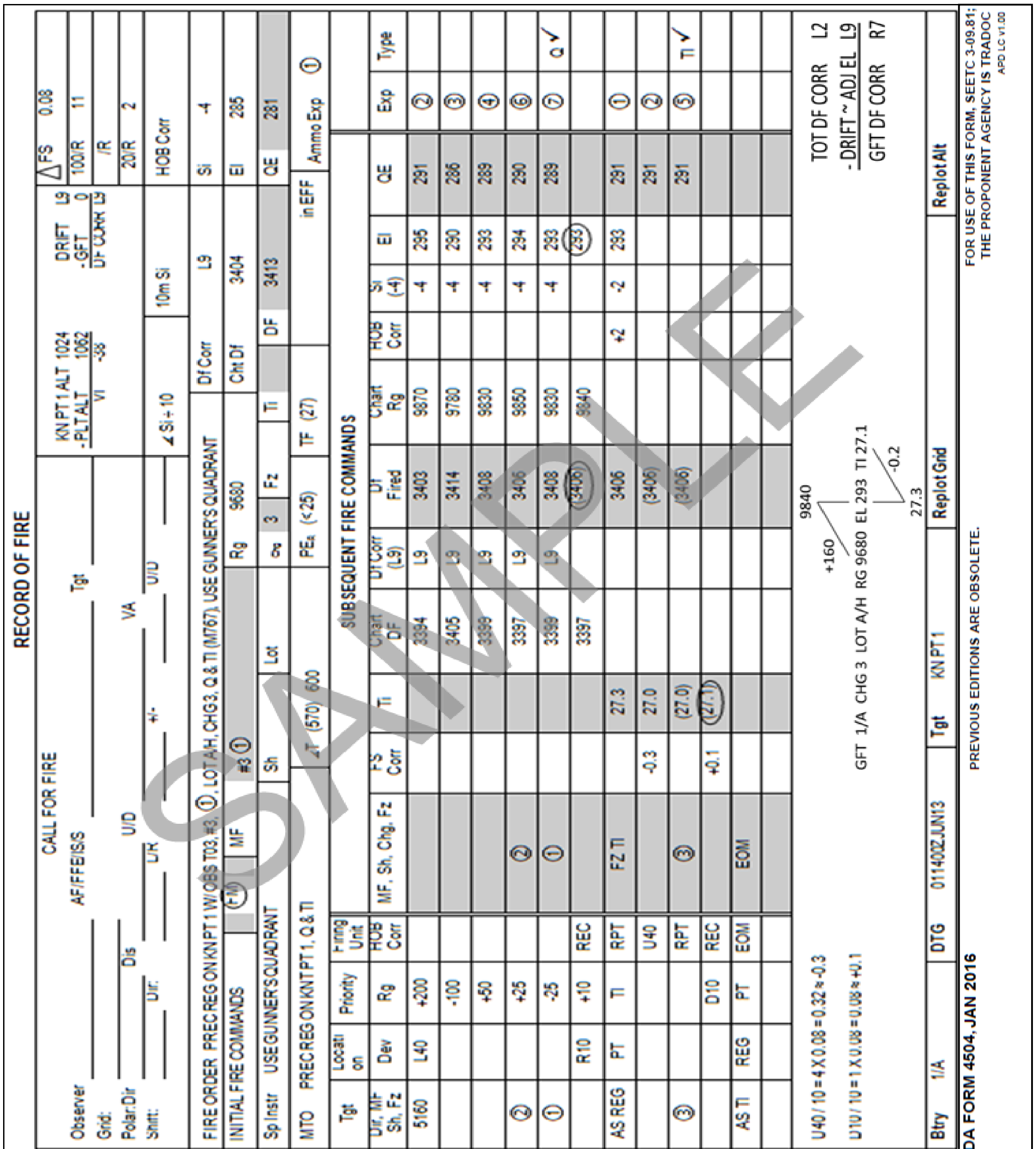
Table 10-4. Time Phase of Precision Registration.

STEP	*REFERENCE*	*ACTION*
1	MF, Sh, Chg, Fz	Computer/RTO records fuze time.
2	Ti	Computer/RTO determines and records the fuze setting (should hit).
3	DF	Computer/RTO records deflection to fire (adjusted deflection).
4	HOB Corr	Computer/RTO determines and records the HOB correction. The positive signed value of 20/R is the HOB correction.
5	SI	Computer/RTO determines total site by algebraically adding the HOB correction to the previously determined ground site. The result is recorded in the site block.
6	El	Computer/RTO records the elevation (adjusted elevation).
7	QE	Computer/RTO determines, records, and announces **QE (EL + TOTAL SI = QE).**
8	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
9	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
10	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.
	Note: Ensure ▲FS is determined during the police of the ROF, it is a function of fuze setting and is determined by using the fuze setting in step 2.	

Table 10-4. Time Phase of Precision Registration (continued).

11	Dir, MF, Sh, Fz, Dev, Rg, HOB Corr	Computer/RTO reads back and records the observer's subsequent corrections.
12	MF, Sh, Chg, Fz	Computer/RTO records any changes to method of fire, shell, charge, or fuze.
13	FS Corr	Computer/RTO determines and records FS correction. The FS correction is determined by dividing the HOB correction by 10 and multiplying the value by ▲FS. The result is expressed to the nearest tenth and is a signed value (See Figure 9-14 for example of USDA). The computations are placed in the lower computational space of the **ROF [(HOB CORR ÷ 10) x ▲FS = FS CORR ~ 0.1 FSI (±)]**. Up correction = negative FS CORR/ Down Correction = positive FS CORR.
14	Ti	Computer/RTO determines and records the fuze setting. The fuze setting is determined by applying the FS correction to the previous fuze setting fired **(FS CORR + PREVIOUS FS = Ti).**
15	Df	Computer/RTO records deflection in parentheses (it does not change).
16	QE	Computer/RTO records the quadrant elevation (QE does not change but must be announced in the subsequent fire commands).
17	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
18	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
19	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations (See Chapter 9).
	Note: Repeat steps 10 through 19 for each subsequent time adjustment. The observer will request HOB corrections until an airburst is observed. The observer will then request **THREE ROUNDS, REPEAT.**	
Legend: CHG – charge CHT – chart CORR – correction DF – deflection FDO – fire direction officer FM – fire mission FS – fuze setting GFT – graphical firing table HOB – height of burst MF – method of fire QE – quadrant elevation RG – range ROF – record of fire RTO – radio telephone operator SH – shell SI – site		

10-43. After spotting the last round, the observer will provide final refinement data to adjust the mean height of burst to **20 meters**. The observer will also direct **RECORD AS TIME REGISTRATION POINT, END OF MISSION**. Record this transmission on two lines of the ROF. The first line is used to process the final HOB correction and determine the adjusted time (did hit). The adjusted time is recorded and circled on the record of fire for quick reference. These data are not sent to the howitzer(s). The second line is used to record end of mission, which is sent to the howitzer(s). Once end of mission (EOM) is sent to the howitzer(s), a final police of the ROF is conducted. A completed ROF for a precision registration using the M767 time fuze is shown in figure 10-3 on page 10-12.



RECORD OF FIRE

CALL FOR FIRE

Observer ____ AF/FFE/IS/S ____ Tgt ____
Grid: ____
Polar:Dir ____ Dis ____ VA ____
Shift: ____ Dir: ____ L/R ____ U/D ____ +/- ____ U/D ____ ∠Si ÷ 10

KN PT 1 ALT 1024
-PLT ALT 1062
VI -38

DRIFT L9
-GFT 0
DF CORR L9

ΔFS 0.08
100/R 11
/R
20/R 2
HOB Corr
10m Si

FIRE ORDER PREC REG ON KN PT 1 W/OBS T03, #3 ①, LOT A/H, CHG 3, Q & TI (M767), USE GUNNER'S QUADRANT | Df Corr L9 | Si -4

INITIAL FIRE COMMANDS | FM | MF | #3 ① | Rg 9680 | Cht Df 3404 | El 285

Sp Instr USE GUNNER'S QUADRANT | Sh | Lot | c/q 3 | Fz | Ti | DF 3413 | QE 281

MTO PREC REG ON KN PT 1, Q & TI | ∠T (570) 600 | PEᴿ (<25) | TF (27) | in EFF | Ammo Exp ①

SUBSEQUENT FIRE COMMANDS

Tgt: Dir, MF, Sh, Fz	Location: Dev	Priority: Rg	Firing Unit: HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L9)	Df Fired	Chart Rg	HOB Corr	Si (-4)	El	QE	Exp	Type
5160	L40	+200					3394	L9	3403	9870		-4	295	291	②	
		-100					3405	L9	3414	9780		-4	290	286	③	
		+50					3399	L9	3408	9830		-4	293	289	④	
②		+25		②			3397	L9	3406	9850		-4	294	290	⑥	
①		-25		①			3399	L9	3408	9830		-4	293	289	⑦	Q ✓
	R10	+10	REC				3397		(3406)	9840			(293)			
AS REG	PT	TI	RPT	FZ TI		27.3			3406		+2	-2	293	291	①	
			U40		-0.3	27.0			(3406)					291	②	
③			RPT	③		(27.0)			(3406)					291	⑤	TI ✓
		D10	REC		+0.1	(27.1)										
AS TI	REG	PT	EOM	EOM												

U40/10 = 4 X 0.08 = 0.32 ≈ -0.3
D10/10 = 1 X 0.08 = 0.08 ≈ +0.1

GFT 1/A CHG 3 LOT A/H RG 9680 EL 293 TI 27.1
9840 +160 27.3 -0.2

TOT DF CORR L2
- DRIFT ~ ADJ EL L9
GFT DF CORR R7

Btry	1/A	DTG	011400ZJUN13	Tgt	KN PT1	Replot Grid	Replot Alt

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SAMPLE

Legend:
ADJ - adjusted
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
IS – immediate suppression
KN PT – known point
L/R – left/right
MF – method of fire
OBS – observer
PER – probable error in range
PLT – platoon
PREC – precision
Q – quick
QE – quadrant elevation
REC – record
REG – registration
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TFT – tabular firing table
TGT – target
TOF – time of flight
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 10-3. ROF for a Precision Registration.

ABBREVIATED PRECISION REGISTRATION

10-44. The tactical situation or ammo restraints may prohibit conducting a full-scale registration. In such cases, the FDO may conduct an abbreviated precision registration. Although having a lower assurance of validity, an abbreviated precision registration often provides adequate compensation for the effects of nonstandard conditions. The observer ends the registration when he believes that his next correction will put the next round on the registration point. The advantages of this type of registration are fewer rounds are fired so less ammunition is consumed and the registration takes less time so the unit is exposed to enemy TA devices for a shorter period of time.

10-45. After making the decision to register, the FDO announces a fire order. Once the RTO hears the fire order, he transmits a MTO to alert the forward observer. After the observer has received the MTO, he sends a direction, which signifies he is ready to observe, to the FDC.

10-46. The observer procedures for an abbreviated precision registration are different than those used for a normal precision registration.

- The observer will use normal adjust-fire procedures until the 100-meter bracket is split.
- The correction then sent is an add (or drop) 50 meters FFE or time repeat or time add or drop 50 meters.
- The burst which is a result of an add (or drop) 50 meters is spotted. Minor corrections for both deviation and range are sent to the FDC in the following format:
  - For both a quick and time registration: **L10, -20, RECORD AS REGISTRATION POINT, TIME REPEAT.**
  - For an impact only registration: **R30, -10, RECORD AS REGISTRATION POINT, END OF MISSION.**
  - Normal time adjustment procedures are followed in the time portion.
  - Once an airburst is obtained, a correction for a 20-meter HOB is determined.
  - Instead of firing for effect, refinement is sent to the FDC in the following format: **U5, RECORD AS TIME REGISTRATION POINT, END OF MISSION.**

Note: If the abbreviated registration is conducted as part of a normal adjust-fire mission, steps c(2) and c(3)(e) are modified to allow the observer to request FFE.

10-47. The GFT setting and total corrections are determined in the same manner as in a normal precision registration. A completed ROF for an abbreviated registration using the M767 time fuze is shown in figure 10-4 on page 10-14.

RECORD OF FIRE

CALL FOR FIRE			
Observer ______	AF/FFE/IS/S ______	Tgt ______	
Grid: ______			
Polar:Dir ______	Dis ______	U/D ______	VA ______
Shift: ______	Dir: ______	L/R ______ +/- ______	U/D ______

TGT#AA7010 1030	DRIFT L9	FS	0.08
PLT ALT 1062	GFT 0	100/R	10
VI -32	DF CORR L9	/R	
		20/R	2
Si ÷ 10	10m Si	HOB Corr	

FIRE ORDER ABBR REG ON TGT#AA7010 W/ C19, #3, ①, LOT A/H, CHG 3, Q & TI (M767), USE GUNNER'S QUADRANT		Df Corr	L9	Si	-4
INITIAL FIRE COMMANDS (FM) MF #3, ①	Rg 9700	Cht Df	3250	El	286
Sp Instr USE GUNNER'S QUADRANT Sh Lot	Chg 3 Fz Ti	DF	3259	QE	282
MTO ABBR REG ON TGT#AA7010, Q & TI <T (250)	PER (<25) TF (27)	in EFF		Ammo Exp	①

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L9)	Df Fired	Chart Rg	HOB Corr	Si (-4)	El	QE	Exp	Type
4500	R50	-200					3231	L9	3240	9520		-4	277	273	②	
		+100					3235	L9	3244	9610		-4	281	277	③	
		-50					3234	L9	3243	9570		-4	279	275	④	Q✓
	L20	+20	REC				3236	L9	(3245)	9580		-4	(280)			
AS REG	PT	TI	RPT	FZ TI		26.3			3245		+2	-2	280	278	①	
			U40		-0.3	26.0			(3245)					278	②	TI✓
		D15	REC		+0.1	(26.1)										
AS TI	REG	PT	EOM	EOM												

U40 / 10 = 4 X 0.08 = 0.32 → -0.3

D15 / 10 = 1.5 X 0.08 = 0.12 → +0.1

9580 / -120

GFT 1/A CHG 3 LOT A/H RG 9700 EL 280 TI 26.1 (M767)

26.3 / -0.2

TOT DF CORR R5
- DRIFT AT ADJ EL L9
GFT DF CORR R14

Btry 1/A	DTG 011400ZJUN13	Tgt #AA7010	Replot Grid	Replot Alt

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SAMPLE

Legend:
ABBR – abbreviated
ADJ - adjusted
AF – adjust fire
ALT - altitude
AMC – at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
IS – immediate suppression
KN PT – known point
L/R – left/right
MF – method of fire
OBS – observer
PER – probable error in range
PLT – platoon
PREC – precision
Q – quick
QE – quadrant elevation
REC – record
REG – registration
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TFT – tabular firing table
TGT – target
TOF – time of flight
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 10-4. ROF for an Abbreviated Precision Registration.

SECTION III: HIGH-BURST/MEAN POINT OF IMPACT REGISTRATIONS

10-48. When registration is necessary, clearly defined and accurately located registration points may be limited or not available. Dense vegetation or ground fog may prevent the observers from seeing the ground. At night, adjustment of fire on a registration point is impossible without some type of illumination. The tactical situation may not allow the firing of numerous rounds required for a precision registration. The HB/MPI registration can overcome these problems. This section describes HB and MPI registrations.

DESCRIPTION

10-49. In HB and MPI registrations, the unit fires a number of rounds (ideally six) with the same set of firing data. These rounds are observed by two observers in surveyed positions, usually designated 01 and 02, who can measure the direction to each bursting round. One observer measures the VA to each round. On the basis of the observers' average directions and the average VA from one observer, determine and plot the mean burst location (MBL) or the mean point of impact. Lastly, determine chart data and compare them to the adjusted data that were fired.

10-50. A MPI registration is fired with fuze quick. The HB registration is freed with time-tied rounds. The HB offers an advantage over the MPI registration by allowing the FDC to determine a fuze correction. The HB registration is also easier to observe, especially at night, and registration corrections can be determined in areas where the observers cannot see the ground.

10-51. The requirement for surveyed observer locations with directional control is the primary limitation of HB and MPI registrations.

10-52. The six basic steps to an HB or MPI registration are as follows:

- Select an orienting point.
- Orient the observers.
- Determine firing data to the orienting point.
- Fire the HB or MPI registrations.
- Determine the MBL.
- Determine chart data and registration corrections.

SELECTING AN ORIENTING POINT

10-53. The S-3 or FDO selects an orienting point at which all of the rounds will be fired. This point may be located at a grid intersection for convenience. The orienting point is only a temporary point on the firing chart. After computing firing data, the orienting point is no longer needed.

10-54. The orienting point for either a HB or MPI registration point should meet the following criteria.

- It must be visible to both observers.
- It should be close to the center of the area of responsibility (unless an eight-directional met technique is to be used to determine a valid GFT setting).
- It should ensure an acceptable apex angle (Figure 10-5 on page 10-16). (**The *apex angle* is the angle formed by the lines from each observer to the orienting point.**) Since two of the methods used to determine the MBL involve the use of trigonometry (polar plot and grid coordinate), a strong apex angle (See figure 10-5 on page 10-16) is needed to minimize the effects of small measurement errors. More information can be found in FM 6-2 (Tactics, Techniques and Procedures for Field Artillery Survey).

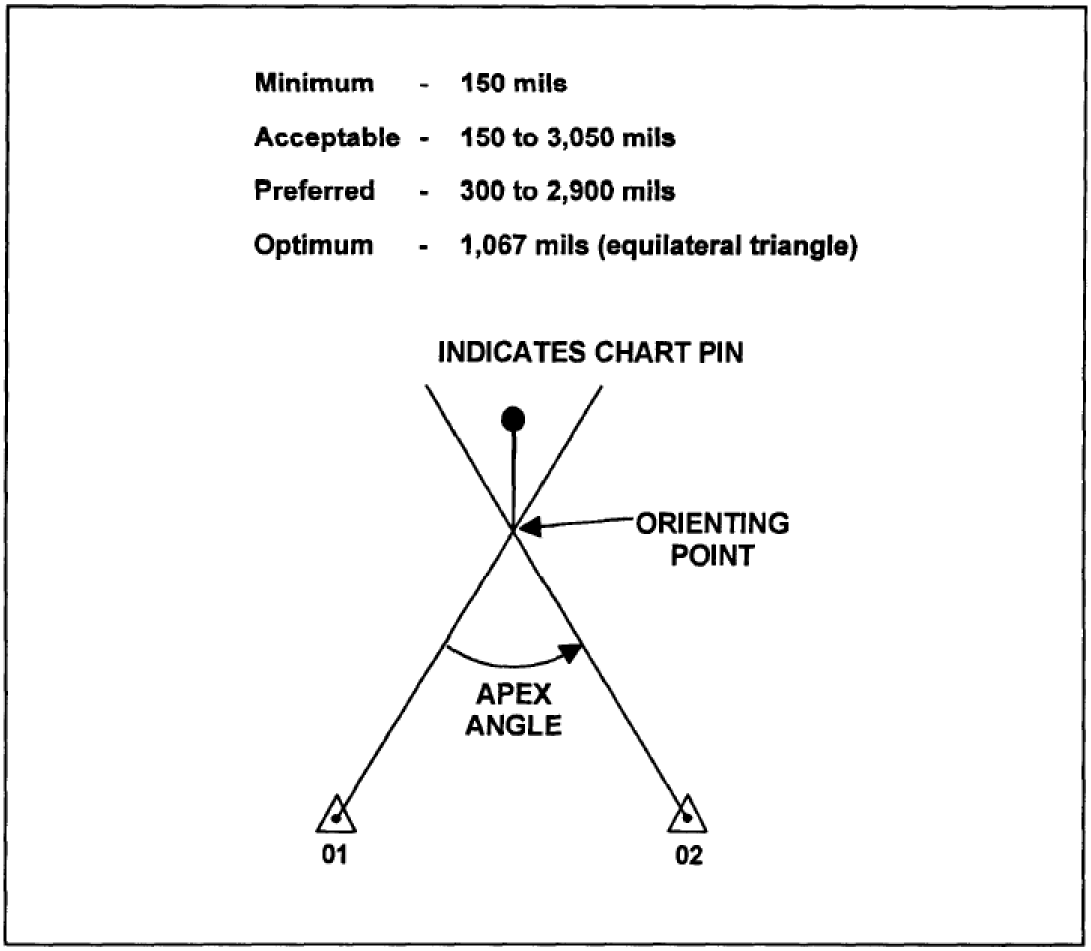


Figure 10-5. Apex Angle.

10-55. For an MPI registration, the orienting point should be in a relatively flat (level) area to eliminate the need to replot the MBL.

10-56. For a HB registration, the orienting point must be high enough to ensure an airburst. The selected height of burst must be at least 2 PE in height of burst above the ground expressed up to the next 10 meters. The FDO can increase the HOB as long as it exceeds the minimum selected HOB. An example of this is below.

EXAMPLE
FDO of a M109A6 unit is selecting an orienting point for a HB registration and is firing charge 3H (M232A1). **Range to Orienting Point**: 11,140 meters (Enter AM-3 TFT, Table G, Column 5 with 3H (M232A1) and the range expressed up to the next 1,000 meters). **PE_{HOB}**: 12 meters (extracted from AM-3 TFT) (2PE x 12 = 24 ≈ 30 meters. Thus, 30 meters is the lowest HOB that should be selected).

10-57. The FDO initiates the HB/MPI registration with a fire order; for example, HIGH-BURST REGISTRATION AT GRID 4128, HEIGHT OF BURST PLUS 30, WITH T03 AND C19, 6 ROUNDS, FUZE TIME, BY ROUND AT MY COMMAND. The fire order for this type of registration is no different than any other registration and may include the information outlined in (See Paragraph 10-10). The FDO has specified by-round at my command (BRAMC) to be sure that the observers have enough time to spot each round fired and transmit spotting before the next round is fired.

ORIENTING THE OBSERVERS

10-58. After selecting the orienting point and issuing the fire order, the two observers must be told where to orient to observe the rounds. Plot the observers' locations on the firing chart (if not already done), and measure the direction and distance from each observer to the orienting point. The VCO uses the distances and the VI between each observer location and the orienting point to determine the VA for each observer. Determine the VA by use of the C and D scales of the GST.

10-59. Transmit a message to each observer. The MTO contains the information the observers need to orient their instruments. Record the MTO on DA Form 4201, *High Burst (Mean Point of Impact) Registration* (See figure 10-6). The message contains the following elements:

- **A warning order (for example, OBSERVE HIGH-BURST REGISTRATION)**. The warning order informs the observers for what type of registration they are preparing.
- **Orienting data for 01 (T03)**. The HCO measures the direction and distance chart data from 01 to the orienting point. The direction reported to the observer is the direction determined on the firing chart. The FDO determines the ground altitude of the orienting point and then adds the HOB to determine the altitude of the orienting point. The VCO subtracts the altitude of the observer from the altitude of the orienting point to determine the vertical interval. The VCO uses the C and D scales of the GST, the vertical interval, and the distance measured by the HCO to determine 01's vertical angle. The vertical angle and direction reported to 01 will enable him to orient on the orienting point.
- **A directive to 01 to measure the vertical angle**. Normally, 01 is assigned to the more experienced observer and will measure the VA. Observer 01 measures the vertical angles that will be used to compute the altitude of the mean burst location as well as direction. Only one observer reports the vertical angle.
- **Orienting data for 02 (C19)**. The HCO measures the chart data from 02 to the orienting point. The VCO subtracts the altitude of the observer from the altitude of the orienting point to determine the vertical interval. The VCO uses the C and D scales of the GST, the vertical interval, and the distance measured by the HCO to determine 02's vertical angle. The vertical angle and direction reported to 02 will enable him to orient on the orienting point.
- **A directive to the observers to report when they are ready to observe**. When the observers report that they are ready to observe, the FDC can begin the registration.

Message to Observers

OBS HB REG
T03 DIR 5136 VA -8
MEASURE THE VA
C19 DIR 4541 VA -1
REPORT W/R TO OBSERVE

Legend: DIR – direction HB – high-burst OBS – observer
REG – registration VA – vertical angle W/R – when ready

Figure 10-6. Example Message to Observer on DA Form 4201.

10-60. Each observer orients his instrument on the direction and vertical angle announced to him and announces when he is ready to observe the registration.

DETERMINING FIRING DATA

10-61. The HCO determines the range and deflection from the firing unit to the orienting point and announces the data to the computer.

10-62. The VCO subtracts the altitude of the firing unit from the orienting point altitude to determine the vertical interval. The VCO determines and announces site to the computer.

10-63. The computer records the site on the ROF and determines and announces the fire commands to the howitzer(s). The HOB correction (20/R) is not used for the HB registration since the HOB was already accounted for in the orienting point altitude. The data fired are the adjusted (did hit) data.

FIRING THE HB OR MPI REGISTRATION

10-64. After both observers and the registering howitzer have reported ready, the FDO directs **FIRE THE REGISTRATION**. The first round that is fired may not be observed by either of the observers. There may be cases in which the nonstandard conditions cause the round to impact behind a hill or in a ravine, out of sight of one or both of the observers. Sometimes graze bursts occur at the start of an HB registration. The observers' data for these rounds cannot be used to determine the mean burst location. If this happens, change the firing data to the orienting point by increasing the HOB by at least 2 additional probable errors in HOB (Table G of the TFT) until both observers can observe the bursting rounds (see paragraph 10-18). **Remember, if the orienting point is changed, new orienting data must be transmitted to the observers (that is, a new MTO) so that they can orient on the new location.**

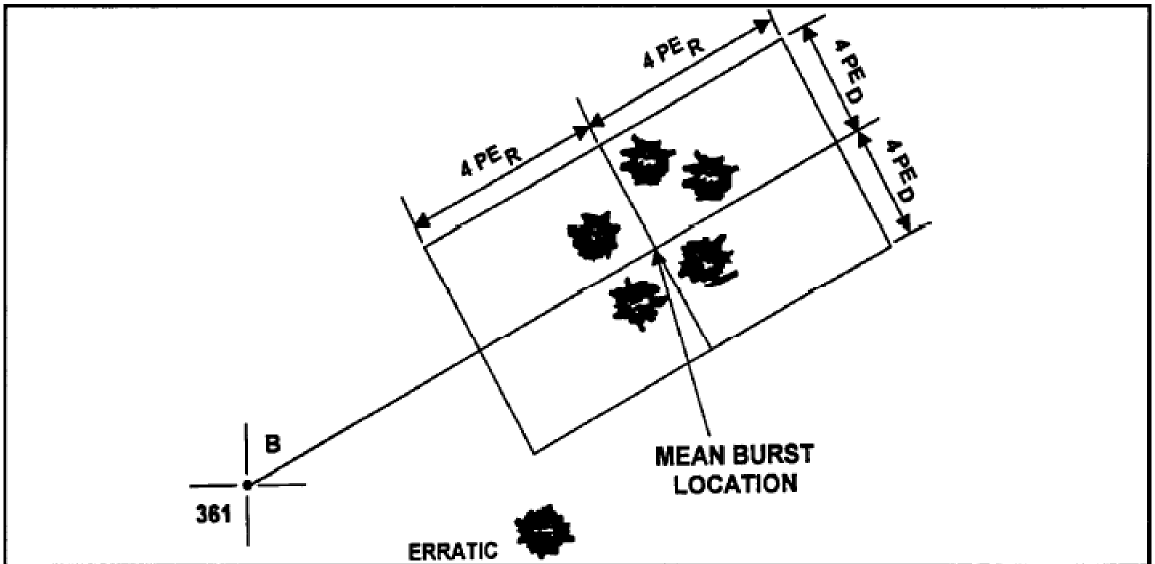
10-65. Once both observers have spotted the round, the firing data are not changed. All rounds used to determine the MBL and/or MPI must be fired with the same set of firing data. These firing data are adjusted (did hit) data.

10-66. When both observers have reported that they have observed the bursting round, the computer transfers the firing data from the ROF to DA Form 4201 and writes "SEE ATTACHED DA FORM 4201" on the ROF. Record all information for the rest of the registration on DA Form 4201.

10-67. After observing each round, each observer reports the direction to the round and 01 reports the vertical angle. The computer records the data on DA Form 4201 as it is transmitted by the observers. The FDO must determine if any rounds fired were erratic and their spotting discarded. There are no exact rules for determining which rounds are erratic. The following are methods in which erratic rounds may be determined.

10-68. Determine the MBL by using graphic intersection (see paragraph 10-22). Using the range to the MBL (expressed to the nearest 100 meters and interpolated), determine the PE_R and PE_D and construct a rectangle (8 PE_R x 8 PE_D) centered over the MBL and along the GTL. Reject any rounds that plot outside this rectangle (See figure 10-7 on page 10-19).

Note: All rounds should have functioned within the dispersion zone defined by ±4 PE_R and ±4 PE_D. Any rounds outside of the rectangle are considered erratic.



Legend: PE_D – probable error in deflection PE_R – probable error in range

Figure 10-7. 8 PE_R x 8 PE_D Rectangle for HB Registration.

10-69. At the range to the MBL, expressed to the nearest listed value in the TFT, determine the PE_{HB}. Using 01's reported vertical angles, the measured distance from 01 to the MBL, and the ground altitude, determine the MBL altitude. Determine the altitude of each round, and compare this altitude with the average altitude. Reject any round that falls outside the average altitude ±4 PE_{HB}.

10-70. The FDO may use his judgment and experience in determining if a round should be rejected. Care must be taken to ensure that erratic rounds are not used or that useable rounds are not rejected. If a round is considered erratic because of the reported direction from 01 or 02 or because of an incorrect vertical angle, the data from the other observer must also be discarded.

DETERMINE THE MEAN BURST LOCATION

10-71. List the observers' measured azimuths (spotting) on DA Form 4201 (figure 10-8 on page 10-20) as they are sent by the observers. As the rounds are fired, circle the round number to record the expenditure of rounds during the registration. Some rounds may be considered erratic. Erratic rounds are crossed out, and additional rounds may be fired to replace them.

10-72. Once the data from the useable rounds are recorded, the FDC determines the MBL. Determine the location by one of three methods. The methods are listed below in increasing order of accuracy and time of computation. The method used by the FDC will depend on the tactical situation. Usually, the graphic intersection method is acceptable. However, when increased accuracy is needed, use one of the other methods if time permits. See paragraph 10-24 for specific steps.

- **Graphic intersection**. Draw the observers' average directions on the firing chart. The point at which the lines intersect is the mean burst location.
- **Polar plot**. Determine the direction and distance from 01 to the mean burst location, and polar plot the MBL on the firing chart.
- **Grid coordinates**. Compute the actual grid coordinates of the MBL, and plot the coordinates on the firing chart.

Observer Readings				
Rd	O1		O2	
No	Az	VA	Az	
①	5102	-11	4551	
②	5105	-10	4547	
③	5103	-9	4552	
④	5106	-10	4548	
⑤	5107	-11	4546	
⑥	5102	-9	4550	
7				
8				
9				
10				
	30625	-60	27294	Total
	5104	-10	4549	Average
Legend: Az – azimuth No – number Rd – round VA – vertical angle				

Figure 10-8. Observers' Measured Azimuths.

10-73. Example of an HB/MPI Registration. The steps in table 10-5 are used to process an HB/MPI registration.

Table 10-5. HB/MPI Registration.

STEP	*REFERENCE*	*ACTION*
1	Fire Order	Computer/RTO reads back and records the fire order announced by the FDO.
2	Initial Fire Commands	Computer/RTO determines and records the fire commands.
	FM	Announced and circled or checked.
	MF	Computer/RTO determines, announces, and records the howitzer to fire and method of fire.
	SP Instr	Computer/RTO records as directed by the fire order. BRAMC is announced and recorded.
	Sh	Computer/RTO records if other than standard, as directed by the fire order.
	Lot	Computer/RTO records if other than standard, as directed by the fire order.
3	Orienting Point Data	The FDC determines the orienting point altitude and data to orient both observers. These data are announced to the Computer/RTO, who records it on two separate lines in the subsequent fire commands portion of the ROF.
	Ground Altitude of the Orienting Point	The FDO determines and announces the ground altitude of the orienting point. The Computer/RTO records it.
	Orienting Point Altitude	(ORIENTING POINT ALT = HOB + GROUND ALT).
	Note: The remaining steps are completed for O2 as well.	

Table 10-5. HB/MPI Registration (continued).

STEP	*REFERENCE*	*ACTION*
	Direction	The HCO determines and announces the direction from O1 to the orienting point. The Computer/RTO records this value on the corresponding line in the subsequent fire commands portion of the ROF.
	Distance	The HCO determines and announces the distance from O1 to the orienting point. The Computer/RTO records this value on the corresponding line in the subsequent fire commands portion of the ROF.
	VI	The VCO determines and announces VI between the observer and the orienting point. The Computer/RTO records this value on the corresponding line in the subsequent fire commands portion of the ROF.
	VA	The VCO determines and announces the VA from O1 to the orienting point. The Computer/RTO records this value on the corresponding line in the subsequent fire commands portion of the ROF.
4	MTO	The RTO transmits the MTO. Computer/RTO records the MTO on the DA Form 4201.
5	Rg	HCO determines and announces range. Computer/RTO places the MHL of the appropriate GFT over the announced range, reads back the range, and records it.
6	Chg	Computer/RTO announces and records charge.
7	Fz	Computer/RTO announces and records if other than standard. Fuze time will be fired for a HB; fuze quick for a MPI registration.
8	Chart Df	HCO determines and announces chart deflection. Computer/RTO records it.
9	El	Computer/RTO determines and records elevation.
10	Ti	Computer/RTO determines and records the fuze setting if firing a HB registration.
11	Drift	Computer/RTO determines and records drift in the upper computational space.
12	Df Corr	Computer/RTO record the deflection correction. This is the sum of drift plus the GFT deflection correction (DRIFT + GFT DF CORR = DF CORR). If no GFT deflection correction is available, the deflection correction will be the same as drift.
13	Df	Computer/RTO determines, announces, and records the deflection to fire (DF CORR + CHT DF = DF TO FIRE).
14	SI	VCO determines site to the orienting point and announces it. Computer/RTO records it.
15	QE	Computer/RTO determines, announces, and records quadrant elevation.
16	Verification	Computer/RTO verifies fire commands with either the FDO or chief.
17	Transmit Fire Commands	Chief/Computer transmits fire commands to the howitzer(s).
18	Police of the ROF	Computer/RTO ensures that all data pertaining to the mission are recorded. Computer/RTO also determines and records data that could be used in subsequent computations.

Table 10-5. HB/MPI Registration (continued).

STEP	***REFERENCE***	***ACTION***
	Computational Space	Computer/RTO records the VCO's math steps used to determine the orienting point altitude and VI.
	Ammo Exp	Computer/RTO circles number of rounds when the registration is complete.
	EOM	Computer/RTO announces and records EOM when directed by the FDO. The Computer/RTO also records "SEE ATTACHED DA FORM 4201" in the subsequent fire commands block.
	Observers' VI	Computer/RTO records on the corresponding line in the observers subsequent correction block the VCO's math steps used to compute the observers' Vis.
	DTG	Computer/RTO records the DTG of when the mission ends.
	Btry	Computer/RTO records the battery or platoon firing the registration
	Data Fired	Computer/RTO transfers from the ROF to the DA Form 4201 the charge, deflection, fuze setting, and QE fired.

Legend: ALT – altitude BRAMC – by round at my command CFF – call for fire CHG – charge CHT – chart
CORR – correction DF – deflection DTG – 13 April 2016 time group EOM – end of mission EXP – expenditure
FDC – fire direction center FDO – fire direction officer FM – fire mission FS – fuze setting GFT – graphical firing table
HCO – horizontal control operator HOB – height of burst MF – method of fire MHL – manufacturer's hair line
MTO – message to observer PE_R – probable errors in range QE – quadrant elevation RG – range ROF – record of fire
RTO – radio telephone operator SH – shell SI – site SP INSTR – special instructions TI – time VA – vertical angle
VCO – vertical control operator VI – vertical interval

Note: A completed ROF for an HB registration using fuze M767 is shown in figure 10-9, page 10-23.

RECORD OF FIRE

CALL FOR FIRE		
Observer ______	AF/FFE/IS/S ______	Tgt ______
Grid: ______		
Polar:Dir ______	Dis ______ U/D ______	VA ______
Shift: ______	Dir: ______ L/R ______ +/- ______	U/D ______

GRND ALT 1050 HOB + 50 O.P. ALT 1100 PLT ALT 1062 VI + 38	DRIFT L8 GFT 0 DF CORR L8	△FS 100/R /R 20/R
∠Si ÷ 10	10m Si	HOB Corr

FIRE ORDER HB REG AT GRID 4128, HOB +50, W/ T09 & C19, #3, ⑥, LOT A/H, CHG 3, FZ TI, BRAMC, USE GUNNER'S QUAD				Df Corr	L8	Si	+4
INITIAL FIRE COMMANDS	FM (circled)	MF	#3, ⑥	Rg 9420	Cht Df 3289	El	272
Sp Instr BRAMC, USE GUNNER'S QUADRANT	Sh	Lot	Chg 3	Fz TI	Ti 25.7	DF 3297	QE 276
MTO	∢T (370)	PE$_R$ (≤25)	TF (26)	in EFF		Ammo Exp ⑥ TI ✓	

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ()	El	QE	Exp	Type
				EOM		(SEE ATTACHED DA FORM 4201)										
ORIENT	POINT	ALT	1100	(T03)	01		DIR	5136		DIST	3280				VA	-8
	01	ALT	1127													
	01	VI	-27													
ORIENT	POINT	ALT	1100	(C19)	02		DIR	4541		DIST	3670				VA	-1
	02	ALT	1103													
	02	VI	-3													

PE_{HB} = 24M X 2 = 48 ≈ 50M

Btry 1/A	DTG 011400ZJUN13	Tgt	Replot Grid	Replot Alt

DA FORM 4504, JAN 2016 — PREVIOUS EDITIONS ARE OBSOLETE. — FOR USE OF THIS FORM, SEETC 3-09.81; THE PROPONENT AGENCY IS TRADOC. APD LC v1.00

Legend:
ABBR – abbreviated
ADJ - adjusted
AF – adjust fire
ALT - altitude
AMC – at my command
BRAMC – by round at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
GRND – ground
HB – high burst
HOB – height of burst
I/E – in effect
IS – immediate suppression
KN PT – known point
L/R – left/right
MF – method of fire
OBS – observer
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REG – registration
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TOF – time of flight
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 10-9. Completed ROF for a HB Registration.

DETERMINATION OF THE MBL

10-74. After all rounds have been fired and the observer spottings recorded, the FDO will determine if any rounds fired were erratic and should be discarded. If any round(s) are discarded, the FDO may decide to fire more rounds. If more rounds are to be fired, the method of fire and QE will be recorded on the ROF and announced to the registering howitzer. Use the procedures in table 10-6 to determine the average observer readings.

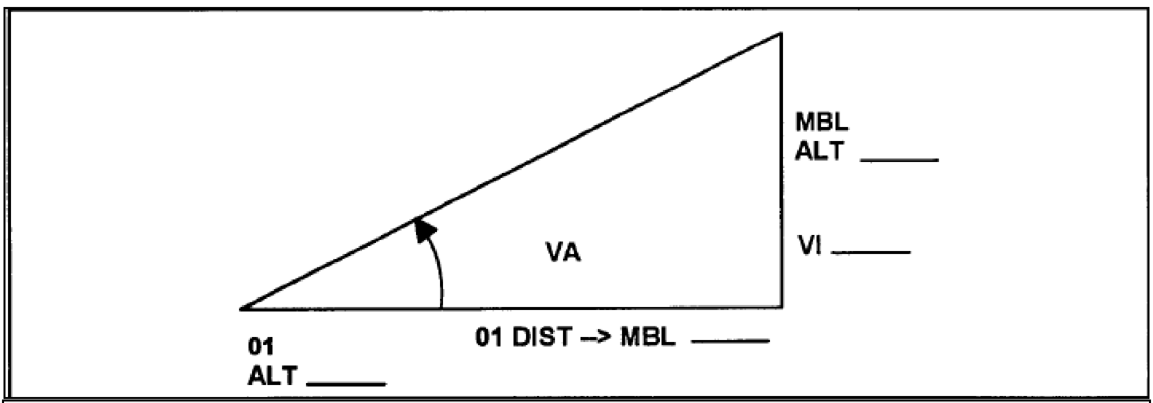
Table 10-6. Average Observer Readings.

STEP	***REFERENCE***	***ACTION***
1	Distance O1→ O2	Record the distance and azimuth from O1 to O2 if provided by the survey section. If they are not provided by the survey section, determine them from the firing chart.
2	Observer Readings	Determine and record on the DA Form 4201 the totals of O1's and O2's reported azimuths and O1's reported Vas.
3	Observer Readings	Determine the average azimuths and VA by dividing the totals determined in step 2 by the number of useable rounds, and record them. Express each result to the nearest mil.
Legend: O1 – observer 1 O2 – observer 2 VA – vertical angle		

10-75. The MBL is determined by using one of the methods below:

10-76. **Graphic intersection**. The HCO orients the RDP by using the average direction of 01. Once the RDP is oriented, a line is drawn along the arm of the RDP by using a 6-H pencil. He repeats the same procedure from 02 by using 02's average direction. The point at which the two lines intersect is the mean burst location. The HCO places a plotting pin at the MBL and determines and announces the distance from 01 to the MBL. The VCO uses the average vertical angle of 01, the 01 distance to the MBL, and the GST to determine and announce the vertical interval between 01 and the MBL. The computer adds the vertical interval to 01's altitude to determine the altitude of the MBL **(01 ALT + VI = MBL ALT)**. Figure 10-10 can be used to aid in the determination of the MBL altitude. If this aid is used, it is recorded in the margin of DA Form 4201. A completed DA Form 4201 is shown in figure 10-11 on page 10-26 for the graphic intersection technique.

10-77. **Polar plot**. Use the procedures in table 10-7 on page 10-25 and DA Form 4201 (figure 10-12, page 10-27) to determine the MBL.

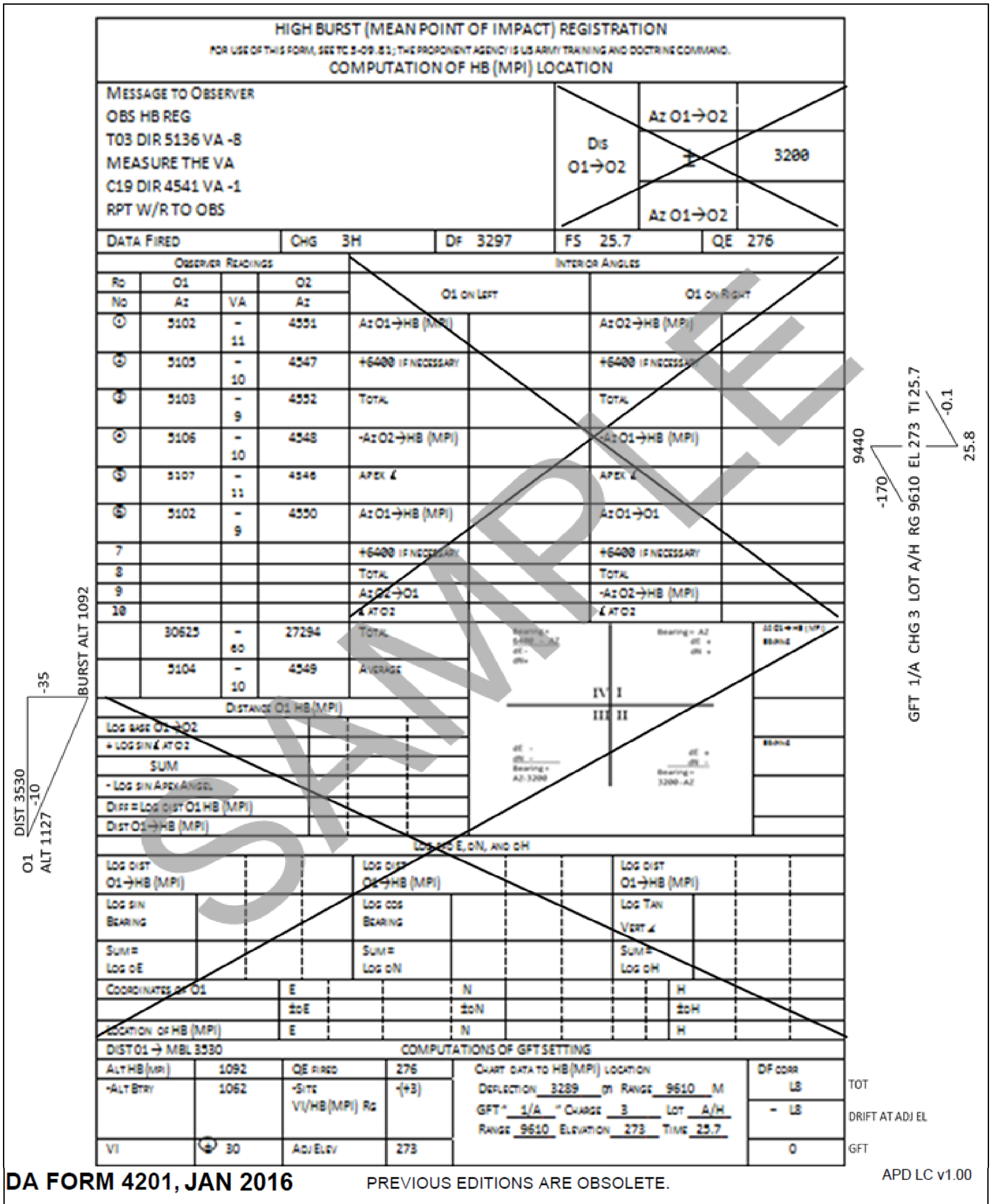


Legend: ALT – altitude DIST – distance MBL – mean burst location VA – vertical angle VI – vertical interval

Figure 10-10. Aid for Determining the MBL Altitude.

Table 10-7. Determining the MBL.

STEP	*REFERENCE*	*ACTION*
1	Interior Angles O1 on Left	Select the appropriate column based on whether O1 is on the left or right of O2 as the observers face the orienting point. Cross out the section not used.
2	Az O1(O2)→HB(MPI)	Record the average azimuth from O1 (O2) to the HB (MPI).
3	+6,400 if necessary	Record 6400 in the block if O1 average azimuth (O2 average azimuth) is less that O2 average azimuth (O1 average azimuth). If not, leave the block blank.
4	Total	Record the sum of steps 2 and 3.
5	- Az O2(O1)→HB(MPI)	Record the average azimuth from O2 (O1) to the HB (MPI).
6	Apex ∡	Subtract O2(O1) Az from O1(O2) Az.
7	Az O2→HB(MPI)	Record the average azimuth from O2 to the HB (MPI).
8	+6,400 if necessary	Record 6400 in the block if Az O2→HB (MPI) is less than Az O2→O1. If not, leave the block blank.
9	Total	Record the sum of steps 7 and 8.
10	- Az O2→O1	Record the azimuth from O2 to O1 as reported by the survey section.
11	∡ at O2	Subtract the Az O2→O1 recorded in step 10 from the total in step 9.
	Note: The section of DA Form 4201 labeled "Distance O1 HB (MPI)" is used to determine the O1 distance to the MBL by using algorithms. A slide rule, the Natural Trigonometric Tables located in the Supplementary Tables of the Introduction of the Tabular Firing Tables, or scientific calculator may also be used to compute the distance with the formula shown in figure 10-13 (on page 10-28). If a calculator is used, first convert the angles in mils to degrees by dividing them by 17.7778 (6,400 divided by 360 equals 17.7778).	
12	Log base O1→O2	Use a scientific calculator to determine the log base O1→O2 distance as reported by the survey section.
13	+ Log sin ∡ at O2	Use a scientific calculator to determine the log sine (sin) ∡ at O2 determined in step 11.
14	Sum	Record the sum of steps 12 and 13.
15	- Log sin Apex Angle	Use a scientific calculator to determine the log sine of the Apex Angle as recorded in step 6.
16	Diff = Log dist O1 HB(MPI)	Record the difference between the values determined in steps 14 and 15
17	Dist O1→HB(MPI)	Determine and record the antilog of the value recorded in step 16.
18	Computation of a GFT Setting	Express the value determined in step 17 to the nearest 10 meters and record it on the left of the heading "COMPUTATION OF GFT SETTING." Precede the value with the statement "DIST O1→MBL."
18a	The HCO places the vertex of the RDP on O1's location and orients it to the average direction determined for O1 to the MBL. He then places a pin at the distance determined for O1 to the MBL. This is the MBL.	
18b	The VCO uses the average vertical angle of O1, the O1 distance to the MBL, and the GST to determine and announce the vertical interval between O1 and the MBL. The computer adds the vertical interval to O1's altitude to determine the altitude of the MBL (**O1 ALT + VI = MBL ALT).**	
Legend: ALT – altitude AZ – azimuth DIFF – difference DIST – distance GFT – graphical firing table GST – graphical site table HB – high burst HCO – horizontal control operator MBL – mean burst location MPI – mean point of impact O1 – observer 1 O2 – observer 2 RDP – range deflection protractor VCO – vertical control operator VI – vertical interval		


HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS US ARMY TRAINING AND DOCTRINE COMMAND.

COMPUTATION OF HB (MPI) LOCATION

MESSAGE TO OBSERVER
OBS HB REG
T03 DIR 5136 VA -8
MEASURE THE VA
C19 DIR 4541 VA -1
RPT W/R TO OBS

Az O1→O2 | Dis O1→O2 | 3200 | Az O1→O2

DATA FIRED | CHG 3H | DF 3297 | FS 25.7 | QE 276

OBSERVER READINGS				INTERIOR ANGLES	
RD NO	O1 AZ	VA	O2 AZ	O1 ON LEFT	O1 ON RIGHT
1	5102	-11	4551	AZ O1→HB (MPI)	AZ O2→HB (MPI)
2	5105	-10	4547	+6400 IF NECESSARY	+6400 IF NECESSARY
3	5103	-9	4552	TOTAL	TOTAL
4	5106	-10	4548	-AZ O2→HB (MPI)	-AZ O1→HB (MPI)
5	5107	-11	4546	APEX ∠	APEX ∠
6	5102	-9	4550	AZ O1→HB (MPI)	AZ O1→O1
7				+6400 IF NECESSARY	+6400 IF NECESSARY
8				TOTAL	TOTAL
9				AZ O2→O1	-AZ O2→HB (MPI)
10				∠ AT O2	∠ AT O2
TOTAL	30625	-60	27294	TOTAL	
AVERAGE	5104	-10	4549	AVERAGE	

DISTANCE O1 HB (MPI)
LOG BASE O1→O2
+ LOG SIN ∠ AT O2
SUM
- LOG SIN APEX ANGLE
DIFF = LOG DIST O1 HB (MPI)
DIST O1→HB (MPI)

LOG dE, dN, AND dH
LOG DIST O1→HB (MPI) | LOG DIST O1→HB (MPI) | LOG DIST O1→HB (MPI)
LOG SIN BEARING | LOG COS BEARING | LOG TAN VERT ∠
SUM = LOG dE | SUM = LOG dN | SUM = LOG dH
COORDINATES OF O1 | E | N | H
±dE | ±dN | ±dH
LOCATION OF HB (MPI) | E | N | H

DIST O1 → MBL 3530

COMPUTATIONS OF GFT SETTING

ALT HB (MPI)	1092	QE FIRED	276	CHART DATA TO HB (MPI) LOCATION	DF CORR
-ALT BTRY	1062	-SITE	-(+3)	DEFLECTION 3289 ON RANGE 9610 M	LB
		VI/HB (MPI) RG		GFT 1/A CHARGE 3 LOT A/H	- LB
				RANGE 9610 ELEVATION 273 TIME 25.7	
VI	30	ADJ ELEV	273		0

TOT
DRIFT AT ADJ EL
GFT

O1 DIST 3530 ALT 1127 -10 -35 BURST ALT 1092

GFT 1/A CHG 3 LOT A/H RG 9610 EL 273 TI 25.7 9440 -170 -0.1 25.8

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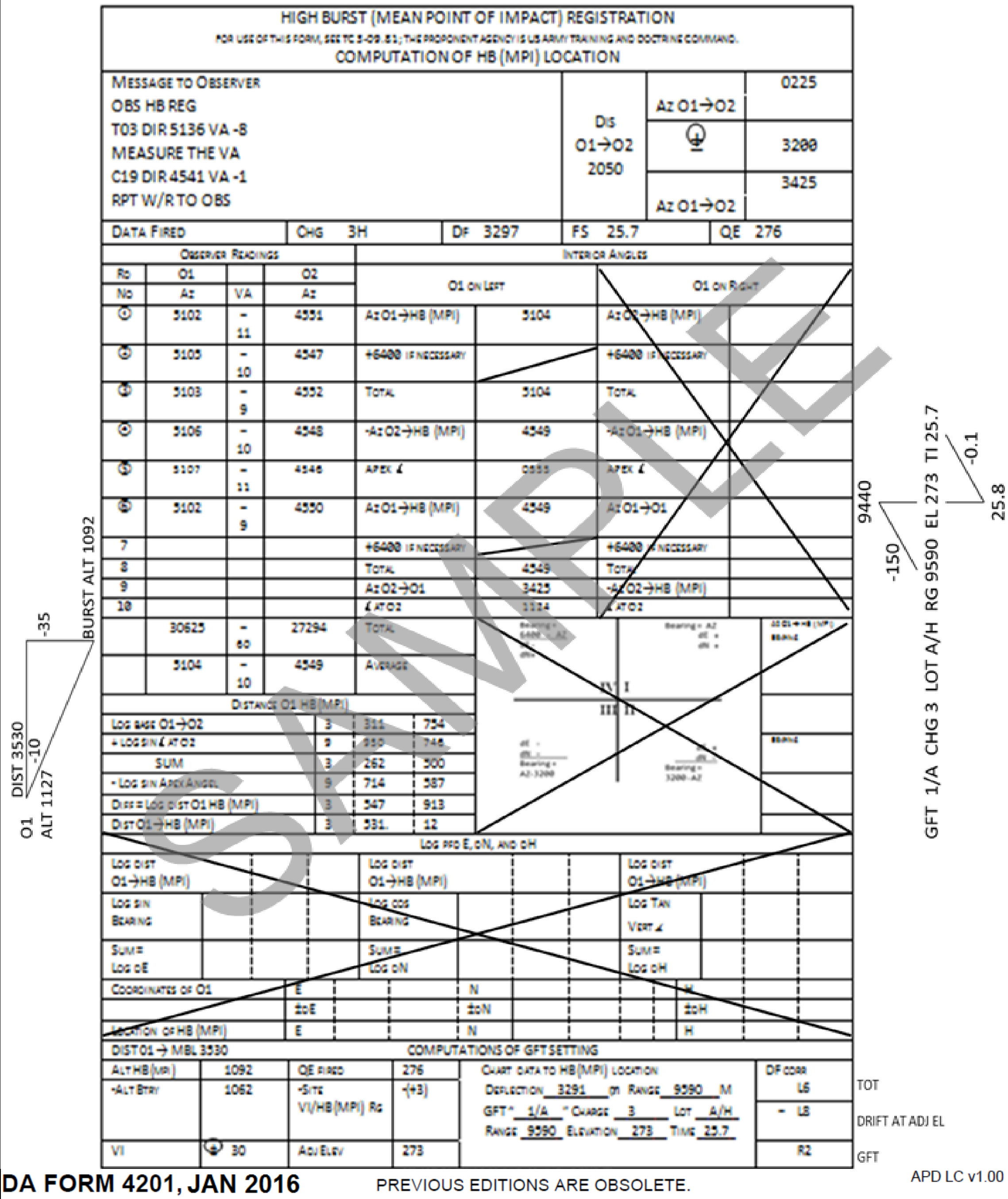
SAMPLE

Legend:
ADJ ELEV – adjusted elevation
ALT – altitude
AZ – azimuth
BTRY – battery
CHG – charge
CORR – correction
DF – deflection
DIR – direction
DIS – distance
EL – elevation
FS – fuze setting
GFT – graphical firing table
HB – high burst
LOG – logarithm
MPI – mean point of impact
No – number
OBS – observer
QE – quadrant elevation
RD – round
REG – registration
RG – range
RPT W/R – report when ready
TI – time
VA – vertical angle
VI – vertical interval

Figure 10-11. Completed DA Form 4201 for the Graphic Intersection Technique.



HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS US ARMY TRAINING AND DOCTRINE COMMAND.

COMPUTATION OF HB (MPI) LOCATION

MESSAGE TO OBSERVER
OBS HB REG
T03 DIR 5136 VA -8
MEASURE THE VA
C19 DIR 4541 VA -1
RPT W/R TO OBS

DIS O1→O2 2050 | Az O1→O2 0225 | 3200 | 3425 | Az O1→O2

DATA FIRED | CHG 3H | DF 3297 | FS 25.7 | QE 276

OBSERVER READINGS

RD No	O1 Az	VA	O2 Az
1	5102	-11	4551
2	5105	-10	4547
3	5103	-9	4552
4	5106	-10	4548
5	5107	-11	4546
6	5102	-9	4550
7			
8			
9			
10			
	30625	-60	27294
	5104	-10	4549

INTERIOR ANGLES

O1 ON LEFT		O1 ON RIGHT	
Az O1→HB (MPI)	5104	Az O2→HB (MPI)	
+6400 IF NECESSARY		+6400 IF NECESSARY	
TOTAL	5104	TOTAL	
-Az O2→HB (MPI)	4549	-Az O1→HB (MPI)	
APEX ∠	0555	APEX ∠	
Az O1→HB (MPI)	4549	Az O1→O1	
+6400 IF NECESSARY		+6400 IF NECESSARY	
TOTAL	4549	TOTAL	
Az O2→O1	3425	-Az O2→HB (MPI)	
∠ AT O2	1124	∠ AT O2	
TOTAL			
AVERAGE			

DISTANCE O1 HB (MPI)

LOG BASE O1→O2	3	311	754
+ LOG SIN ∠ AT O2	9	950	746
SUM	3	262	500
- LOG SIN APEX ANGLE	9	714	587
DIST = LOG DIST O1 HB (MPI)	3	547	913
DIST O1→HB (MPI)	3	531.	12

LOG PFD E, dN, AND dH

LOG DIST O1→HB (MPI) | LOG SIN BEARING | SUM = LOG dE | LOG DIST O1→HB (MPI) | LOG COS BEARING | SUM = LOG dN | LOG DIST O1→HB (MPI) | LOG TAN VERT ∠ | SUM = LOG dH

COORDINATES OF O1 | E | ±dE | N | ±dN | H | ±dH

LOCATION OF HB (MPI) | E | N | H

DIST O1 → MBL 3530

COMPUTATIONS OF GFT SETTING

ALT HB (MPI)	1092	QE FIRED	276
-ALT BTRY	1062	-SITE	-(+3)
		VI/HB (MPI) RG	
VI	⊕ 30	ADJ ELEV	273

CHART DATA TO HB (MPI) LOCATION
DEFLECTION 3291 RANGE 9590 M
GFT* 1/A * CHARGE 3 LOT A/H
RANGE 9590 ELEVATION 273 TIME 25.7

DF CORR: L6 / - L8 / R2

TOT
DRIFT AT ADJ EL
GFT

9440 -150 GFT 1/A CHG 3 LOT A/H RG 9590 EL 273 TI 25.7 -0.1 25.8

O1 ALT 1127 DIST 3530 -10 -35 BURST ALT 1092

SAMPLE

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Legend:

ADJ ELEV – adjusted elevation	DF – deflection	LOG – logarithm	RG – range
ALT – altitude	DIR – direction	MPI – mean point of impact	RPT W/R – report when ready
AZ – azimuth	DIS – distance	No – number	TI – time
BTRY – battery	EL – elevation	OBS – observer	VA – vertical angle
CHG – charge	FS – fuze setting	QE – quadrant elevation	VI – vertical interval
CORR – correction	GFT – graphical firing table	RD – round	
	HB – high burst	REG – registration	

Figure 10-12. Completed DA Form 4201 for the Polar Plot Technique.

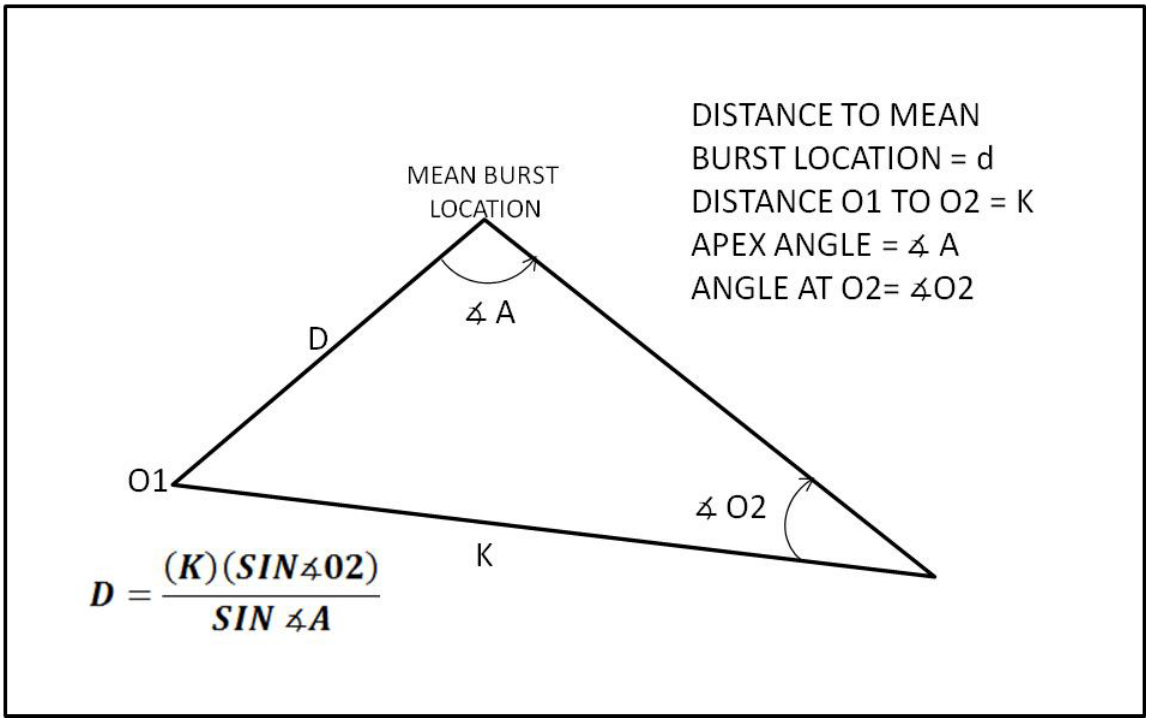


Figure 10-13. Formula for Computing Distance to the MBL.

10-78. **Grid coordinate**. The steps in table 10-8 and a DA Form 4201 (see figure 10-14 on page 10-30) are used to determine the MBL.

Table 10-8. Determination of the MBL.

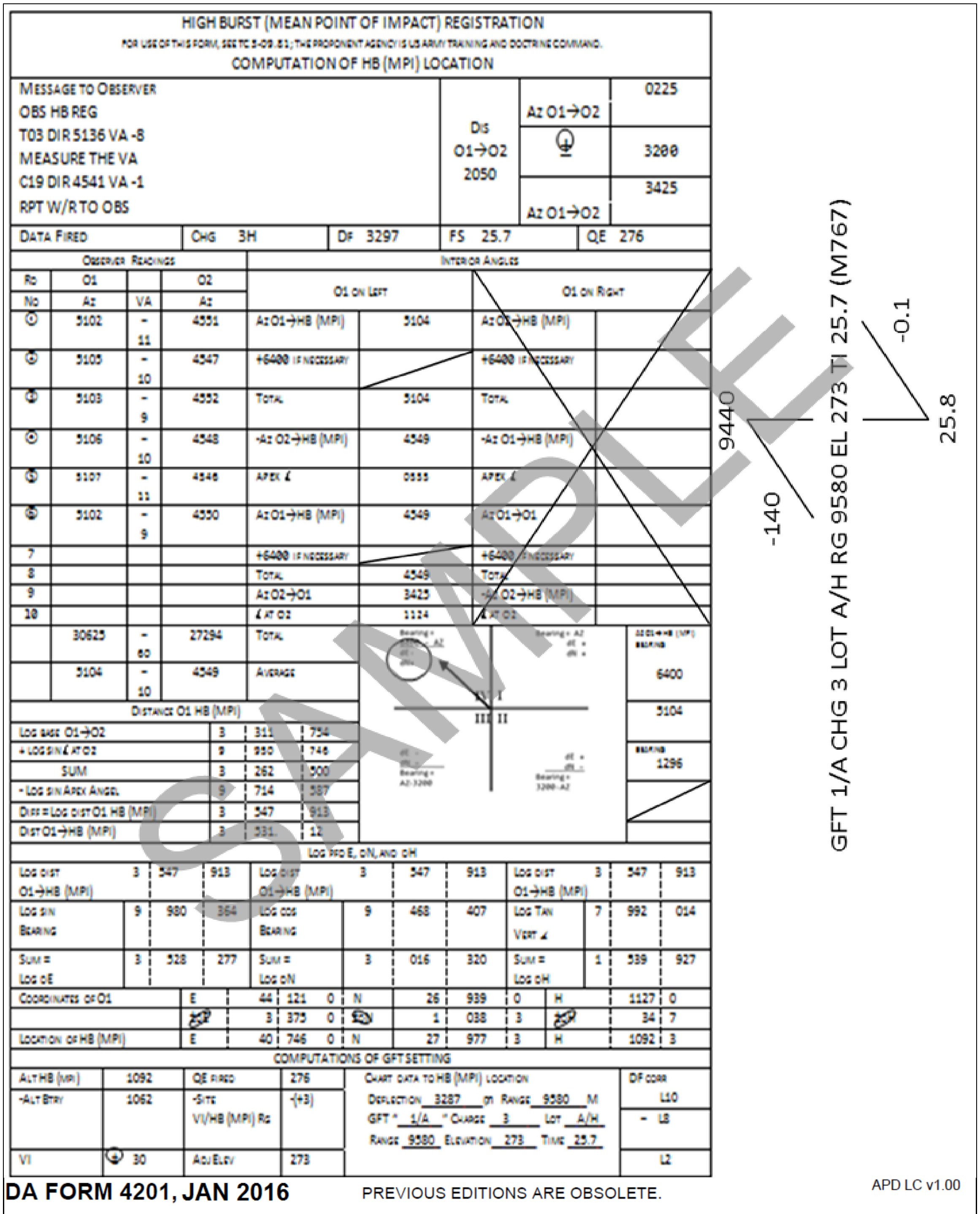
STEP	***REFERENCE***	***ACTION***
1	Dist O1→HB(MPI)	Compute O1 distance to the MBL in the same manner as the polar plot technique.
2	Bearing	Determine the bearing angle from O1 to the MBL. Use the diagram (with the top of the form representing north, or 0 mils) and draw a line along the average azimuth from O1 to the MBL. The instructions for each quadrant are listed below. **QUADRANT I BEARING ANGLE = O1 AZ → MBL** **QUADRANT II BEARING ANGLE = 3200 – (O1 AZ → MBL)** **QUADRANT III BEARING ANGLE = (O1 AZ → MBL) – 3200** **QUADRANT IV BEARING ANGLE = 6400 – (O1 AZ → MBL)**
3	Az O1→HB(MPI) → Bearing	On the basis of the quadrant selected in step 2, record the values used to determine the bearing angle.
	Note: The Log of DE, dN, and dH section on the DA Form 4201 is used to determine the coordinates of the MBL.	
4	Log dist O1→HB(MPI)	Record the Log dist O1→HB (MPI) determined in step 16 of the polar plot technique.
5	Log Sin Bearing	Use a scientific calculator to determine the log sine bearing angle.

Table 10-8. Determination of the MBL (continued).

STEP	*REFERENCE*	*ACTION*
6	Sum = Log dE	Determine and record the log of the change in easting between O1 and the MBL by adding the values from steps 4 and 5.
7	Coordinates of O1 (Easting)	Record O1’s five-digit easting.
8	Space below Coordinates of O1	Record the antilog of the value determined in step 6. This is the change in easting between O1 and the MBL.
9	Location of the HB(MPI) (Easting)	Determine and record the MBL easting by applying the change in easting (step 8) to O1’s easting (step 7). Add or subtract the change in easting on the basis of the quadrant used in step 3 **(Quadrant I or II, add; Quadrant II or IV, subtract).**
10	Log Cos Bearing	Use a scientific calculator to determine the log cosine (cos) of the bearing angle.
11	Sum = Log dN	Determine and record the log of the change in northing between O1 and the MBL by adding the values from steps 4 and 10.
12	Coordinates of O1 (Northing)	Record O1’s five-digit northing.
13	Space below Coordinates of O1	Record the antilog of the value determined in step 11. This is the change in northing between O1 and the MBL.
14	Location of the HB(MPI) (Northing)	Determine and record the MBL northing by applying the change in northing (step 13) to O1’s northing (step 12). Add or subtract the change in northing on the basis of the quadrant used in step 3 **(Quadrant I or II, add; Quadrant II or IV, subtract).**
15	Log Tan Vert ∡	Use a scientific calculator to determine the log tangent (tan) of the average vertical angle.
16	Sum = Log dH	Determine and record the log of the change in altitude between O1 and the MBL by adding the values from steps 4 and 15.
17	Coordinates of O1 (Height)	Record O1’s altitude.
18	Space below Coordinates of O1	Record the antilog of the value determined in step 16. This is the change in altitude between O1 and the MBL.
19	Location of the HB(MPI) (Height)	Determine and record the MBL altitude by applying the change in altitude (step 18) to O1’s altitude (step 17). Add or subtract the change in altitude on the basis of the sign of the average vertical angle.
20	Coordinates of the MBL	Announce the determined coordinates and altitude to the HCO. The HCO plots the MBL on the firing chart in the same manner as any surveyed location.

Legend: AZ – azimuth DIFF – difference DIST – distance HB – high burst HCO – horizontal control operator MBL – mean burst location MPI – mean point of impact O1 – observer 1 O2 – observer 2 VI – vertical interval

Note: A completed DA Form 4201 for the grid coordinates technique is shown in figure 10-14 on page 10-30.


HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS US ARMY TRAINING AND DOCTRINE COMMAND.

COMPUTATION OF HB (MPI) LOCATION

MESSAGE TO OBSERVER
OBS HB REG
T03 DIR 5136 VA -8
MEASURE THE VA
C19 DIR 4541 VA -1
RPT W/R TO OBS

DIS O1→O2 2050 | AZ O1→O2 0225 | 3200 | 3425 | AZ O1→O2

DATA FIRED | CHG 3H | DF 3297 | FS 25.7 | QE 276

OBSERVER READINGS				INTERIOR ANGLES			
RD NO	O1 AZ	VA	O2 AZ	O1 ON LEFT		O1 ON RIGHT	
1	5102	-11	4551	AZ O1→HB (MPI)	5104	AZ O2→HB (MPI)	
2	5105	-10	4547	+6400 IF NECESSARY		+6400 IF NECESSARY	
3	5103	-9	4552	TOTAL	5104	TOTAL	
4	5106	-10	4548	-AZ O2→HB (MPI)	4549	-AZ O1→HB (MPI)	
5	5107	-11	4546	APEX ∠	0555	APEX ∠	
6	5102	-9	4550	AZ O1→HB (MPI)	4549	AZ O1→O2	
7				+6400 IF NECESSARY		+6400 IF NECESSARY	
8				TOTAL	4549	TOTAL	
9				AZ O2→O1	3425	-AZ O2→HB (MPI)	
10				∠ AT O2	1124	∠ AT O2	
	30625	-60	27294	TOTAL			
	5104	-10	4549	AVERAGE			

AZ O1→HB (MPI) BEARING 6400 / 5104; BEARING 1296

DISTANCE O1 HB (MPI)			
LOG BASE O1→O2	3	311	754
+ LOG SIN ∠ AT O2	9	950	746
SUM	3	262	500
- LOG SIN APEX ANGEL	9	714	587
DIFF = LOG DIST O1 HB (MPI)	3	547	913
DIST O1→HB (MPI)	3	531.	12

LOG AND E, dN, AND dH

LOG DIST O1→HB (MPI)	3	547	913	LOG DIST O1→HB (MPI)	3	547	913	LOG DIST O1→HB (MPI)	3	547	913
LOG SIN BEARING	9	980	364	LOG COS BEARING	9	468	407	LOG TAN VERT ∠	7	992	014
SUM = LOG dE	3	528	277	SUM = LOG dN	3	016	320	SUM = LOG dH	1	539	927

COORDINATES OF O1	E	44 121 0	N	26 939	0	H	1127	0
		3 375 0		1 038	3		34	7
LOCATION OF HB (MPI)	E	40 746 0	N	27 977	3	H	1092	3

COMPUTATIONS OF GFT SETTING

ALT HB (MPI)	1092	QE FIRED	276	CHART DATA TO HB (MPI) LOCATION	DF CORR
-ALT BTRY	1062	-SITE	(+3)	DEFLECTION 3287 @ RANGE 9580 M	L10
		VI/HB (MPI) RG		GFT " 1/A " CHARGE 3 LOT A/H	- L8
				RANGE 9580 ELEVATION 273 TIME 25.7	
VI	(+) 30	ADJ ELEV	273		L2

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Legend:
ADJ ELEV – adjusted elevation
ALT – altitude
AZ – azimuth
BTRY – battery
CHG – charge
CORR – correction
DF – deflection
DIR – direction
DIS – distance
EL – elevation
FS – fuze setting
GFT – graphical firing table
HB – high burst
LOG – logarithm
MPI – mean point of impact
No – number
OBS – observer
QE – quadrant elevation
RD – round
REG – registration
RG – range
RPT W/R – report when ready
TI – time
VA – vertical angle
VI – vertical interval

Figure 10-14. Completed DA Form 4201 for the Grid Coordinates Technique.

DETERMINATION OF CHART DATA AND REGISTRATION CORRECTIONS

10-79. After plotting the MBL on the firing chart, the HCO determines and announces the chart range and deflection from the firing unit to the MBL. For the determination of the GFT setting, use table 10-9 to determine and record the data in the "COMPUTATION OF GFT SETTING" section on the DA Form 4201.

Table 10-9. Determination of the GFT Setting.

STEP	*REFERENCE*	*ACTION*
1	Deflection	Computer/RTO records the chart deflection to the MBL as announced by the HCO.
2	Range	Computer/RTO records the chart range to the MBL as announced by the HCO.
3	Alt HB(MPI)	Computer/RTO records the altitude (to the nearest meter) of the MBL as determined by the technique being used.
4	- Alt Btry	Computer/RTO records the registering piece altitude.
5	VI	Computer/RTO determines and records the VI by subtracting the altitude of the battery from the altitude of the HB (MPI).
6	QE fired	Computer/RTO records the quadrant elevation fired during the registration.
7	- Site VI/HB(MPI) Rg	Computer/RTO determines and records site on the basis of the VI from step 5 and the range announced (chart range) to the MBL from step 2.
8	Adj Elev	Computer determines the adjusted elevation by **subtracting the site** from step 7 from the QE in step 6.
9	GFT .	Computer/RTO records the firing unit designation.
10	Charge .	Computer/RTO records the charge fired during the registration.
11	Lot .	Computer/RTO records the lot fired during the registration.
12	Range .	Computer/RTO records the chart range to the MBL as announced by the HCO (from step 2).
13	Elevation .	Computer/RTO records the adjusted elevation from step 8.
14	Time .	Computer/RTO records adjusted time.
	Note: If the vertical interval between the firing unit and the MBL is less than or equal to 100 meters, the fuze setting used to fire the useable rounds is the adjusted fuze setting. If the vertical interval is greater than 100 meters, see the steps in paragraph 10-26.	
15	Df Corr	Computer/RTO determines and records the total deflection correction in the first block. The total deflection correction is determined by using the LARS rule and subtracting the chart deflection from the adjusted deflection. Record "TOT" to the right of the determined value.
16	Drift	Computer/RTO determines drift (using the appropriate GFT) corresponding to the adjusted elevation and records it in the middle block. Record "DRIFT @ ADJ EL" to the right of the determined value.
17	GFT Df Corr	Computer/RTO determines the GFT deflection correction by subtracting the drift from the total deflection correction and records it in the last block. Record "GFT" to the right of the determined value.
Legend: ADJ – adjusted ALT – altitude BTRY – battery DF – deflection EL/ELEV – elevation GFT – graphical firing table HB – high burst HCO – horizontal control operator LARS – left add right subtract MBL – mean burst location MPI – mean point of impact QE – quadrant elevation RG – range RTO – radio telephone operator TOT – time on target VI – vertical interval		

EFFECT OF COMPLEMENTARY ANGLE OF SITE ON ADJUSTED FUZE SETTING

10-80. Fuze setting is determined as a function of elevation and complementary angle of site. When the vertical interval is equal to or less than 100 meters, the CAS is generally so small that it has little effect on the quadrant and fuze setting fired and is disregarded. If the vertical interval is greater than 100 meters, the value of the CAS becomes increasingly large and begins to affect the fuze setting. In this case, the CAS must be added to the elevation to determine the proper fuze setting.

10-81. As the CAS increases, the setting also must be increased to reach the desired burst location. If the effect of CAS is not included in the fuze setting, the fuze will function before it reaches the desired location.

10-82. If the vertical interval is greater than 100 meters, modify the adjusted the setting to correct for the inaccuracy introduced by the large complementary angle of site. The 100-meter VI is only a rule of thumb; CAS may affect the adjusted fuze setting at vertical intervals of less than 100 meters. The FDO should check the effects of CAS anytime he feels it will affect the adjusted fuze setting. Use table 10-10 to correct the effect of complementary angle of site on adjusted fuze setting when VI is greater than 100 meters.

Table 10-10. Effect of Complementary Angle of Site.

STEP	***ACTION***
1	Computer determines the angle of site to the MBL by using the VI to the MBL, chart range to the MBL, and GST.
2	Computer determines the CAS by subtracting the angle of site to the MBL from the site to the MBL. **SITE** **- ANGLE OF SITE** **CAS**
3	Computer determines the elevation plus CAS by adding the CAS to the adjusted elevation. **CAS** **+ ADJ EL** **EL PLUS CAS**
4	Computer determines the fuze setting corresponding the elevation plus CAS by placing the MHL (of the appropriate GFT) over that value and reading the fuze setting under the MHL on the appropriate fuze setting scale.
5	Computer determines the total fuze correction by subtracting the fuze setting corresponding to the elevation plus CAS from the fuze setting fired. **FUZE SETTING FIRED** **- FUZE SETTING ≈ ELEVATION PLUS CAS** **TOTAL FUZE CORRECTION**
6	Computer determines the fuze setting corresponding to the adjusted elevation by placing the MHL (of the appropriate GFT) over the adjusted elevation and reading the fuze setting under the MHL on the appropriate fuze setting scale.
7	Computer determines the adjusted fuze setting by adding the total fuze correction from step 5 to the fuze setting corresponding to the adjusted elevation in step 6. The value is then recorded as the adjusted fuze setting for the GFT setting on the DA Form 4201.
Legend: ADJ – adjusted CAS – complementary angle of site EL – elevation GFT – graphical firing table GST – graphical site table MBL – mean burst location MHL – manufacturer's hair line VI – vertical interval	

SECTION IV: PROCESS A RADAR REGISTRATION

10-83. Field artillery radars can be used to observe registrations. The conduct of a radar-observed registration (commonly known as a radar registration) is similar to that of other HB or MPI registrations. This section outlines the unique procedures and requirements for radar systems.

CHARACTERISTICS

10-84. The target acquisition radar has two separate modes of operation. The primary mode of operation is hostile fire, which tracks incoming projectiles and is used to locate enemy indirect-fire systems. The secondary mode of operation is the friendly fire mode, which is used by friendly artillery and mortar units for adjust-fire missions and registrations. Since the weapons locating radars cannot radiate in friendly fire mode and hostile fire mode at the same time, the commander must issue specific guidance as to when and how friendly fire mode will be employed.

10-85. A peculiarity of the two separate modes of operation is how the radar operator inputs data into his computer to orient the radar. Data can only be input while the radar is in the hostile fire mode. Once the operator has input all the data into the computer, he switches from hostile to friendly mode, and a delay is experienced while the radar orients itself. If a problem is encountered during the registration, such as around being unobserved, the first thing the operator does is verify his data. This requires him to switch back to the hostile mode, verify his data, and then return to the friendly fire mode. Each time he changes modes, the radar physically reorients itself, taking from 20 to 30 seconds.

10-86. The radar can have six friendly fire target buffers stored, with only one active at any given time. They are used to store all the data needed to conduct a friendly fire mission. The radar also has the capability to store the spotting for six rounds. When the friendly fire storage cues are full and another round is tracked, it will replace the oldest spotting with the new one. Unless an observed round is recorded by the radar operator or transmitted to the FDC, the old data are lost when they are automatically replaced by the radar computer. Therefore, the operator needs to monitor the mission and either transmits each individual spotting to the FDC or clear the buffer by deleting erroneously captured information.

10-87. Do not permit exposure of electro-explosive devices to the radar beam within 268 meters. A danger area exists to the front of the radar. Friendly fire mode falls into the narrow beam sector scan category. For the Q-36 radar, do not permit personnel within an area of 800 mils left or right of the antenna front (pointing direction) out to a distance of five meters for full 1600-mil sector scan, 30 meters for narrow sector scan (including friendly fire) and 75 meters for fixed beam (maintenance aid). For the Q-37 radar, do not permit personnel within an area of 800 mils left or right of the antenna front (pointing direction) out to a distance of seven meters for full 1600-mil sector scan, 40 meters for narrow sector (300-400mils) scan and 100 meters for fixed beam (maintenance aid). The observation areas and various mission types for each radar system are listed below:

- Minimum observing distance for the Q-36 is 750 meters; for the Q-37, 3,000 meters.
- Minimum observing distance for the Q-53 is 3,000 meters (in both 90 and 360 degree modes).
- The Q-53 does not have a dedicated friendly fire mode but can track friendly fire registration while simultaneously tracking hostile fire.
- The Q-36 and Q-37 friendly fire mode has five different mission types that the radar can conduct. They are as follows:
  - Mortar datum plane (MD).
  - Mortar impact prediction (MI).
  - Artillery airburst (AA).
  - Artillery datum plane (AD).
  - Artillery impact prediction (AI).

10-88. The two types most commonly used by artillery are the artillery airburst (HB registration) and the artillery impact prediction (adjust-fire missions and MPI registrations). When the radar sections receives the initiation of a mission and the MTO messages, the radar operator processes the messages and the friendly fire search parameters are entered into the computer memory automatically. This is the usual method of entering the data, but it can be completed manually by the radar operator if needed. The radar will determine if there are any friendly fire search fence errors present. If no errors are present, the radar operator will transmit a Friendly Fire Search Fence status to the selected subscriber, the FDC, and should then expect to receive a fire command from the FDC informing the radar section that they are ready for the specified target. If the radar detects a friendly fire search fence error, then the selection in the computer will generate an end of mission.

10-89. The advantages of a radar registration include the following:

- Requires only one observation post–the radar.
- Requires less survey, fewer communications facilities, and less coordination than other HB or MPI registrations.
- Can be conducted quickly.
- Can be conducted in periods of poor visibility.
- Produces the MBL/MPI grid and altitude or the grid and altitude of each round.

10-90. The disadvantages of a radar registration include the following:

- Exposes radar to detection from the enemy.
- Keeps radar sections from performing their primary mission.
- May need to reposition radar to conduct the registration.

CONDUCT OF A RADAR REGISTRATION

10-91. The six steps in conducting a radar registration are as follows:

- Select an orienting point.
- Orient the radar.
- Determine firing data to the orienting point.
- Fire the HB or MPI registration.
- Determine the mean burst location.
- Determine chart data and registration corrections.

SELECTION OF AN ORIENTING POINT

10-92. The radar must be properly sighted in relation to friendly units to fully use its capabilities. There are three areas that significantly impact the ability of the radar to track friendly fire. They are as follows:

- Electrical line of sight.
- Range from the radar to the target.
- Aspect angle (Aspect ∡).
  - Radar must have electrical line of sight to the point along the descending branch of the trajectory of the round where the burst will occur (HB), or it must be able to track the projectile for enough time to predict its point of impact (MPI). Doctrine calls for radar to be sited in defilade to increase its survivability. This means that there are intervening crests (screening crests) between the radar and the area where the rounds are being fired.
  - If these crests interfere with the radar's electrical line of sight, then the radar search fence must be oriented high enough so that these crests will not mask the emissions. However, if the radar is oriented above the altitude that the time fuzes are set to function, then **ROUND UNOBSERVED** will very likely be received from the radar. The easiest way to counteract this problem is to modify the procedures normally used to select a height of burst for HB registrations so that the radar is sure to "see" the burst.
  - Aspect angle is the angle that is formed by the intersection of the gun-target line and the radar-target line, with the vertex of the angle at the target (Aspect ∡). The aspect angle should be less than 1,200 mils, with 800 mils being the optimum angle. A less than optimal aspect angle is going to decrease the probability of tracking each round. (From 1,300 to 1,600 mils, the tracking picture becomes undefined with the probability of track decreasing significantly.) These factors must be considered when determining where to site your radars to optimize their performance.

10-93. A high-burst registration conducted with the radar requires only an electrical line of sight to the selected point. The on-board computer controls the radar to enable it to intersect the trajectory above the screening crest. The radar tracks the round until the airburst is detected. The radar systems set up a "window" through which the projectile will pass. The window is referred to as the friendly fire search fence (figure 10-15). The search fence allows for the best probability of detection. Because of the size of the radar memory queue, no more than ten rounds should be fired without coordination with the radar section. Rounds should be fired at 30-second intervals with an angle T of less than 1,000 mils.

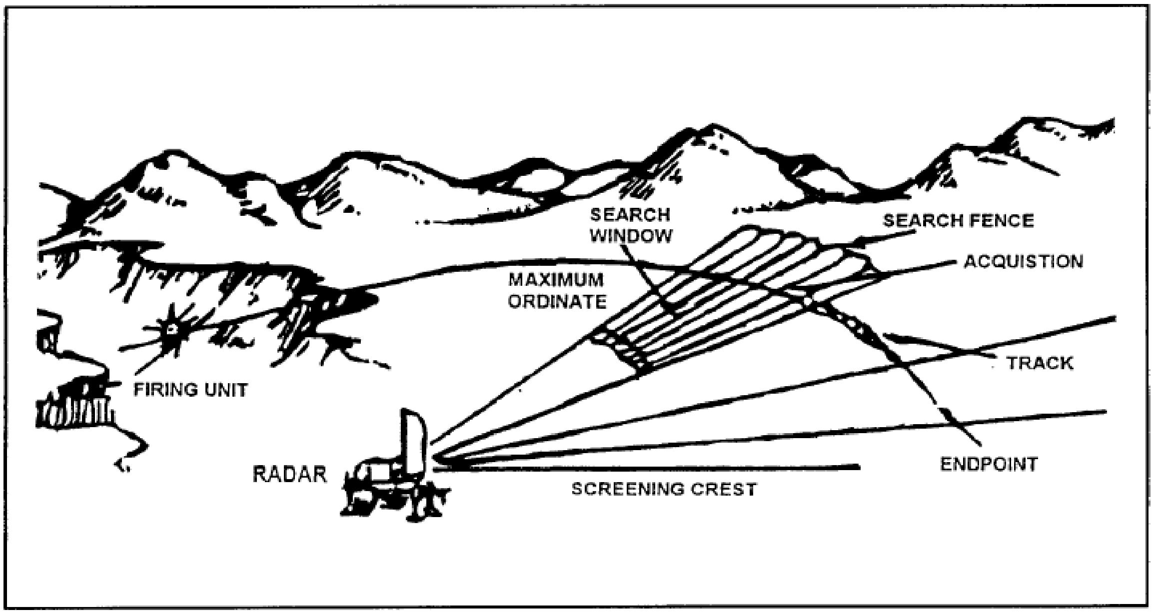


Figure 10-15. Projectile Tracking—Target Acquisition Radar.

10-94. **MPI Registration**. In an impact-predict mission, the radar uses the friendly fire mode to track the round on its descending trajectory toward the registration point and to predict where the round will impact without actually observing the ground burst. To provide data, the radar must track the round along its trajectory for a sufficient distance above the radar's screening crest. The projectile is tracked until it reaches the datum plane height. The radar section reports the grid and altitude of the impact location as predicted by the radar. If the radar cannot track the round far enough along its trajectory, it will notify the operator that it has limited track coverage.

ORIENTING THE RADAR

10-95. The FDC initiates the mission by selecting an orienting point and the FDO issues his fire order in order for the FDC to compute orienting data. The proper mission type must be selected based on the observer assigned to perform the registration. The mission must be a weapon locating radar (WLR) before the digitally formatted messages can be processed. The registration is initiated by transmitting an MTO. The purpose of this message is to inform the radar section of the mission and to provide the information required to prepare the radar. The radar section uses the DA Form 5310 (Radar Friendly Fire Log) in order to track and record the mission. The mission differs from standard procedures in that the FDC controls the mission.

10-96. The message to observer must always include the warning order. It is OBSERVE HIGH-BURST (or MPI) REGISTRATION FOR (unit call sign). This informs the radar section of the type of registration to be fired and for whom the registration is conducted. Observe communications security procedures in transmitting information.

10-97. To orient the target acquisition radar, transmit the radar the following:

- Grid and altitude of the orienting point.
- Grid and altitude of the firing unit.
- Quadrant elevation.
- Maximum ordinate (to the nearest meter) from the appropriate TFT. **Entry argument is quadrant elevation (interpolate)**. Special if it is meters or feet and above sea level or above gun.
- Time of flight (not required).
- Target number.
- Angle of fall. (Not required, but determined by interpolation from Table G by using quadrant elevation as the entry argument.)

10-98. Regardless of the radar system used, the message to observer must include the report order. It is **REPORT WHEN READY TO OBSERVE**.

10-99. Determination of Firing Data to the Orienting Point. The determination of firing data for a radar registration is the same as that for a regular HB or MPI registration.

FIRING THE HB OR MPI REGISTRATION

10-100. The radar on-board computer uses the orienting data to check the trajectory and determine whether it fits the capabilities of the radar. Before firing, the radar operator determines whether the data are acceptable, marginal, or unacceptable. The radar section reports when it is ready to observe (for example, **AT MY COMMAND, REQUEST SPLASH, READY TO OBSERVE, OVER**). The computer determines if the search fence is acceptable in order to ensure all rounds fired will be acquired by radar. If the first round is not visible, an error has occurred. The radar operator informs the FDC that the round was unobserved. The FDC should verify firing data. If no errors are found and the next round is unobserved, the FDC should compute new orienting data and send the new data to the radar operator.

DETERMINATION OF THE MEAN BURST LOCATION

10-101. The radar operator normally reports the grid location and altitude of each burst. The grids may be recorded in the observer reading columns of DA Form 4201. The FDO determines which rounds are useable. Once the FDO determines the useable rounds, he averages the grids and altitudes of the useable rounds to compute the mean burst location. The grid and altitude are then recorded in the Location of HB (MPI) block near the bottom of DA Form 4201.

DETERMINATION OF CHART DATA AND REGISTRATION CORRECTIONS

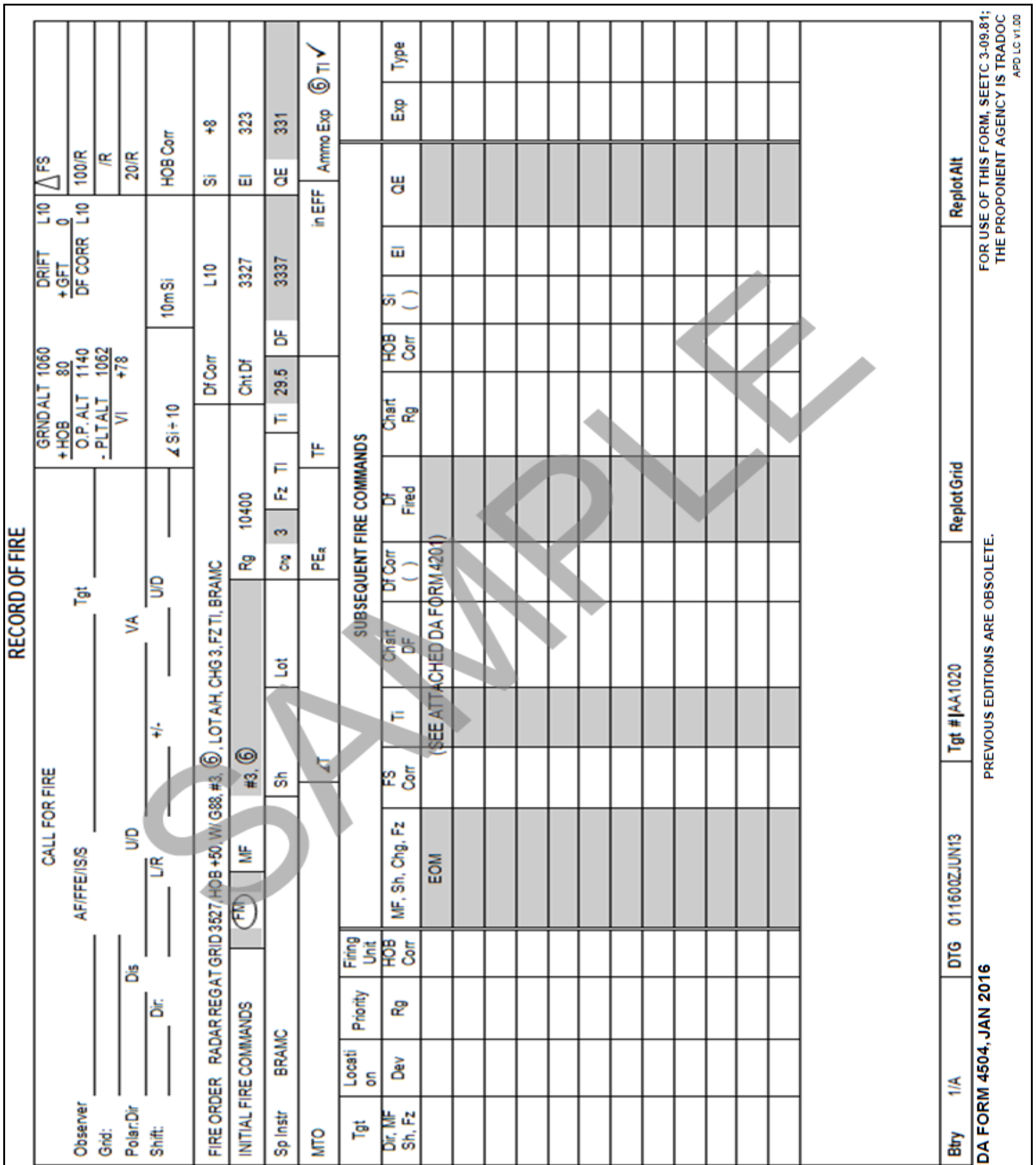
10-102. After determining the MBL and altitude, the procedures for computing chart data and registration corrections are the same as those for regular HB/MPI registrations. Figure 10-16 on page 10-37 shows an example of a completed ROF for an HB radar registration. Figure 10-17 on page 10-38 shows an example of a completed DA Form 4201 for an HB radar registration.

M795 FAMILY REGISTRATIONS

10-103. The development of the HE M795 projectile has enabled a low cost registration munition for the projectiles within the family formerly known as the DPICM family. The same principles and practices used during the application of M107 registration data to other projectiles within its family can be applied to the M795 projectile and projectiles within its family due to the similarities in the ballistic characteristics. The total corrections determined can be applied to firing data in the form of a GFT setting and in the solution of meteorological techniques outlined in Chapter 11.

10-104. The preferred solution for applying registration data for M825/A1, M449A1 and M483A1 is to register with the M795 or M1122 projectile and apply corrections in the form of a GFT setting to the supplementary scales on the AR-2 GFT. An alternative method for applying registration data to the M483A1 projectile is to register with the M107 projectile and apply the registration data to the M483A1 scale on the AM-3 GFT.

10-105. The GFT setting is constructed and total corrections are determined as per precision and HB/MPI instructions.


RECORD OF FIRE

CALL FOR FIRE

Observer ____ AF/FFE/IS/S ____ Tgt ____	GRND ALT 1060 +HOB 80 O.P. ALT 1140 - PLT ALT 1062 VI +78	DRIFT L10 +GFT 0 DF CORR L10
Grid: ____		ΔFS
Polar: Dir ____ Dis ____ U/D ____ VA ____		100/R
Shift: Dir ____ L/R ____ +/- ____ U/D ____	∠Si ÷ 10	10mSi / 20/R / HOB Corr

FIRE ORDER RADAR REG AT GRID 3527, HOB +50, W/ G88, #3, ⑥, LOT AH, CHG 3, FZ TI, BRAMC — Df Corr L10 — Si +8

INITIAL FIRE COMMANDS (FM) — MF #3, ⑥ — Rg 10400 — Cht Df 3327 — El 323

Sp Instr BRAMC — Sh — Lot — Chg 3 — Fz TI — Ti 29.5 — DF 3337 — QE 331

MTO — ∠T — PER — TF — in EFF — Ammo Exp ⑥ TI ✓

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
				EOM	(SEE ATTACHED DA FORM 4201)											

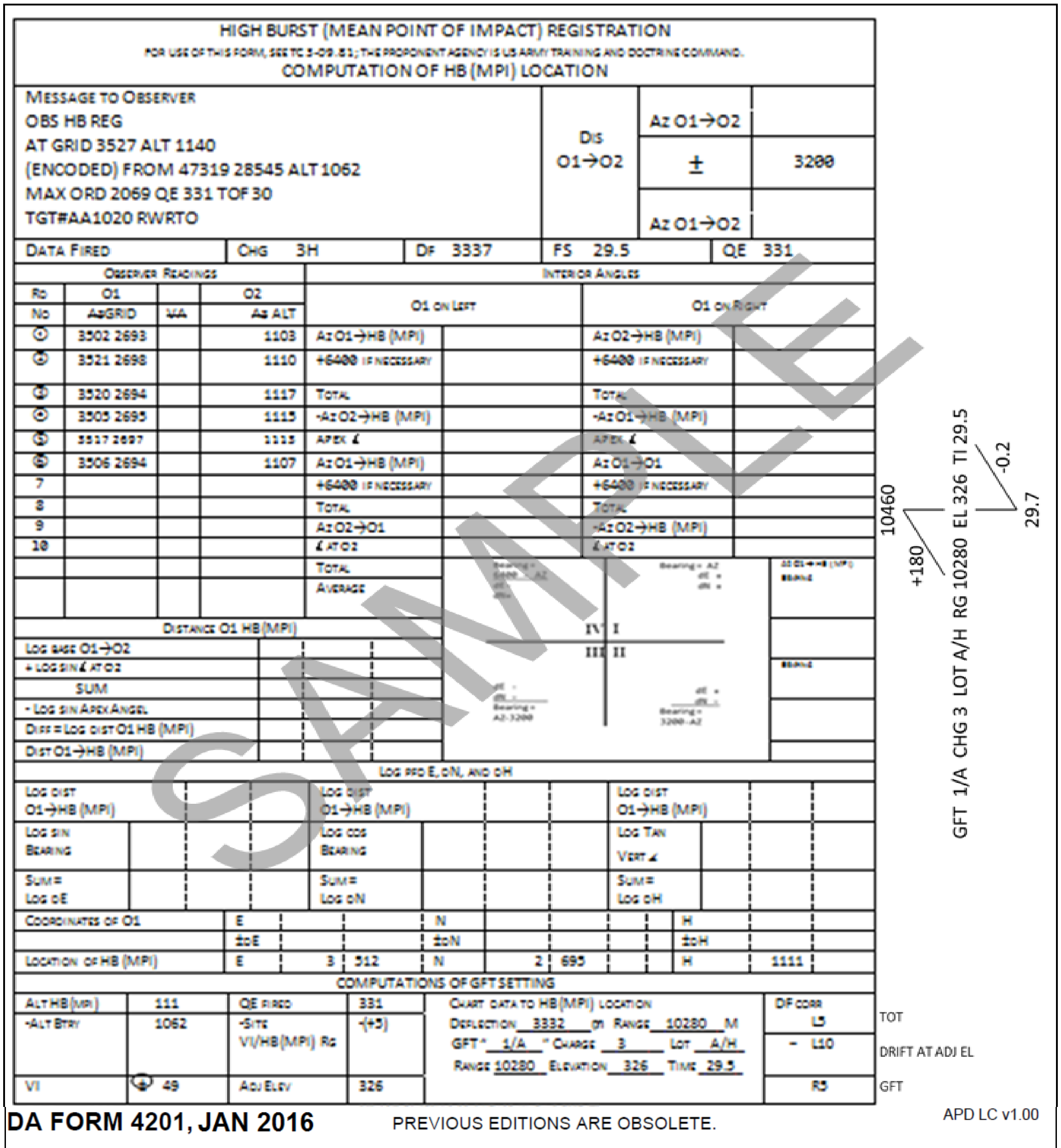
Btry	1/A	DTG	011600ZJUN13	Tgt #	AA1020	Replot Grid	Replot Alt

DA FORM 4504, JAN 2016 — PREVIOUS EDITIONS ARE OBSOLETE. — FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC. APD LC v1.00

SAMPLE

Legend:
AF – adjust fire
ALT - altitude
BRAMC – by round at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
GRND – ground
HOB – height of burst
I/E – in effect
IS – immediate suppression
L/R – left/right
LAT – lateral
MF – method of fire
PER – probable error in range
PLT – platoon
QE – quadrant elevation
REG – registration
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 10-16. Completed ROF for a HB Radar Registration.



HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS US ARMY TRAINING AND DOCTRINE COMMAND.

COMPUTATION OF HB (MPI) LOCATION

MESSAGE TO OBSERVER OBS HB REG AT GRID 3527 ALT 1140 (ENCODED) FROM 47319 28545 ALT 1062 MAX ORD 2069 QE 331 TOF 30 TGT#AA1020 RWRTO	DIS O1→O2	AZ O1→O2 ± AZ O1→O2	3200

DATA FIRED	CHG 3H	DF 3337	FS 29.5	QE 331

RD NO	O1 AZ GRID	VA	O2 AZ ALT
1	3502 2693		1103
2	3521 2698		1110
3	3520 2694		1117
4	3505 2695		1115
5	3517 2697		1113
6	3506 2694		1107
7			
8			
9			
10			

O1 ON LEFT		O1 ON RIGHT	
AZ O1→HB (MPI)		AZ O2→HB (MPI)	
+6400 IF NECESSARY		+6400 IF NECESSARY	
TOTAL		TOTAL	
-AZ O2→HB (MPI)		-AZ O1→HB (MPI)	
APEX ∠		APEX ∠	
AZ O1→HB (MPI)		AZ O1→O1	
+6400 IF NECESSARY		+6400 IF NECESSARY	
TOTAL		TOTAL	
AZ O2→O1		-AZ O2→HB (MPI)	
∠ AT O2		∠ AT O2	
TOTAL			
AVERAGE			

DISTANCE O1 HB (MPI)	
LOG BASE O1→O2	
+ LOG SIN ∠ AT O2	
SUM	
- LOG SIN APEX ANGEL	
DIFF = LOG DIST O1 HB (MPI)	
DIST O1→HB (MPI)	

LOG PRO E, dN, AND dH

LOG DIST O1→HB (MPI)		LOG DIST O1→HB (MPI)		LOG DIST O1→HB (MPI)	
LOG SIN BEARING		LOG COS BEARING		LOG TAN VERT ∠	
SUM = LOG dE		SUM = LOG dN		SUM = LOG dH	
COORDINATES OF O1	E		N		H
	±dE		±dN		±dH
LOCATION OF HB (MPI)	E 3 512		N 2 695		H 1111

COMPUTATIONS OF GFT SETTING

ALT HB (MPI)	111	QE FIRED	331	CHART DATA TO HB (MPI) LOCATION	DF CORR
-ALT BTRY	1062	-SITE	-(+5)	DEFLECTION 3332 RANGE 10280 M	L5
		VI/HB (MPI) RG		GFT 1/A CHARGE 3 LOT A/H	- L10
				RANGE 10280 ELEVATION 326 TIME 29.5	
VI	(+) 49	ADJ ELEV	326		R5

DA FORM 4201, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE.

Legend:

ADJ ELEV – adjusted elevation	DF – deflection	LOG – logarithm	RG – range
ALT – altitude	DIR – direction	MPI – mean point of impact	RPT W/R – report when ready
AZ – azimuth	DIS – distance	No – number	TI – time
BTRY – battery	EL – elevation	OBS – observer	VA – vertical angle
CHG – charge	FS – fuze setting	QE – quadrant elevation	VI – vertical interval
CORR – correction	GFT – graphical firing table	RD – round	
	HB – high burst	REG – registration	

Figure 10-17. Completed DA Form 4201 for a HB Radar Registration.

SECTION V: HIGH-ANGLE REGISTRATION

10-106. On the basis of the tactical considerations, it may become necessary to use high-angle fire instead of low-angle fire. In this situation, a high-angle impact registration can be conducted to improve the accuracy of initial rounds. The use of time fuzes to conduct a time registration is impractical because the height of burst probable error is so large.

HIGH-ANGLE GFT

10-107. When conducting a high-angle impact registration, it is common for the range probable error to be equal to or greater than 25 meters. Since current high-angle GFTs do not have a probable error in range gauge point, the computer must check Table G of the TFT to determine if the probable error in range is equal to or greater than 25 meters. A probable error in range gauge point may be constructed on the high-angle GFT for each charge. The gauge point is constructed on the TF scale.

PROCEDURES FOR HIGH-ANGLE IMPACT REGISTRATION

10-108. Procedures for high-angle impact registrations are the same as low-angle impact registrations with the following three exceptions:

- Because of the large CAS in high-angle fire, special procedures must be used to determine the adjusted elevation.
- The high-angle GFT setting is applied differently to the high-angle GFT.
- High-angle transfer limits are different from low-angle transfer limits because ranges of various charges are smaller.

COMPUTATION OF THE ADJUSTED ELEVATION

10-109. The adjusted elevation, determined from a high angle (HA) impact registration, often includes a false site. This false site is caused by the relationship of the CAS to total site. The CAS is a function of elevation. In low-angle fire, small changes in elevation will cause small changes in CAS. On the other hand, in high-angle fire, small changes in elevation will cause large changes in CAS. In a high-angle registration, the CAS determined at the initial elevation and applied throughout the mission will often differ substantially from the CAS corresponding to the adjusted elevation. This false CAS, when added to the angle of site, will produce a false site. To provide accurate data, the FDC must determine the true site and subtract it from the adjusted QE to compute the true adjusted elevation. To determine the true site, successive approximation is used.

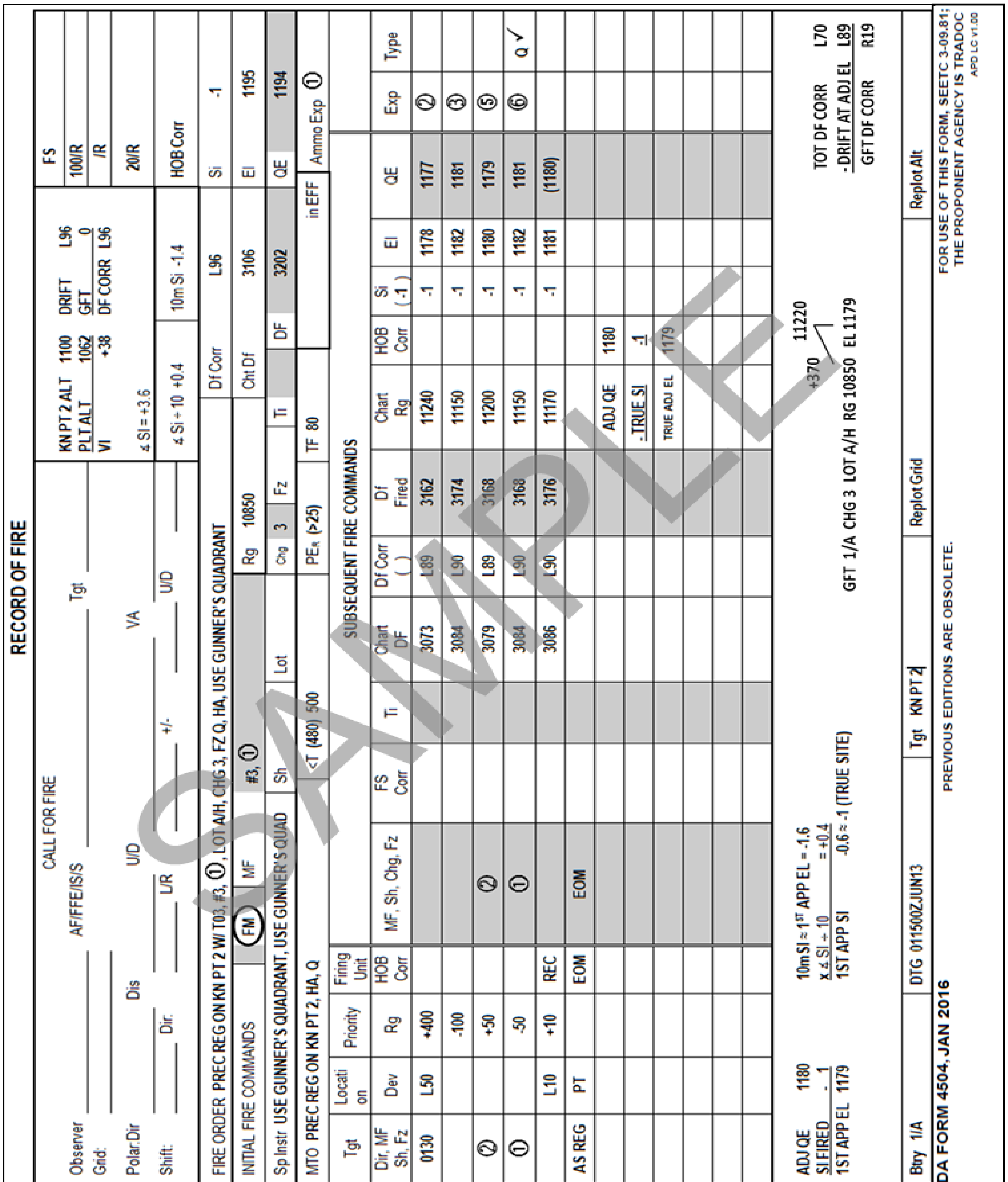
10-110. The steps in table 10-11 are used to determine the true site and true adjusted elevation.

Table 10-11. Determination of True Site and True Adjusted Elevation.

STEP	*ACTION*
1	Determine the first apparent elevation by subtracting the site fired from the adjusted QE. **ADJUSTED QE** **<u>- SITE FIRED</u>** **FIRST APPARENT ELEVATION**
2	Determine the 10-mil site factor corresponding to the first apparent elevation by placing the MHL over the first apparent elevation and reading the value from the 10-mil site factor under the MHL.
3	Determine the firs apparent site by multiplying the 10-mil site factor corresponding to the first apparent elevation (step 2) by the angle of site divided by 10. Express the result to the nearest 1 mil.
4	If the first apparent site is within 1 mil of the site fired, the first apparent site is the true site. If the first apparent site is not within 1 mil of the site fired, continue the process to determine a second apparent elevation.
5	Determine the second apparent elevation by subtracting the first apparent site from the adjusted QE. **ADJUSTED QE** **<u>- FIRST APPARENT SITE</u>** **SECOND APPARENT ELEVATION**

Table 10-11. Determination of True Site and True Adjusted Elevation (continued).

STEP	*ACTION*
6	Determine the 10-mil site factor corresponding to the second apparent elevation by placing the MHL over the second apparent elevation and reading the value from the 10-mil site factor scale under the MHL.
7	Determine the second apparent site by multiplying the 10-mil site factor corresponding to the second apparent elevation (step 6) by the angle of site divided by 10. Express the result to the nearest 1 mil.
8	If the second apparent site is within 1 mil of the last site, the second apparent site if the true site. If the second apparent site is not within 1 mil of the previous apparent site, continue steps 5 through 8 until the last computed site is within 1 mil of the previously computed site. The final computed site is the true site.
9	Compute the true adjusted elevation by subtracting the true site from the adjusted QE. **ADJUSTED QE** **- TRUE SITE** **TRUE ADJUSTED ELEVATION**
10	Record the GFT setting on the ROF. Record the high-angle fire GFT setting in the same manner as for low-angle fire GFT setting. Figure 10-18 on page 10-41 shows a completed ROF for a high-angle impact registration.
Legend: GFT – graphical firing table MHL – manufacturer's hair line QE – quadrant elevation ROF – record of fire	



Legend:

ADJ – adjusted
AF – adjust fire
ALT – altitude
APP – applied
BRAMC – by round at my command
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
IS – immediate suppression
KN PT – known point
L/R – left/right
LAT – lateral
MF – method of fire
PER – probable error in range
PLT – platoon
PREC – precision
PT – point
Q – quick
QE – quadrant elevation
REC – record
REG – registration
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 10-18. Completed ROF of a High-Angle Impact Registration.

SECTION VI: OFFSET REGISTRATIONS OR REGISTRATIONS TO THE REAR

10-111. The tactical situation may make registering from the unit location or along the primary azimuth of fire impractical. The offset registration or registration to the rear should reduce the vulnerability of the firing unit to detection by enemy counter-battery assets. Both of these registrations may require coordination for firing positions or known points. The registrations are conducted by using normal precision or HB/MPI registration procedures.

OFFSET REGISTRATION

10-112. An offset registration is conducted by one howitzer from a position away from the rest of the unit. The offset position must be coordinated to ensure there are no other friendly units in the area as the registration may draw enemy counter-battery fire. The offset position must be on common survey with the firing unit to ensure that any corrections for survey errors in the offset position are valid in the firing unit position.

10-113. Adjusted data and resulting corrections determined from the offset position are valid for that position within normal range and deflection transfer limits.

10-114. The registration corrections are based on the azimuth and range from the offset position to the known point. It is assumed that if a registration were conducted from the firing unit area by using the same range and azimuth (as from the offset position), the adjusted data and resulting corrections would be the same as those obtained in the offset position. (See figure 10-19).

REGISTRATIONS TO THE REAR

10-115. A registration to the rear (or along some other azimuth significantly different from the primary azimuth of fire) may be either a precision or an HB/MPI registration. The registration will result in corrections, but these corrections must be modified for the primary zone of fire by using the eight-direction- met technique (Chapter 11). The actual area where the rounds will be bursting must be coordinated to ensure there are no friendly units in the area.

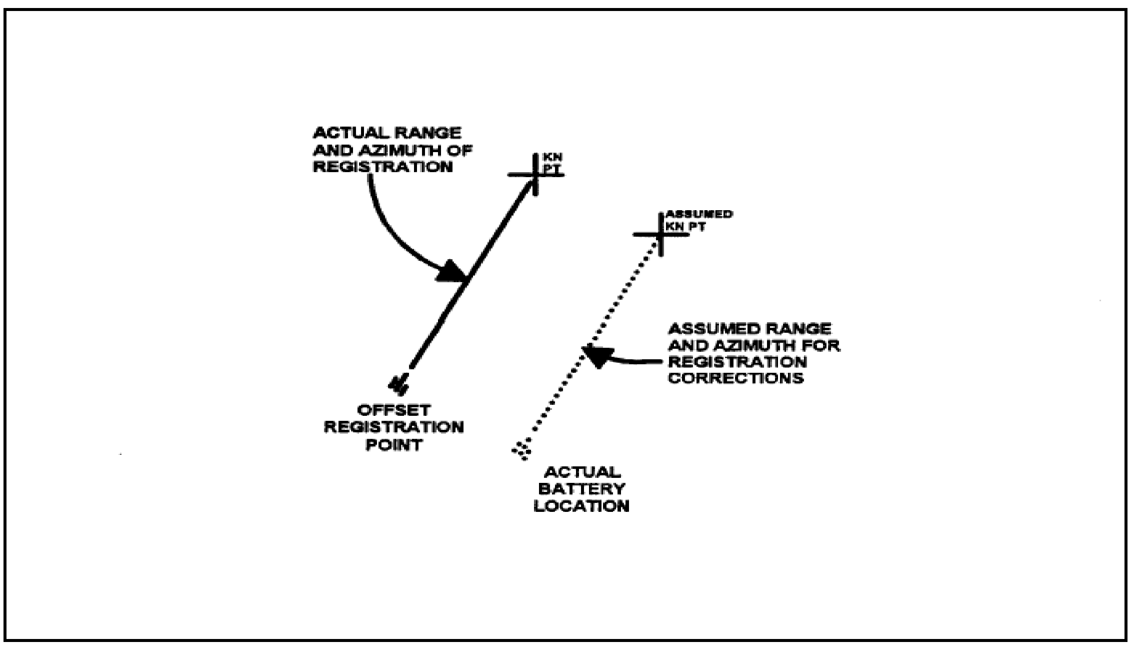


Figure 10-19. Offset Registration Data.

SECTION VII: DETERMINATION AND APPLICATION OF REGITRATION CORRECTIONS

10-116. Registration corrections consist of a total range, total fuze, and total deflection correction. FDC personnel compute these corrections by comparing the chart or should hit data (the data that when fired under standard conditions will cause the round to burst at a point of known location) with the adjusted or did hit data (the data that when fired under nonstandard conditions will cause the round to burst at a point of known location).

COMPUTATION OF TOTAL RANGE CORRECTION

10-117. If standard conditions existed, the elevation fired to achieve the chart range would be the elevation listed in the firing tables for that chart range, When nonstandard conditions exist the range that is achieved by firing a certain elevation is greater or less than the range listed in the firing tables by an amount equal to all of the effects caused by the nonstandard conditions. The difference is the total range correction.

10-118. The total range correction is the difference in meters between the initial chart range and the firing table range corresponding to the adjusted elevation. Determine the total range correction as follows:

- From the TFT or GFT, determine the range (to the nearest 10 meters) corresponding to the adjusted elevation.
- Subtract the initial chart range (or achieved range) from the range corresponding to the adjusted elevation. The result is the total range correction.

EXAMPLE
GIVEN: A M109A6 howitzer platoon registered with charge 3H (M232A1). The base piece was over the platoon center (the location plotted on the firing chart was the base piece). The initial chart charge was 9,680 meters and the adjusted elevation was 293. To determine total range corrections, use the procedures in table 10-12.

Table 10-12. Total Range Correction.

STEP	***ACTION***
1	From the precision registration example in figure 10-3 on page 10-12, the range corresponding to the adjusted elevation of 293 is 9,840 meters.
2	Subtract the initial chart range from the range corresponding to the adjusted elevation. The result is the total range correction of +160 meters (9840 – 9680 = +160 meters) **(DHD-SHD = TOT).**
3	The difference between the initial chart range and the range corresponding to the adjusted elevation +160 meters. This procedure can be portrayed by using part of the "lazy Z" as shown in figure 10-20, page 10-44.
Legend: DHD – did hit data SHD – should hit data TOT – total	

COMPUTATION OF TOTAL FUZE CORRECTION

10-119. The time portion of a precision or high-burst registration will result in an adjusted or did hit time (fuze setting). The time corresponding to the adjusted elevation is the should hit time that must be compared to the actual adjusted time determined by firing. The difference between the time corresponding to the adjusted elevation and the adjusted time is the total fuze correction **(DHD – SHD = TOT).**

10-120. To determine the total fuze correction, subtract the time corresponding to the adjusted elevation (or elevation plus CAS if the VI is greater than 100) from the adjusted time. The total fuze correction is always a signed value and is used in solving a concurrent met. See the following example.

EXAMPLE
Continuing the example above, the firing unit obtained an adjusted time of 27.1. The time corresponding to the adjusted elevation is 27.3. Subtract the time corresponding to the adjusted elevation from the adjusted time to determine the total fuze correction of (27.1 – 27.3 = -0.2). This procedure can be portrayed by using part of the lazing Z shown in figure 10-20.

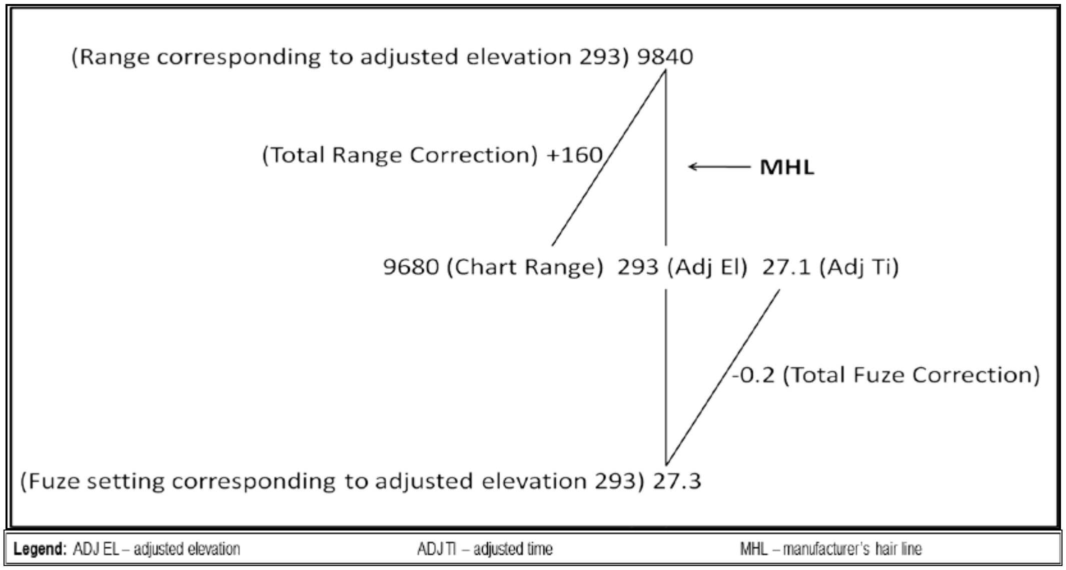


Figure 10-20. A Completed Lazy Z.

COMPUTATION OF TOTAL DEFLECTION CORRECTION

10-121. The total deflection correction is the correction, in mils, that must be added to the chart deflection to correct for all nonstandard conditions.

10-122. To determine the total deflection correction, subtract the chart deflection from the adjusted deflection. The total deflection correction is used in solving the concurrent met technique, in processing immediate type fire missions, and for updating manual safety computations after a registration. For all other missions, the GFT DF correction plus drift is used.

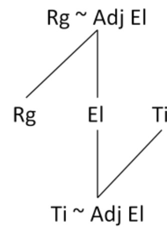
10-123. A GFT deflection correction is determined by subtracting the drift corresponding to the adjusted elevation from the total deflection correction. The GFT deflection correction remains the same for all elevations fired with the registered charge. The drift is applied to the GFT deflection correction to determine the deflection correction to be used for that mission. Using the precision registration example in figure 10-3 (page 10-12), determine the total deflection correction as follows:

ADJUSTED DEFLECTION	**3406**
-CHART DEFLECTION	**-3404**
TOTAL DEFLECTION CORRECTION	**L2**
-DRIFT CORRESPONDING TO ADJ EL	**-L6**
GFT DEFLECTION CORRECTION	**R7**

DETERMINATION OF TOTAL REGISTRATION CORRECTIONS

10-124. The computational space on DA Form 4757 (Registration/Special Corrections Work Sheet) can be used to determine the total corrections. Use table 10-13 on page 10-45 to determine total registration corrections.

Table 10-13. Total Registration Corrections.

STEP	***ACTION***
1	Record the chart range, adjusted elevation, and adjusted time from the registration.
2	Determine and record the range corresponding to the adjusted elevation by placing the MHL over the adjusted elevation and reading the value from the range scale under the MHL. This value is recorded at the top of the lazy Z. 
3	Without moving the cursor, determine and record the fuze setting (M767/M762) corresponding to the adjusted elevation by reading the value from the fuze scale (for the registered fuze) under the MHL.
4	Determine and record the total range correction. If the value of range decreased from chart to adjusted, the sign of the total range correction is negative. If the range increased, the sign is positive. Record the difference in range with the appropriate sign on the lazy Z. **(RG ~ ADJ EL) – (CHT RG) = TOT RG CORR (±)**
5	Determine and record the total fuze correction. If the value of the fuze setting decreased from chart to adjusted, the sign of the total fuze correction is negative. If the fuze setting increased, the sign is positive. Record the difference in fuze setting with the appropriate sign on the lazy Z. **(ADJ FS) – (FS ~ ADJ EL) = TOT FS CORR (±)**
6	Determine and record the total deflection correction. If the value of the chart deflection decreased from chart to adjusted, the sign of the total deflection correction is right I. If the deflection increased, the sign is a left (**L). (ADJ DF) – (CHT DF) = TOT DF CORR (L/R)**
Legend: ADJ – adjusted CHT – chart CORR – correction DF – deflection EL – elevation FS – fuze setting L – left MHL – manufacturer's hair line R – right RG – range TI – time TOT – total	

LOW-ANGLE GFT SETTINGS

10-125. The data determined from a registration must be applied to FDC graphical equipment. This will enable the unit to attack accurately located targets without adjustment (first round fire for effect) within transfer limits.

10-126. Listed below are the elements of a GFT setting. These elements are recorded in the lower computational space of the record of fire used to process the registration. Additionally, they may also be recorded on DA Form 4757 (Registration/Special Correction Worksheet) and on the record of fire of a mission in which they are being used. For the HB/MPI registration, the GFT setting is recorded on DA Form 4201. The acronym **UCARET** is used as an aid in recording the GFT setting. It is used to keep the GFT setting preceding the total and GFT deflection corrections in order.

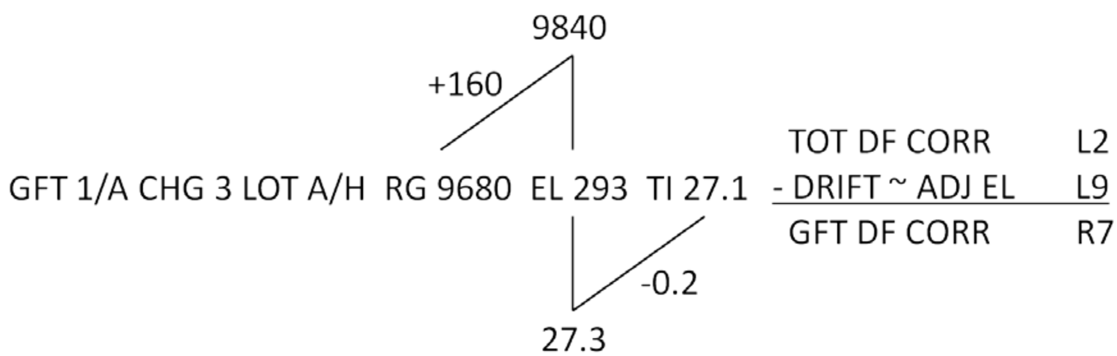
- **U**nit that fired the registration.
- **C**harge fired during the registration and the charge for which the GFT setting applies.
- **A**mmunition lot used in the registration. With separate-loading ammunition, the first letter designates the projectile lot used during the registration. The second letter designates the propellant lot used during the registration.

- **R**ange (chart or achieved) from the howitzer to the point of known location.
- **E**levation (adjusted or did hit).
- **T**ime (adjusted or did hit fuze setting).
- **T**otal deflection correction (the difference between the adjusted deflection and the chart deflection).
- **GFT deflection correction** (the difference between the total deflection correction and the drift corresponding to the adjusted elevation).

10-127. The following is an example of a completed GFT setting as it is written.

GFT 1/A CHG 3 LOT A/H RG 9680 EL 293 TI 27.1 (M767)
TOT DF CORR L2 GFT DF CORR R7

10-128. The following is an example of a completed GFT setting as it is written with total corrections.



Legend: ADJ EL – adjusted elevation CHG – charge DF CORR – deflection correction EL – elevation GFT – graphical firing table RG – range TI – time TOT – total

DETERMINATION OF A GFT SETTING WHEN THE REGISTERING PIECE IS NOT THE BASE PIECE

10-129. It may not always be possible to register with the base piece. When a howitzer other than the base piece is used to register, corrections must be made to compensate for the displacement of the registering piece from the base piece. Use a DA Form 4757 and the steps in table 10-14 to determine the necessary corrections.

Table 10-14. GFT Setting—Registering Piece is not BP.

STEP	*REFERENCE*	*ACTION*
1	Chart Rg	Record the **chart range** determined at the start of the registration.
2	Registering Piece Displ (F-/B+)	Enter the displacement of the registering piece from the base piece either forward or back. For forward displacement, use minus, for back displacement, use plus.
3	Achieved Rg (1 + 2)	Determine and record the achieved range from the registering piece to the registration point by adding the piece displacement (step 2) to the chart range (step 1).
4	Lateral Displ (L/R)	Enter the left or right lateral displacement of the registering piece from the base piece
5	Achieved Rg (3)	Enter the achieved range determined in step 3.
6	Registering Piece Displ Corr (4 ÷ 5)(L+/R-)	Determine and record the base piece displacement correction by dividing the lateral displacement (step 4) by the achieved range, in thousands (step 5). Use a GST for the division, and express the result to the nearest mil. Circle L for left or R for right.

Table 10-14. GFT Setting—Registering Piece is not BP (continued).

STEP	REFERENCE	ACTION
7	Corr Df (Reg)	Record the **correct deflection**. When the piece is displaced laterally, the deflection that hit the registration point is no longer called the adjusted deflection. It is now called the correct deflection.
8	Registering Piece Displ Corr (6) (L+/R-)	Record the base piece displacement correction determined in step 6.
9	Adj Df (7+8)	Determine and record the adjusted deflection by adding the base piece displacement correction (step 8) to the correct deflection (step 7).
10	Chart Df	Record the chart deflection from the registration.
11	Total Df Corr (9-10) (L+/R-)	Determine and record the total deflection correction by subtracting the chart deflection (step 10) from the adjusted deflection (step 9). Use the LARS rule to determine whether the total deflection correction is left or right (+ = L and - = R).
12	Drift Corr ≈Adj El	Determine and record the drift corresponding to the adjusted elevation by placing the MHL (of the appropriate GFT) over the adjusted elevation and reading the drift under the MHL.
13	GFT Df Corr (11-12)	Determine and record the GFT deflection correction by subtracting the drift corresponding to the adjusted elevation (step 12) from the total deflection correction (step 11). Use the LARS rule to determine whether the GFT deflection correction is left or right.
	Note: The GFT setting can now be recorded. Use the acronym UCARET as an aid.	
14	GFT .	Unit: Record the battery or platoon designation.
15	Chg .	Charge: Record the charge fired in the registration.
16	Lot .	Ammo lot: Record the lot fired in the registration.
17	Rg .	Range: Record the chart (achieved) range.
18	El .	Elevation: Record the adjusted elevation.
19	Ti .	Time: Record the adjusted time.
20	Total Df Corr	Record the total deflection correction.
21	GFT Df Corr	Record the GFT deflection correction.

Legend: ADJ – adjusted B – back CHG – charge CORR – correction DF – deflection DISPL – displacement EL – elevation F – forward GFT – graphical firing table GST – graphical site table L – left R – right REG – registration RG – range TI – time

CONSTRUCTION OF A GFT SETTING

10-130. Once the information for the GFT setting has been determined and recorded on DA Form 4757, the GFT setting can be constructed on the GFT. Use the steps in table 10-15 to construct a GFT setting on the GFT.

Table 10-15. Construction of a GFT Setting.

STEP	ACTION
1	Move the cursor of the GFT until the MHL is over the GFT setting range (chart or achieved range to the point of known location) on the range scale.
2	Using a blue soft-lead pencil or water-based fine-tip marker, place a dot over the GFT setting elevation (adjusted elevation).

Table 10-15. Construction of a GFT Setting (continued).

3	Using a red soft-lead pencil or water-based fine-tip marker, place a dot over the GFT setting time (adjusted fuze setting).
4	Move the cursor until the elevation (blue) dot is over the range K line. Using the blue pencil or marker and a straightedge, trace the range K line on the cursor through the dot. The line should be as fine as possible to enhance the accuracy of data determined. This is the elevation gauge line (EGL). Label the top of this line “EL.”
5	Move the cursor until the time (red) dot is over the fuze K line. Using the red pencil or marker and straightedge, trace the fuze K line on the cursor through the dot. The line should be as fine as possible to enhance the accuracy of data determined. This is the time gauge line (TGL). Label the top of this line “TI.”
6	Move the cursor until the MHL is over the GFT setting range (chart or achieved range to the point of known location). Under the EGL, determine elevation from the elevation scale. It should check with 0 tolerance with the adjusted elevation. If not, erase and reconstruct the EGL.
7	Move the cursor until the MHL is over the GFT setting range. Under the TGL, determine FS from the FS scale. It should check with 0.0 tolerance with the adjusted fuze setting. If not, erase and reconstruct the TGL.
8	In the upper left corner of the cursor, record the total deflection correction and circle the value.
9	In the upper right corner of the cursor, record the GFT deflection correction.
	Note: An example of a one-plot GFT setting applied to a GFT is shown in figure 10-21.
Legeend: EGL – elevation gauge line EL – elevation FS – fuze setting GFT – graphical firing table MHL – manufacturer’s hair line TGL – time gauge line TI – time	

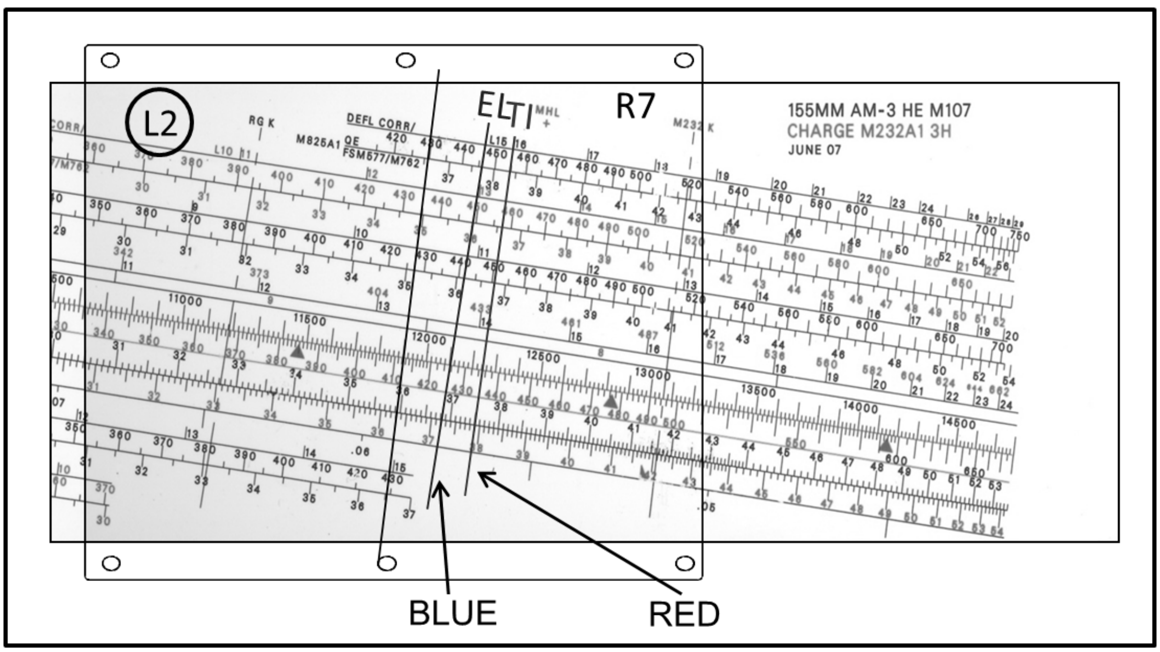


Figure 10-21. GFT with a GFT Setting Applied.

CONSTRUCTION OF A TWO-PLOT OR MULTI-PLOT GFT SETTING

10-131. The steps in table 10-16 on page 10-49 are used to construct a two-plot or multi-plot GFT setting, illustrated in figure 10-22 on page 10-49.

Table 10-16. Construction of a Two-Plot or Multi-plot GFT Setting.

STEP	***ACTION***
1	Move the cursor of the GFT until the MHL is over the GFT setting range on the range scale.
2	Using a blue soft-lead pencil or water-based fine-tip marker, place a dot over the GFT setting elevation.
3	Using a red soft-lead pencil or water-based fine-tip marker, place a dot over the GFT setting time.
4	Repeat steps 1 through 3 for each set of data for the GFT setting.
5	Using the blue and red pencils or markers, connect the elevation dots with a blue line and connect the time dots with a red line. Use as fine a line as possible to enhance the accuracy of data determined. Slide the first blue dot constructed over the Range K line. Continue constructing the blue line along the Range K line. Repeat this step for subsequent blue dots. Slide the first red dot constructed over the Fuze K line. Continue constructing the red line along the Fuze K line. Repeat this step for subsequent red dots. On that portion of the cursor above and below the elevation and time dots, extend the EGL and TGL to the edge of the cursor at an angle appropriate to the last two points used at the top and bottom of the constructed line. This extension is a more accurate portrayal of range K and fuze K. It represents conditions presently existing, determined by firing, rather than those from the computer-generated averages depicted by range K and fuze K lines on the GFT.
6	Move the cursor until the MHL is over each range. Under the EGL, determine elevation from the elevation scale. It should check with 0 tolerance with the adjusted elevation. If not, erase and reconstruct the EGL.
7	Move the cursor until the MHL is over each range. Under the TGL, determine time from the time scale. It should check with 0.0 tolerance with the adjusted fuze setting. If not, erase and reconstruct the TGL.
8	In the upper left corner of the cursor, record the average total deflection correction and circle the value.
9	In the upper right corner of the cursor, record the average GFT deflection correction.
Legend: EGL – elevation gauge line GFT – graphical firing table MHL – manufacturer's hair line TGL – time gauge line	

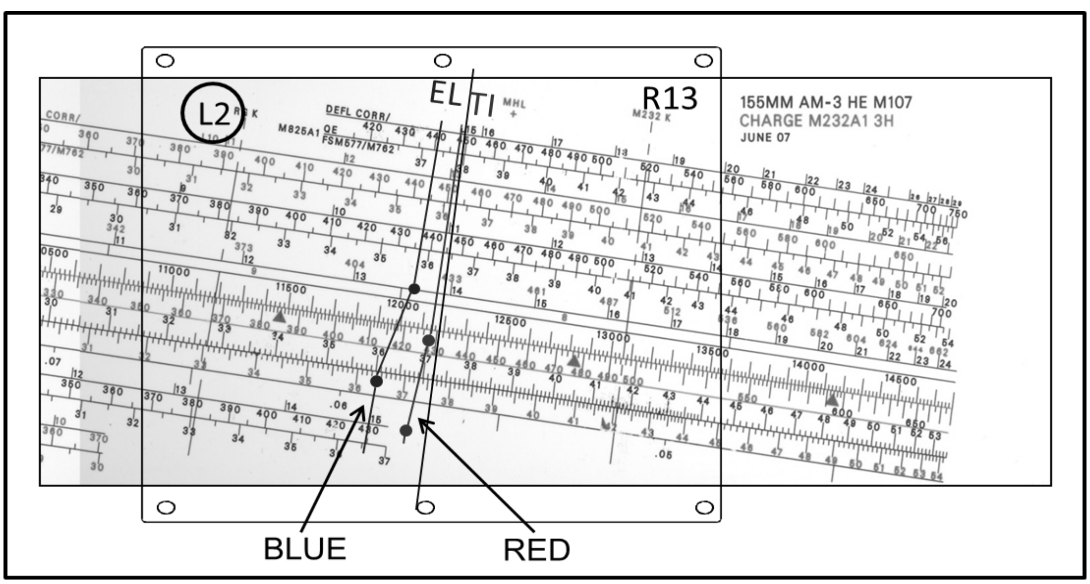


Figure 10-22. GFT with a Two Plot GFT Setting Applied.

CONSTRUCTION OF A GFT SETTING FROM A M107 REGISTRATION ON AN ILLUMINATING GFT

10-132. Table 10-17 shows the procedure for constructing a GFT setting from an HE registration on an illumination GFT.

Table 10-17. Construct GFT Setting on Illuminating GFT (HE Registration).

STEP	*ACTION*
1	Place MHL over the HE adjusted elevation on the HE GFT.
2	Under the MHL, determine the HE range corresponding to the HE adjusted elevation from the range scale.
3	Place the MHL of the illum GFT over the adjusted HE range determined in step 2.
4	On the illum GFT, draw a 1-inch line (length) parallel to MHL at the chart range from the HE GFT setting. Label this line “RG”.
Legend: GFT – graphical firing table HE – high explosive MHL – manufacturer’s hair line RG – range	

UPDATE OF A GFT SETTING WHEN TRANSFERRING FROM A MAP SPOT OR OBSERVED FIRING CHART

10-133. Field artillery units must be able to deliver responsive, accurate fires immediately upon occupation of a new position. Firing must not be delayed because of lack of survey or suitable maps. An initial firing chart may be based on a map spot or an observed firing chart. Once the actual survey is brought into the unit’s area, the firing charts must be reconstructed on the basis of the firing unit’s true location and true azimuth. GFT settings based on map spot or observed fire charts are accurate but must be updated.

10-134. When a registration is conducted on the basis of the map spot data for the registration point and/or firing unit location, the corrections determined will include corrections for map spot errors and possible human errors in plotting the locations. Once survey data are available, the GFT setting(s) determined must be updated to account for the initial inaccuracies.

10-135. Once survey data become available, the HCO will construct and plot the locations on a surveyed firing chart. He will determine a new chart range and deflection to the known point. The new chart range will be the range for the GFT setting. The VCO will use the new chart range and an updated VI to recompute site. The computer will recompute the adjusted elevation and new total and GFT deflection corrections. The adjusted fuze setting was determined by firing and will not change. Use table 10-18 to update a GFT setting when transferring from a map spot or observed firing chart to a surveyed firing chart.

Table 10-18. Update of a GFT When Transferring From Map Spot or Observed Firing Chart.

STEP	*ACTION*
1	The HCO plots the updated location of the base piece and/or registration point on the basis of the information provided by the survey section.
2	The HCO determines and announces a new chart range and deflection to the known point. The announced range is the range for the GFT setting.
3	The VCO computes a new VI. Subtract the updated base piece (firing unit) altitude from the known point altitude. (One or both of the altitudes may be different). **TGT ALT** **- PLT ALT** **VI**
4	The VCO uses the new chart range (step 2) and the new VI (step 3) to recomputed and announce a new site. The charge will be the charge fired during the registration.

Table 10-18. Update of a GFT When Transferring from Map Spot or Observed Firing Chart (continued).

STEP	*ACTION*
5	The computer determines a new adjusted elevation by subtracting the new site from the adjusted quadrant of the registration. **ADJ QE** **- NEW SITE** **NEW ADJ EL**
6	The Computer/RTO records the adjusted fuze setting from the registration.
7	The computer determines a new total deflection correction by comparing the new chart deflection to the adjusted deflection from the registration. **ADJ DF** **- NEW CHT DF** **TOT DF CORR**
8	The computer determines the new GFT deflection correction by subtracting the drift corresponding to the new adjusted elevation from the total deflection correction. The drift corresponding to the new adjusted elevation is determined by placing the MHL over the new adjusted elevation and extracting the value on the drift scale under the MHL. **TOT DF CORR** **- DRIFT ~ NEW ADJ EL** **GFT DF CORR**
9	The computer will apply the new GFT setting to the appropriate GFT.
	Note: A VI greater than 100 meters will cause the complementary angle of site to increasingly affect the fuze setting. If the new VI is greater than 100 meters, recomputed the adjusted fuze setting.
Legend: ADJ – adjusted ALT – altitude CHT – chart CORR – correction DF – deflection EL – elevation GFT – graphical firing table HCO – horizontal control operator PLT – platoon QE – quadrant elevation TGT – target TOT – total VCO – vertical control operator VI – vertical interval	

REGISTRATION TRANSFER LIMITS

10-136. In manual gunnery techniques, the total corrections determined from a registration are valid only within certain range and deflection transfer limits. Transfer limits define the ranges and deflections within which the GFT setting is expected to produce accurate firing data. The total corrections for nonstandard conditions are valid only when the weapons are firing toward the known point. For example, when weapons are firing on a different azimuth than that of the known point, the wind will not affect the round in the same manner as it did along the azimuth to the known point.

10-137. Range Transfer Limits.

- The range transfer limits for a one-plot GFT setting are shown on the GFT corresponding to the red numbered elevations.
- The range transfer limits for a two-plot GFT setting are between the two ranges used to apply the GFT setting(s). This type of GFT setting becomes less accurate outside these two ranges.
- The range transfer limits for a multi-plot GFT setting are eliminated when three or more sets of corrections are available for the same charge. The optimum multi-plot GFT setting reflects a plot for each met line number that the charge may cause the projectile to pass through (met check gauge points).

10-138. Deflection Transfer Limits.

- The total registration corrections are valid only within certain deflection transfer limits.
- When the chart range to a target is 10,000 meters or less, the total corrections are valid within an area 400 mils left and 400 mils right of a line between the unit and the known point (mean burst location) (figure 10-23 on page 10-52).

- When the chart range to a target is greater than 10,000 meters, the total corrections are valid within an area 4,000 meters left and 4,000 meters right of the line. (See figure 10-24.)
- Total registration corrections may be determined throughout the entire 6,400 mils around the firing unit by using the eight-direction met technique (Chapter 11).

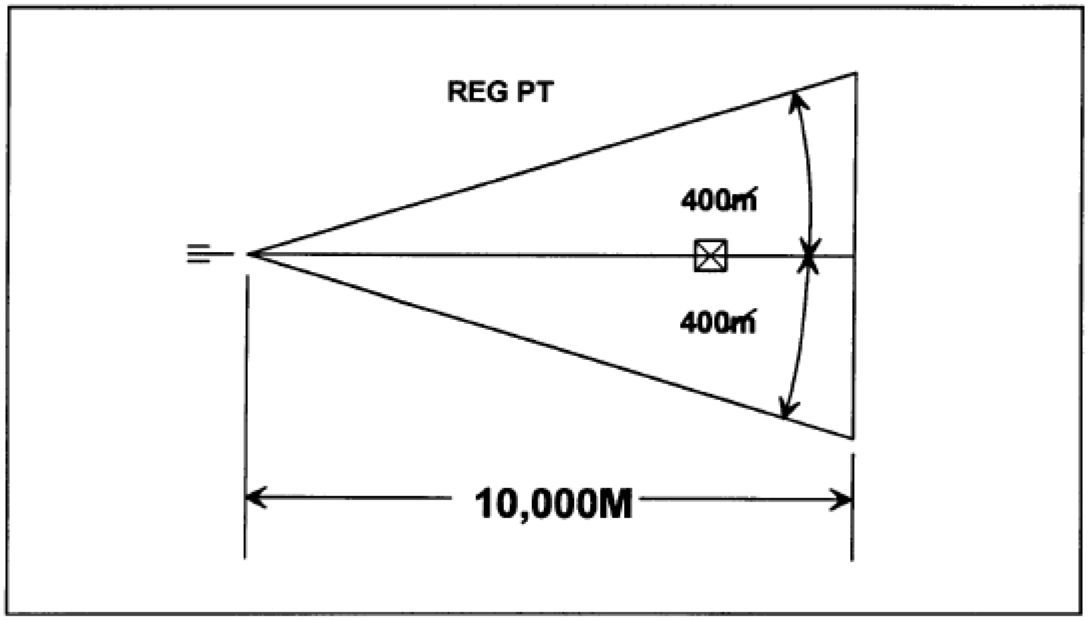


Figure 10-23. Deflection Transfer Limits—10,000 Meters or Less.

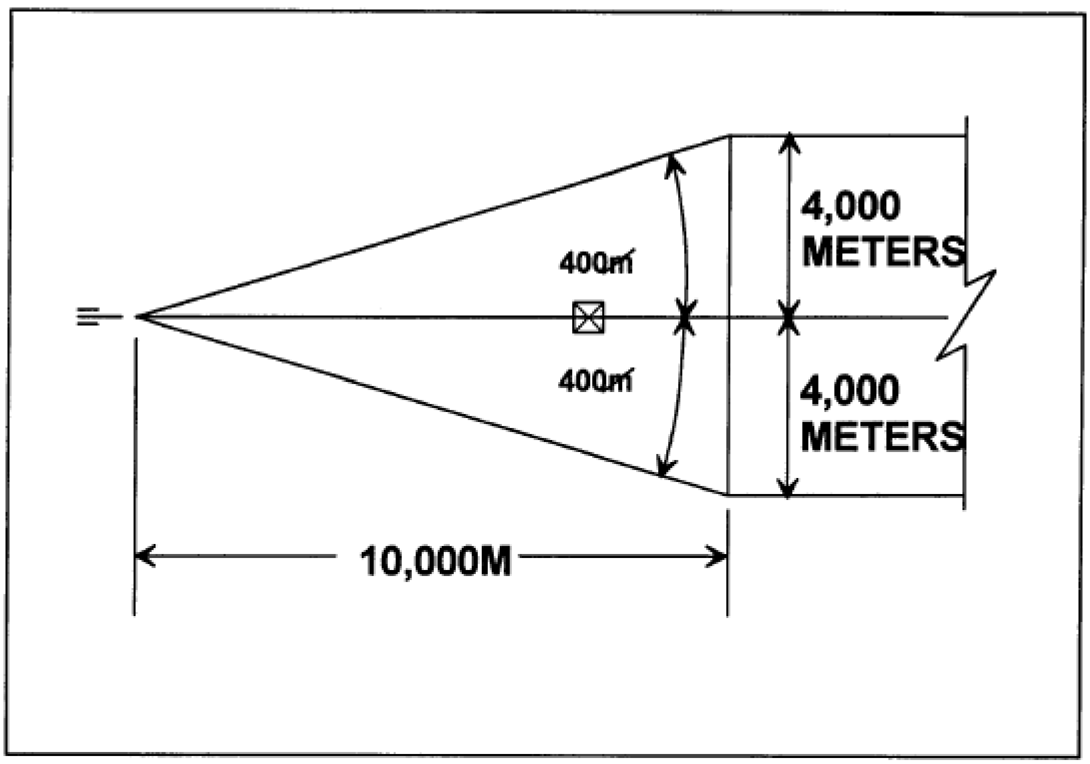


Figure 10-24. Deflection Transfer Limits—Ranges Greater Than 10,000 Meters.

HIGH-ANGLE GFT SETTINGS.

10-139. GFT settings for high-angle fire are written in the same manner as those for low-angle fire. An example is shown below.

GFT 1/A, CHG 3, LOT A/H, RG 10850, EI 1179
TOT DF CORR L70 GFT DF CORR R19

10-140. The high-angle GFT setting is constructed on the GFT by placing the MHL over the adjusted elevation for the charge fired and drawing a range gauge line through the GFT setting range on the range scale parallel to the MHL. The MHL becomes the elevation gauge line, and all data except for range and 100/R are read under the MHL. The GFT deflection correction and charge are recorded on the cursor.

HIGH-ANGLE TRANSFER LIMITS

10-141. Standard range transfer limits are not applicable to high-angle fire because the **range span of each charge is so short.** Corrections in the form of GFT settings and GFT deflection corrections are considered valid for the charge used in determining the corrections and are also considered valid for other charges as shown in table 10-19.

Table 10-19. High-Angle Transfer Limits.

WEAPON	***CHARGE REGISTERED WITH***	***TRANSFER LIMITS***
105-mm Howitzer	***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 Howitzer	***M231 CHG 1***	***All ranges***
	M231 CHG 2	Charge 2 only ± 1,500 meters
	M232/A1 CHG 3	Charge 3 only ± 1,500 meters
	M232/A1 CHG 4	Charge 4 only ± 1,500 meters
	M232/A1 CHG 5	Charge 5 only ± 1,500 meters
* ± 2,000 meters for registration point ranges greater than 10,000 meters		
Legend: CHG – charge mm – millimeter		

TRANSFER OF GFT SETTINGS

10-142. When only one unit of a battalion equipped with weapons for which the same firing tables are used is allowed to register, the GFT setting determined by the registering unit maybe transferred to the non-registering units in the absence of better information.

10-143. Transferring of GFT settings should only occur if a concurrent met technique cannot be performed and position constants cannot be isolated (Chapter 11). To transfer a GFT setting, certain conditions must exist as follows:

- Common survey between positions.
- Azimuth of fire (octant) are the same.
- Ability to correct for MVVs for the registered lot.

10-144. The distance over which the GFT settings are transferred should be monitored closely. The further from the registration point the GFT setting is transferred, the less accurate the GFT setting will be. This is due to the different effects of the met (weather) conditions. The guidance given in Chapter 11 on the validity of met messages should be used when transferring GFT settings.

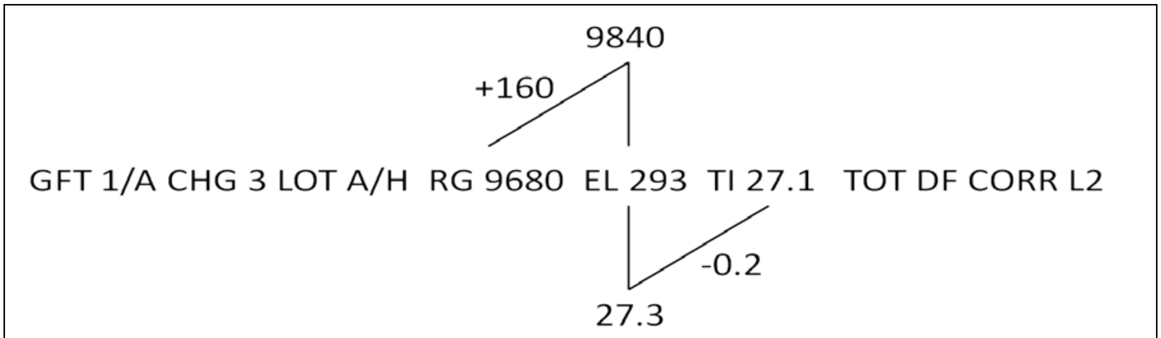
10-145. The procedures for determining a GFT setting for a non-registering unit is listed in table 10-20 on page 10-54. The registering unit must send the GFT setting and registering piece MVV to the non-registering unit.

Table 10-20. GFT Setting for Non-registering Unit.

STEP	***ACTION***
1	Record the GFT setting and MVV of the registering piece.
2	Determine and record the total corrections from the registration.
3	Determine and record the difference in MVV between the registering howitzer and the base piece. **BASE PIECE MVV** **- REGISTERING PIECE MVV** **DIFFERENCE IN MVV**
4	Determine and record the MV correction factor from the TFT, Table F, Column 10 or 11 (decrease or increase). Enter with the registration range (to the nearest 100 meters) and record as a signed value.
5	Determine the range correction by multiplying the MV correction factor by the difference in MVV (step 4 x step 3). Express the result to the nearest 10 meters. **This value will have the same sign as the correction factor extracted from the TFT**. (See the note below).
6	Apply the range correction to the total registration range correction (step 5 + step 2). Ensure that all values are signed during this step. Record the new total range correction (±).
7	Apply the new total range correction to the registration range. This is the new range corresponding to the adjusted elevation. Determine the new adjusted elevation by placing the MHL over the new range corresponding to the adjusted elevation.
8	Determine a new fuze setting corresponding to the adjusted elevation by placing the MHL over the elevation determined in step 7.
9	Determine the fuze setting correction for the difference in MVV. Enter the TFT, Table J, Column 2 or 3 with the fuze setting determined in step 8 expressed to the nearest whole increment and determine the MV correction factor.
10	Determine the fuze setting correction by multiplying the MV unit correction by the difference in MVV (step 9 x step 3). Express the result to the nearest tenth (0.1). **This value will have the same sign as the correction factor extracted from the TFT**. (See the note below).
11	Apply the fuze setting correction to the total registration FS correction (step 10 + step 2). Ensure that all values are signed during this step. Record new total fuze setting correction (±).
12	Apply the new total fuze setting correction (step 11) to the fuze setting corresponding to the adjusted elevation (step 8). This value is the new adjusted fuze setting.
13	Determine the new total deflection correction by applying drift corresponding to the adjusted elevation (step 7) to the GFT deflection correction (step 1).
14	The corrected GFT setting is recorded as follows: **U**nit: designation of nonregistered unit **C**harge: registered charge **A**mmo lot: registered charge **R**ange: step 1 **E**levation: step 7 **T**ime: step 12 Tot Df Corr: step 13 GFT Df Corr: step 1
Note: The reason for the range correction (step 5) and the fuze setting correction (step 10) having the same sign as the TFT correction value is the actual unit of measurement. The unit conversion factor indicates the correction needed for each 1-meter-per-second change. Solving the mathematical formula would lead to the same sign as simply using the sign listed in the TFT. This procedure is only applied in certain situations and is the exception and not the rule.	
Legend: CORR – correction DF – deflection GFT – graphical firing table MV – muzzle velocity MVV – muzzle velocity variation TFT – tabular firing table	

EXAMPLE OF TRANSFERRING A GFT SETTING

10-146. Battery A, 1st Platoon registered (see figure 10-25), and Battery C, 1st Platoon wants the GFT setting transferred to their unit (see figure 10-26). Battery A, 1st Platoon registered with their base piece which has an MVV of -1.6 M/s. The base piece for Battery C, 1st Platoon has an MVV of -7.7 m/s.



Legend: CHG – charge EL – elevation GFT – graphical firing table RG – range TI – time TOT DF CORR – total deflection correction

Figure 10-25. GFT Setting for Battery A, 1st Platoon (Example).

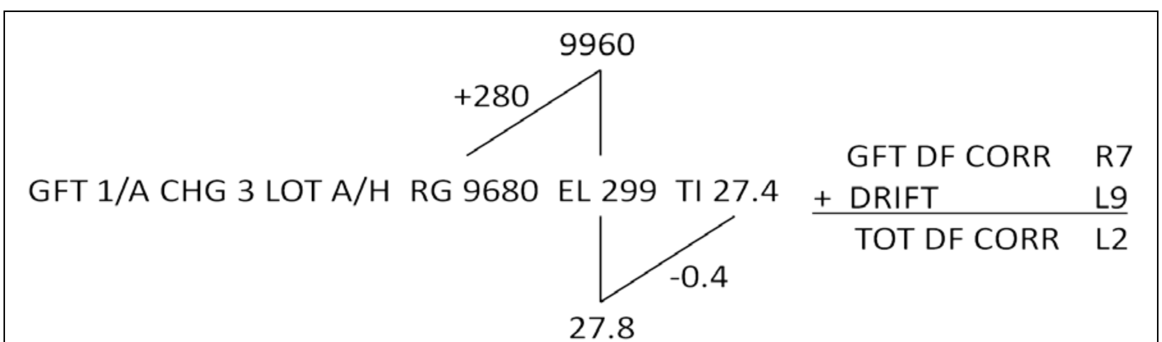
BASE PIECE MVV	**-7.7**
- REGISTERING PIECE MVV	**-1.6**
DIFFERENCE IN MVV	**-6.1**

DIFFERENCE IN MVV	**D 6.1**
x MV UNIT CORRECTION	**+20.4**
MV RG CORRECTION	**124.4 ≈ +120 METERS**

MV RG CORRECTION	**+120 METERS**
+ TOT RG CORRECTION	**+160 METERS**
NEW TOT RG CORRECTION	**+280 METERS**

DIFFERENCE IN MVV	**D 6.1**
x MV UNIT CORRECTION	**-0.037**
MV FS CORRECTION	**0.2257 ≈ -0.2**

MV FS CORRECTION	**-0.2**
+ TOT FS CORRECTION	**-0.2**
NEW TOT FS CORRECTION	**-0.4**



Legend: ADJ EL – adjusted elevation CHG – charge DF CORR – deflection correction EL – elevation GFT – graphical firing table RG – range TI – time TOT – total

Figure 10-26. GFT Setting for Battery C, 1st Platoon (Example).

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Chapter 11

Meteorological Techniques

Met techniques described in this chapter allow a unit to account for the effects of nonstandard conditions and achieve first round fire for effect.

SECTION I: PRINCIPLES

11-1. Understanding the applications of met techniques requires basic knowledge of registration and met principles.

PURPOSE AND USE OF MET TECHNIQUES

NONSTANDARD CONDITIONS

11-2. Accurate fires can be placed on targets of known location without adjustments. Under standard conditions, the firing table data would achieve the desired results. However, it is valid to assume that standard conditions will not exist. Corrections need to be applied to firing table data to compensate for the nonstandard conditions of weather, position, and material. The most accurate means of determining these corrections is by registering. Registration corrections are only valid within transfer limits and for a specified period of time. However, conducting a registration may not be an option. Therefore, techniques are needed to mathematically determine corrections and compensate for changing nonstandard conditions. The met techniques are used to measure deviations from standard conditions and to compute corrections for them.

11-3. The firing tables used to determine firing data for artillery weapons are based on an **arbitrary set of standard conditions** of weather, position, and material at sea level. The standards for weather are established by the ICAO (International Civil Aviation organization). (See figure 11-1.)

WEATHER	***STANDARD CONDITIONS***
1	AIR TEMPERATURE 100 PERCENT (59° F)
2	AIR DENSITY 100 PERCENT (1,225 gm/m^3)
3	NO WIND
POSITION	***STANDARD CONDITIONS***
1	GUN, TARGET AND MDP AT SAME ALTITUDE
2	ACCURATE RANGE
3	NO ROTATION OF THE EARTH
MATERIAL	***STANDARD CONDITIONS***
1	STANDARD WEAPON, PROJECTILE AND FUZE
2	PROPELLANT TEMPERATURE (70° F)
3	LEVEL TRUNNIONS AND PRECISION SETTINGS
4	FIRING TABLE MUZZLE VELOCITY
5	NO DRIFT
LEGEND: gm/m3 = grams per cubic meter	

Figure 11-1. Standard Conditions.

11-4. The first seven columns of Table F of the TFT are based on one of two conditions occurring:

- Standard conditions are in effect.
- The sum of the corrections for all nonstandard conditions in effect equals zero.

11-5. It is obvious that the first will never occur and the second has a minimal chance of occurring. Therefore, if a unit wants to provide surprise and massed fires, it must consider the effects of nonstandard conditions in some way. The best solution to correct for all nonstandard conditions in effect is to register. This allows a unit to achieve first round FFE on an accurately located target. To correctly determine registration corrections and the effects of nonstandard conditions as they change over time, a unit must follow the five steps to improve firing data. (See table 11-1)

Table 11-1. Five Steps to Improve Firing Data.

STEP	***ACTION***
1	Round bursts at a point of known location. (Known point for precision registration and mean burst location for HB/MPI registration.)
2	Determine should hit and did hit data.
	***Should hit data (SHD)* are data that when fired under standard conditions cause the round to burst at the point of known location**.
	***Did hit data (DHD)* are data that when fired under nonstandard conditions cause the round to burst at the point of known location**
3	Determine total correction **(TOTAL CORR = DHD – SHD).** Determine the GFT setting (this always represents total corrections). Apply the total corrections to the subsequent missions to achieve first round FFE. Total corrections equal the sum of met corrections and position (pos) constants **(TOTAL CORR = MET CORR + POS CONSTANTS).** TOTAL CORR MET? | POS?
	***Met corrections* are all measurable nonstandard conditions for which you can account**. These are the effects of weather, propellant temperature, projectile weight, MVV, VI, and rotation of the earth (that is, any corrections for nonstandard conditions in the TFT).
	***Position constants* are all nonstandard conditions that are difficult to identify, relatively small in magnitude, and remain relatively constant**. These include, but are not limited to, met not up to 13 April 2016, unknown errors in measuring met, errors in measuring MV, unknown errors in survey, firing chart construction, inherent error captured during the registration, and any human error that occurred during the registration procedures (in other words, anything that caused a correction during the registration that cannot be classified as a met correction). There are three position constants: position deflection correction, position velocity error, and position fuze correction. For more detail, refer to paragraph 11-5 above.
	Note: These are the first three steps of registration. Met corrections and position constants are unknown. Total corrections are the only known quantity. The procedures a unit follows at this time will determine its ability to accurately apply the corrections from the registration to future missions as the effects of nonstandard conditions change. Presently, the unit can achieve first round FFE on accurately located targets. However, this accuracy degrades as the effects of nonstandard conditions change. Then the unit is faced with two options: register again or adjust fire. Neither is acceptable. Registering repeatedly needlessly exposes the unit to the counterfire threat and wastes ammo and time. Adjusting fire prevents a unit from achieving surprise and massed fires. **Therefore, it is imperative that a unit account for all measurable nonstandard conditions in effect (met corrections) DURING the registration.** Step 4 outlines this procedure, and step 5 outlines the procedure for application of registration corrections over time so that accuracy is maintained.
4	Isolate position constants (concurrent met technique) **(TOTAL CORR – MET CORR = POS CONSTANTS)**. TOTAL CORR MET | POS

Table 11-1. Five Steps to Improve Firing Data (continued).

<table>
<tr><th>STEP</th><th>ACTION</th></tr>
<tr><td></td><td>Note: To successfully complete step 4, a unit must account for the following measurable nonstandard conditions that are in effect during the registration:

Weather. Conditions are forecasted through automated means that predict the effects of nonstandard air temperature, air pressure, and wind
Muzzle velocity variation. The unit should calibrate during the registration so that a current MVV is determined
Propellant temperature. A nonstandard propellant temperature affects the achieved muzzle velocity, which affects the achieved range
Projectile square weight. A nonstandard projectile square weight affects the drag on the projectile throughout the trajectory, which affects the achieved range.
Rotation of the earth. Rotation affects achieved range and azimuth.
Vertical Interval. A difference in altitude between the target (point of known location) and the battery causes a range correction. This is called complementary range and is caused by CAS.
Drift. Since howitzer tubes are rifled, projectiles drift to the right. A left deflection correction is determined.
</td></tr>
<tr><td></td><td>By quantifying all met corrections, the position constants are isolated. Once this is completed, the unit can maintain first round fire for effect over time without adjusting (assuming accurate target location) or repeatedly registering by completing step 5. Also, these position constants are used to improve the fires of other units. There are two requirements to transfer position constants:
Common survey is established between transferring units. Common survey (or common grid) can be defined as orienting all concerned fire support assets in the same fashion with respect to direction and location. Fire support assets include, but are not limited to, firing platforms, target acquisition assets, sensors and force protection assets. Common survey is most often achieved when units orient for direction and location through survey control points established by the same higher echelon.
Registering and receiving FDC must account for all measurable nonstandard conditions in effect during the registration that affected the howitzer and the projectile.</td></tr>
<tr><td></td><td>Updating survey is still a concurrent met technique and allows a unit to correct for any errors in survey that were in effect during the registration.
There are two types of survey error we are concerned with:

Position survey. This survey of the firing unit location and establishes accurate howitzer locations and directional control. This updated survey affects chart range, direction of fire, battery altitude, and total corrections
Target survey. This is survey of the known point used in the registration and establishes accurate location of the known point. This updated survey affects chart range, direction of fire, target (known point) altitude, and total corrections.

Over time, the effects of nonstandard conditions change. As this happens, new met corrections are determined to maintain accuracy of fires.</td></tr>
<tr><td>5</td><td>Determine new total corrections (subsequent met technique) (NEW TOTAL CORR = NEW MET CORR + POS CONSTANTS).
<table>
<tr><td colspan="2">NEW TOTAL CORR</td></tr>
<tr><td>NEW MET</td><td>POS</td></tr>
</table></td></tr>
</table>

Table 11-1. Five Steps to Improve Firing Data (continued).

STEP	*ACTION*
5	This bar diagram implies that total corrections get larger. It could get smaller. The key point is that total corrections change because met corrections change. Position constants remained the same because they were completely isolated in step 4. Once the unit determines the new met corrections, they are added to the position constants to derive new total corrections. The new total corrections are graphically portrayed as a GFT setting. The unit is once again achieving first round FFE on accurately located targets. As time passes and nonstandard conditions change (mainly weather and propellant temperature), total corrections are updated. New met corrections are determined and added to the position constants, and new total corrections are derived (GFT setting). Once step 5 is completed, a unit then returns to step 3 and enters a step 3 to step 5 loop. To enter this loop, step 4 must be completed. If a unit registered and never quantified the met corrections that were valid during the registration, it would have no position constants with which to start step 5. All the effort expended during the first three steps becomes worthless.
Note: Subsequent met applications are as follows: Eight-direction met. Met to a target Met to a met check gauge point. Met + VE.	
Legend: CAS – complementary angle of site CORR – correction DHD – did hit data FDC – fire direction center FFE – fire for effect GFT – graphical firing table HB – high burst MPI – mean point of impact MV – muzzle velocity MVV – muzzle velocity variation POS – position SHD – should hit data TFT – tabular firing table VE – velocity error VI – vertical interval	

POSITION CONSTANTS

11-6. When a unit displaces to a new position and cannot register, the position constants from the last position may be used as a basis for determining a GFT setting by solving a subsequent met. The use of this technique may cause slight inaccuracies, but it will produce the most accurate data possible until the unit can conduct another registration or met + VE with a check round. Once new position constants are determined, the old position constants are not used.

11-7. The position deflection correction generally accounts for errors in survey and chart construction. The position deflection correction should only be transferred if common survey exists between positions.

11-8. The position fuze correction should be considered a fuze characteristic and not a correction for existing weather conditions. The position fuze correction should only be applied to the same lot of fuzes.

11-9. The position velocity error is expressed in meters per second. It is the position constant which accounts for all range errors not accounted for by meteorological data, muzzle velocity variation, and propellant temperature. Therefore, it will include any errors in survey and should only be transferred if common survey exists. However, the position VE is a constant for projectiles within the registering projectile family.

11-10. Part of the position VE and position deflection correction are charge independent, specifically errors in the firing chart and survey. The position fuze correction is charge independent because it is a fuze characteristic. Since position constants are relatively small and a portion of the position constants are charge independent, it is possible to compute a GFT setting for other charges and lots. The GFT setting will not be as accurate as a GFT setting derived from a registration, but it will be more accurate than firing with no GFT setting.

MET MESSAGES

11-11. Among the nonstandard conditions that affect the projectile after it leaves the tube is the atmosphere (weather conditions) through which the projectile passes. The three properties of the atmosphere that the artillery considers in its gunnery computations are wind (both direction and speed), air temperature, and air density derived from air pressure.

11-12. **Wind.** The effects of wind on a projectile are easy to understand. A tail wind causes an increase in range and a head wind causes a decrease in range. A crosswind blows the projectile to the right or left, which causes a deflection error. The FDC converts ballistic wind measurements into range and deflection components and applies corrections to the deflection and elevation of the howitzer.

11-13. Variations in air temperature cause two separate effects on a projectile. One effect is caused by the inverse relationship between density and temperature. This effect is compensated for when density effects are considered. The second effect is regarded as the true temperature. It is the result of the relationship between the speed of the projectile and the speed of the air compression waves that form in front of or behind the projectile. These air compression waves move with the speed of sound, which is directly proportional to the air temperature. The relationship between the variation in air temperature and the drag on the projectile is difficult to determine. This is particularly true for supersonic projectiles, since they break through the air compression waves after they are formed. As firing tables indicate, an increase in air temperature may increase, decrease, or have no effect on achieved range, depending on the initial elevation and muzzle velocity of the weapon.

11-14. **Air density.** Density of the air through which a projectile passes creates fiction, which affects the forward movement of the projectile. This affects the distance a projectile travels. The density effect is inversely proportional to the projectile ranges; that is, an increase in density causes a decrease in range.

11-15. The AN/GMK-2 Computer Meteorological Data – Profiler (CMD-P) provides meteorological data for indirect artillery forces. The CMD-P uses Global Forecast System (GFS) and other meteorological software models to produce a vertical profile of wind speed and direction, temperature, relative humidity, cloud base height, type precipitation, and horizontal visibility along the trajectory from the firing platform to the target area, for precise targeting of various munitions. These weather data are transmitted to artillery units in fixed formats called met messages. The field artillery uses the following two types of met messages:

- Computer met message. This message is used by artillery computer systems.
- Target acquisition met message. This message is used by weapon locating radars of the target acquisition battery (TAB).

Note: Only the computer met message will be described in the following paragraphs. The ballistic met message is no longer utilized in field artillery. Data must be derived from the computer met message and converted to ballistic atmospheric data in order to conduct meteorological techniques.

COMPUTER MET MESSAGE

11-16. The computer met message is a coded message that reports the atmospheric conditions in selected layers starting at the surface and extending to an altitude that will normally include the maximum ordinate of field artillery weapons that use these data. The computer met message reports actual average wind direction, wind speed, air temperature, and pressure in each layer. The computer met message is used by automated systems in the computation of the equations of motion used in the computer program. The computer met message is recorded on DA Form 3677 (Computer Met Message) and is divided into two parts–an introduction and a body.

11-17. The introduction of the computer met message consists of four six-character groups:

11-18. **Group 1.** The first three letters (MET) in group 1 identify the transmission as a met message. The next two letters (CM) indicate that it is a computer met message. The last digit (1) designates the octant of the earth in which the met station is located. (See figures 11-2 and 11-3.) In figure 11-3 on page 11-6, octant 1 indicates that the met station is located between 90°W and 180°W longitude and is north of the equator.

Symbols	***Definitions***
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	To be used when the location of the MET station is not indicated by latitude and longitude

Figure 11-2. Global Octants.

Note: The number 4 is not used. The number 9 is used when the location is coded.

11-19. **Group 2.** This group designates the center of the area in which the met message is valid. This is expressed in tens, units, and tenths of degrees of latitude and longitude (347= 34.7 and 984 = 98.4°). When the longitude is 100 or greater, the initial digit (1) is omitted. If the number 9 is used to designate the octant, the six digits or letters represent the coded location (in latitude and longitude) of the met station that produced the message. (See figure 11-3.)

11-20. **Group 3.** The first two digits (07) in group 3 represent the day of the month that the met message is valid. The next three digits (125) indicate the hour in tens, units, and tenths of hours (138 = 13.8 hours = time 1348) the met message is valid. The hours refer to Greenwich Mean Time (GMT). The last digit (0) in group 3 indicates the number of hours the message will remain valid. The US does not try to predict the length of time a met message will remain valid. Therefore, the last digit in group 3 of a computer met message will always be 0. Some allied nations predict the length of time a met message will remain valid. These predictions vary from 1 to 8 hours. Code 9 indicates 12 hours. (See figure 11-3.)

11-21. **Group 4.** The first three digits (036) of group 4 indicate the altitude of the met station meteorological datum plane (MDP) above sea level in tens of meters (036 = 360). The last three digits (974) indicate the atmospheric pressure, in millibars, at the met station. When the pressure value is greater than 999 millibars, the first digit (1) is omitted. (For example, 009= 1009). (See figure 11-3.)

Note: Meteorological datum plane (MDP) is the altitude of the met station from which all met computations are based it also refers to an area where the target and battery needs to fall within to be valid.

COMPUTER MET MESSAGE

For use of this form, see TC 3-09.81; the proponent agency is TRADOC.

IDENTIFI-CATION	OCTANT	LOCATION		DATE	TIME (GMT)	DURATION (HOURS)	STATION HEIGHT (10's M)	MDP PRESSURE MB
		$L_a L_a L_a$ or	$L_o L_o L_o$ or					
METCM	Q	XXX	XXX	YY	$G_O G_O G_O$	G	hhh	$P_d P_d P_d$
METCM	**1**	**347**	**984**	**07**	**138**	**0**	**036**	**974**

Legend: GMT – Greenwich Mean Time MB – millibars MDP – meteorological datum plane

Figure 11-3. Introduction of the Computer MET Message.

11-22. The body of the met message can consist of 27 met message lines (00-26). Each line consists of **two eight-number groups** (ZZdddFFF TTTTPPPP). Each line contains the actual average weather data for a particular zone. The parameters for each zone are outlined in figure 11-4 on page 11-7.

Line No.	***Height Above MDP from Base to Top of Zone (Meters)***	***Line No.***	***Height Above MDP from Base to Top of Zone (Meters)***
00	0	14	7,000 to 8,000
01	0 to 200	15	8,000 to 9,000
02	200 to 500	16	9,000 to 10,000
03	500 to 1,000	17	10,000 to 11,000
04	1,000 to 1,500	18	11,000 to 12,000
05	1,500 to 2,000	19	12,000 to 13,000
06	2,000 to 2,500	20	13,000 to 14,000
07	2,500 to 3,000	21	14,000 to 15,000
08	3,000 to 3,500	22	15,000 to 16,000
09	3,500 to 4,000	23	16,000 to 17,000
10	4,000 to 4,500	24	17,000 to 18,000
11	4,500 to 5,000	25	18,000 to 19,000
12	5,000 to 6,000	26	19,000 to 20,000
13	6,000 to 7,000	**Legend:** MDP – meteorological datum plane	

Figure 11-4. Zone Number Codes for Computer MET Messages.

- The first two digits in the first group on each line identifies the altitude zone (00 [surface] through 26 [20,000 meters]). Line 00 is used as an example. (See figure 11-5, page 11-8.)
- The next three digits in the first group (329) indicates the direction from which the wind is blowing. It is expressed in tens of mils true azimuth (329= 3290). (See figure 11-5, page 11-8.)
- The last three digits of the first group (003) indicate the wind speed expressed in knots (003 =3 knots). (See figure 11-5, page 11-8.)
- The first four digits of the second group (3060) indicate the actual air temperature expressed in degrees Kelvin (K) to the nearest tenth of a degree (306.0°K). (See figure 11-5, page 11-8.)
- The last four digits of the second group (974), indicate the actual air pressure, in millibars, to the nearest millibar (974 millibars). (See figure 11-5, page 11-8.)

COMPUTER MET MESSAGE

For use of this form, see TC 3-09.81 the proponent agency is TRADOC.

IDENTIFICATION	OCTANT	LOCATION $L_a L_a L_a$ or	LOCATION $L_o L_o L_o$ or	DATE	TIME (GMT)	DURATION (HOURS)	STATION HEIGHT (10's M)	MDP PRESSURE MB
METCM	Q	XXX	XXX	YY	$G_O G_O G_O$	G	hhh	$P_d P_d P_d$
METCM	**1**	**347**	**984**	**07**	**138**	**0**	**036**	**974**

ZONE HEIGHT (METERS)	LINE NUMBER ZZ	ZONE VALUES: WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10°K) TTTT	PREASURE MILLIBARS) PPPP
SURFACE	00	329	003	3060	0974
200	01	362	006	3040	0959
500	02	406	014	3030	0933
1000	03	403	018	3020	0891
1500	04	378	010	2990	0842
2000	05	356	007	2950	0795
2500	06	329	004	2910	0750
3000	07	304	004	2870	0707
3500	08	299	004	2840	0665
4000	09	306	004	2800	0627
4500	10	321	004	2770	0590
5000	11	349	003	2740	0554
6000	12	415	003	2690	0504
7000	13	438	003	2630	0443
8000	14	443	003	2580	0389
9000	15	494	004	2510	0340
10000	16	527	007	2430	0296
11000	17	525	009	2350	0256
12000	18	482	006	2270	0221
13000	19	423	007	2190	0190
14000	20	390	007	2120	162
15000	21	350	005	2070	0137
16000	22	300	007	2040	0115
17000	23	174	008	2020	0098
18000	24	156	013	2030	0083
19000	25	153	017	2040	0070
20000	26	152	019	2070	0059

FROM B BTRY 1-30th FA TO: A BBRTY 1-30th FA	DATE AND TIME (GMT) 270800RMAY13	DATE AND TIME (LST) 270800RMAY13
MESSAGE NUMBER 1307-04	RECORDER RB	CHECKED RB

DA FORM 3677, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend: BTRY – battery FA – field artillery GMT – Greenwich Mean Time LST – local standard time MB – millibars MDP – meteorological datum plane

Figure 11-5. Completed DA Form 3677.

MET MESSAGE CHECKING PROCEDURES

11-23. When the FDC receives a met message, it should be checked to ensure that it is valid. Any peculiarities in the message should be noted. If the timeliness or validity of a met message is doubted, that should be questioned and referred to the battalion FDC. While most messages are transmitted digitally, verbal transmission of met messages may cause copying errors, particularly if the message is copied down on something other than the standard (computer) met form. FDC personnel should use the guidelines below when checking met messages.

11-24. Check the computer met message heading as follows: (See figure 11-6, page 11-10.)

- Check message type, octant, and location entries for correctness, ensuring validity for the area of operations. The location of the met message should be the midpoint between the gun and target areas.
- Check 13 April 2016-time entries to ensure they are current (date-time entries are expressed in Greenwich Mean Time).

11-25. Check for possible line to line errors in the computer met message as follows: (See figure 11-6, page 11-10.)

- Question drastic wind direction changes (1,000 mils or greater) or sudden reverses of wind direction from line to line, particularly if wind speeds are more than 10 knots. Direction changes greater than 1,000 mils are common when wind speeds are 10 knots or less.
- Question severe increases or decreases (10 knots or greater) in wind speed from line to line.
- Temperature accuracy is hard to evaluate because of natural erratic changes. Question a severe increase or decrease (over 20°K) in temperature from line to line.
- Check for increases in pressure. Pressure should decrease smoothly from line to line. Pressure will never increase with height.

11-26. Computer met messages that do not reflect the correct location or current date-time are invalid and do not accurately represent the current weather conditions for the area of operations. Invalid met messages should be brought to the attention of the battalion FDC for the processing of a new, valid met message.

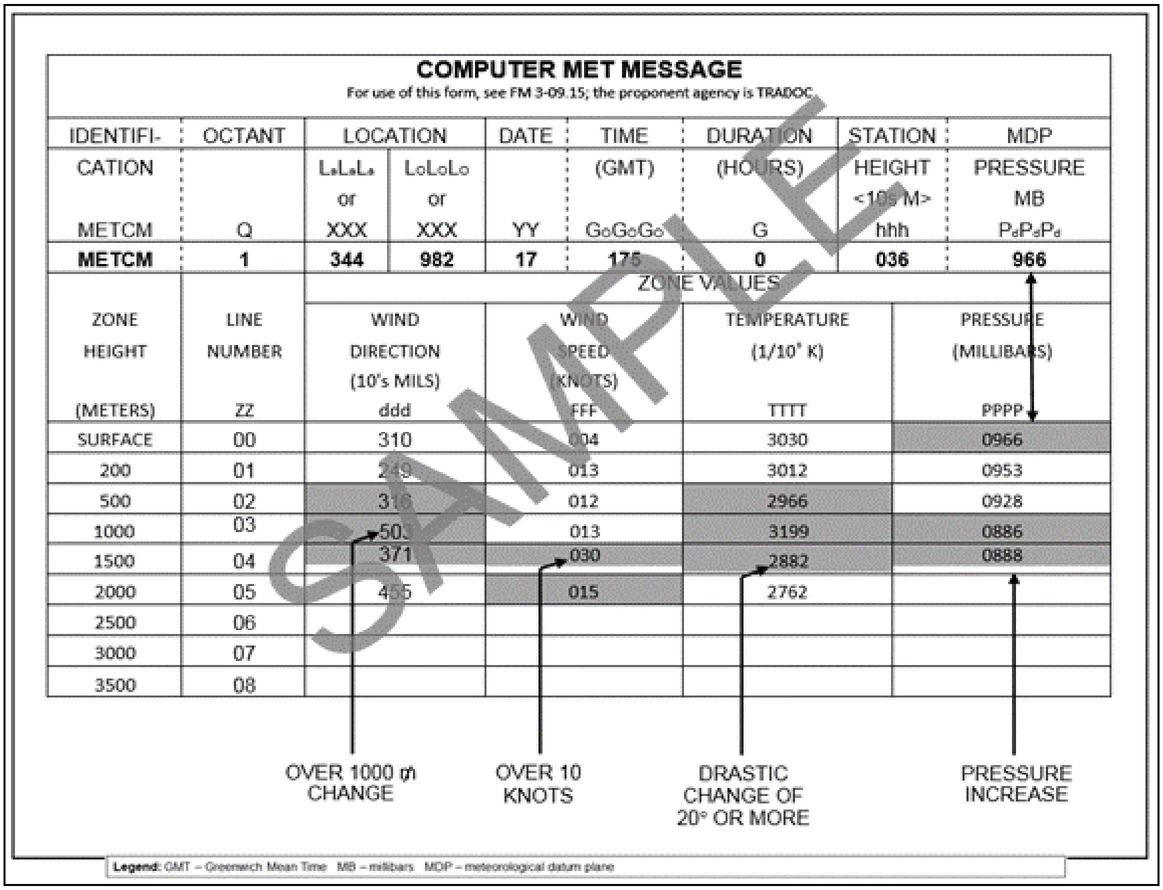
11-27. The line to line checks reflect basic weather behavior patterns. Regional and topographical characteristics can often produce unusual variances in wind direction and speed. The CMD-P numerical model does not necessarily produce a 100% accurate forecast, but it does not produce non-physical results. The deviations noted do not invalidate the met message but should be referred to the battalion FDC for clarification, especially in cases where the message was transmitted verbally.

11-28. In cases where the met message's validity is called into question, the FDO has a few available options.

- If this is the first met message and it cannot be checked against previous met data, a precision registration should be conducted in order to account for all nonstandard conditions. If a registration is not feasible and line to line errors are in question, the met may be applied and a check round fired to verify accuracy.
- If the met in question is not the first produced by the CMD-P and the FDC has maintained accuracy during fire mission processing with the current met, a dry-fire verification may be conducted in order to compare firing solutions. With the current met, compute and record firing data (deflection, quadrant elevation, and time fuze setting) for a known point. Next, make the new met current and compute firing data for the same known point, comparing the two firing solutions. As a general rule, apply the standard tolerances for deflection (±3 mils), quadrant elevation (±3 mils), and time fuze setting (±0.1 seconds).

Note: Additional analysis may be needed when firing at maximum ranges, where each mil causes a greater deviation on the ground. Use the appropriate TFT to compare the differences in firing data at the known point target range.

- The FDO also maintains the option to discard the new met and continue firing with the current met while maintaining accuracy. While made feasible by the ability of the CMD-P to provide a new met every 30 minutes, the FDC should strive to improve accuracy with every chance afforded.



COMPUTER MET MESSAGE

For use of this form, see FM 3-09.15; the proponent agency is TRADOC.

IDENTIFICATION	OCTANT	LOCATION		DATE	TIME (GMT)	DURATION (HOURS)	STATION HEIGHT <10s M>	MDP PRESSURE MB
METCM	Q	LaLaLa or XXX	LoLoLo or XXX	YY	GoGoGo	G	hhh	PdPdPd
METCM	**1**	**344**	**982**	**17**	**175**	**0**	**036**	**966**

ZONE HEIGHT (METERS)	LINE NUMBER ZZ	WIND DIRECTION (10's MILS) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10° K) TTTT	PRESSURE (MILLIBARS) PPPP
SURFACE	00	310	004	3030	0966
200	01	249	013	3012	0953
500	02	316	012	2966	0928
1000	03	503	013	3199	0886
1500	04	371	030	2882	0888
2000	05	455	015	2762	
2500	06				
3000	07				
3500	08				

Figure 11-6. Computer MET Message Errors.

MET MESSAGE TIME VALIDITY

11-29. **Time Consideration.** The passage of time may decrease the accuracy of a message because of the changing nature of weather. With existent equipment and technology, the battalion FDC has the ability to provide met messages every 30 minutes. A met message at this frequency has been shown to dramatically increase the accuracy and lethality of munitions. This however may be impractical and could slow the responsiveness of the firing unit. Generally speaking, a firing unit should request a new met message every 2 to 4 hours, depending on the tactical situation.

11-30. It is critical for a firing unit to request and receive a met message when:

- Upon entering the initial firing position.
- Any movements more than 4 kilometers, but the target area remains the same.
- Anytime direction of fire is more than 800 mils from the original target location.
- Anytime there is a significant change in weather; that is, a storm front comes through or the temperature increases or decreases.
- During transition periods.

SECTION II: DERIVATION OF BALLISTIC DATA

11-31. Techniques described in this section provide a timely and accurate manual backup and alternative when automated means are unavailable.

THE NEED FOR BALLISTIC DATA

11-32. In the current automated age of fire direction, the use of the tabular firing tables (TFTs) as well as the five steps to improve firing data have been somewhat marginalized. While automated systems utilize many of the techniques and procedures described in this publication, the ability to comprehend and recreate the solutions of automated systems is essential. Meteorological techniques allow the solutions of automated systems to be recreated and analyzed.

11-33. The meteorological techniques are predicated on the ability to use the TFT. The TFT, in turn, is based on information taken from a ballistic met message (old message format). With the loss of this message format the only solution is to use a computer met message to derive "ballistic" data.

11-34. Ballistic data, as could be found in a ballistic met message, is defined as the weighted average of the conditions that exist from the surface up through the altitude zone, indicated by the line number, and back to the surface.

11-35. Deriving "ballistic" data is based on a few guidelines:

- There must be an understanding of the differences between the atmospheric structures utilized by computer and ballistic met messages.
- Wind direction and wind speed can be directly used regardless of the met line number.
- The air pressure values found in the computer met message must converted into values for air density in order to match the data found in a ballistic met message.
- Values for air temperature and air density must be based on the varying temperature and density standards at the needed line number.
- The most accurate result would make use of weighting factors for density dependent on the met message line number.

11-36. The following equations convert computer met message data into simulated "ballistic" data:

$$\text{Air Temperature \% of Stnd} = \frac{\text{Air Temp (From needed line \#)}}{\text{Stnd Air Temp @ needed line \#}} \times 100\%$$

$$\text{Air Density \% of Stnd} = \frac{\text{Air Pressure (From needed line \#)} \times 0.34836764}{\text{Air Temp (From needed line \#)}}$$

$$= \frac{\text{Air Density Ratio}}{\text{Stnd Air Density @ needed line \#}} \times 100\%$$

Where 0.34836764 is the conversion from millibars to kilograms per meter cubed

ATMOSPHERIC STRUCTURE AND STANDARD CONDITIONS

11-37. The first step in converting computer met data into "ballistic" data is determining which ballistic line number corresponds to the selected line in the computer met message. This decision is dictated by the atmospheric structures of each message. These atmospheric structures are depicted in figure 11-7 on page 11-12. The top of each altitude zone is pictured in the figure.

<table>
<tr><th rowspan="2">HEIGHT (meters)</th><th colspan="2">LINE (ZONE) NUMBERS</th><th rowspan="2">HEIGHT (meters)</th><th colspan="2">LINE (ZONE) NUMBERS</th></tr>
<tr><th>COMPUTER MET MESSAGE</th><th>BALLISTIC MET MESSAGE</th><th>COMPUTER MET MESSAGE</th><th>BALLISTIC MET MESSAGE</th></tr>
<tr><td>SURFACE</td><td>00</td><td>00</td><td>3500</td><td>08</td><td rowspan="2">07</td></tr>
<tr><td>50</td><td rowspan="3">01</td><td rowspan="3">01</td><td>4000</td><td>09</td></tr>
<tr><td>100</td><td>4500</td><td>10</td><td rowspan="2">08</td></tr>
<tr><td>200</td><td>5000</td><td>11</td></tr>
<tr><td>300</td><td rowspan="3">02</td><td rowspan="3">02</td><td>6000</td><td>12</td><td>09</td></tr>
<tr><td>400</td><td>7000</td><td>13</td><td rowspan="2">10</td></tr>
<tr><td>500</td><td>8000</td><td>14</td></tr>
<tr><td>600</td><td rowspan="5">03</td><td rowspan="5">03</td><td>9000</td><td>15</td><td rowspan="2">11</td></tr>
<tr><td>700</td><td>10000</td><td>16</td></tr>
<tr><td>800</td><td>11000</td><td>17</td><td rowspan="2">12</td></tr>
<tr><td>900</td><td>12000</td><td>18</td></tr>
<tr><td>1000</td><td>13000</td><td>19</td><td rowspan="2">13</td></tr>
<tr><td>1100</td><td rowspan="5">04</td><td rowspan="5">04</td><td>14000</td><td>20</td></tr>
<tr><td>1200</td><td>15000</td><td>21</td><td rowspan="2">14</td></tr>
<tr><td>1300</td><td>16000</td><td>22</td></tr>
<tr><td>1400</td><td>17000</td><td>23</td><td rowspan="2">15</td></tr>
<tr><td>1500</td><td>18000</td><td>24</td></tr>
<tr><td>1600</td><td rowspan="5">05</td><td rowspan="5">05</td><td>19000</td><td>25</td><td rowspan="2"></td></tr>
<tr><td>1700</td><td>20000</td><td>26</td></tr>
<tr><td>1800</td><td colspan="3" rowspan="10"></td></tr>
<tr><td>1900</td></tr>
<tr><td>2000</td></tr>
<tr><td>2100</td><td rowspan="5">06</td><td rowspan="7">06</td></tr>
<tr><td>2200</td></tr>
<tr><td>2300</td></tr>
<tr><td>2400</td></tr>
<tr><td>2500</td></tr>
<tr><td>2600</td><td rowspan="2">07</td></tr>
<tr><td>3000</td></tr>
</table>

Figure 11-7. Atmospheric Structure of Met Messages.

11-38. The standard conditions for weather that were previously mentioned in this chapter are the conditions that exist at sea level. There are in fact standard values for air temperature and air pressure that exist up to 20,000 meters above sea level. These varying standards must also be utilized in order to simulate ballistic data within any altitude zone (see figure 11-8).

Line No.	***Standard Air Temperature*** ***Degrees Kelvin***	***Standard Air Density*** ***kg/m³***
00	288.2	1.2250
01	287.5	1.2133
02	285.9	1.1844
03	283.3	1.1392
04	280.0	1.0846
05	276.8	1.0320
06	271.9	0.9569
07	265.4	0.8632
08	258.9	0.7768
09	252.4	0.6971
10	242.7	0.5895
11	229.7	0.4664
12	218.3	0.3612
13	216.7	0.2655
14	216.7	0.1937
15	216.7	0.1413

Figure 11-8. Standard Conditions for Weather.

DENSITY WEIGHTING FACTORS

11-39. As previously stated ballistic data are data that is weighted based on the conditions within a given altitude zone as well as the conditions between that zone and the surface. Much of this weight is placed on the derived values by using the varying standard values for each altitude zone. However, an additional weighting factor must be applied to density because of its significant effects on range. The impact of density displays the greatest effect on range at line 04 and above (see figure 11-9).

Line No.	***Weighting Factor***
00 -03	1.0000
04	0.9945
05	0.9978
06	1.0162
07	1.0025
08	0.9663
09	1.0272

Figure 11-9. Density Weighting Factors for Lines 00-09.

Note: Due to the volatility and unpredictability of weather conditions are greater altitudes there are no weighting factors above line 09. As a result, the use of this derivation within those altitude zones decreases significantly in accuracy.

SECTION III: CONCURRENT MET TECHNIQUE

11-40. A concurrent met is solved to isolate position constants. To perform a concurrent met technique, the firing unit must have total corrections determined from a registration and the met conditions that were valid at the time of the registration. Met corrections are determined and then subtracted from the total corrections to isolate position constants. Any errors in the met corrections and total corrections will be contained in the position constants. Every effort must be made to obtain the most accurate met corrections available.

DA FORM 4200 MET DATA CORRECTION SHEET

11-41. The concurrent met technique is solved on DA Form 4200 (Met Data Correction Sheet). There are two methods to solve a concurrent met technique. The first is the vowel rule. This follows the sequence of the tables in the TFT, and computations are completed after extracting data from a vowel table. Table 11-2 provides the abbreviated steps for this method. The second is the RATT rule. RATT is an acronym for record, apply, transfer, tables. This also follows the sequence of the tables in the TFT, but computations are completed after extracting data from each table. Table 11-3 on page 11-16 provides the abbreviated steps for this method.

Table 11-2. Concurrent Met Technique (Vowel Rule).

STEP	***ACTION***
1	Determine and enter total corrections from the GFT setting.
2	Enter the known data. For a concurrent met, these include the following: ● Charge. ● Adjusted Quadrant. ● Chart range. ● Latitude. ● Battery altitude. ● Altitude of target and burst. ● Direction of fire. ● Equations for position deflection correction, position velocity error, and position fuze correction. ● Muzzle velocity variation. ● Propellant temperature. ● Total range correction. ● Fuze setting corresponding to (~) adjusted elevation. ● GFT setting with lazy Z. ● Total fuze correction. ● Target number. ● 13 April 2016-time group.
3	Determine the met line number from Table B of the TFT.
4	Extract and convert the computer met message data based on the line number determined.
5	Enter the met message data.
6	Compute ∆h, height of target above gun, and the chart direction of wind.

Table 11-2. Concurrent Met Technique (Vowel Rule) continued.

STEP	*ACTION*
7	Enter the TFT, and determine and extract the following: ● Complementary (comp) range from Table B. ● Wind components from Table C. ● Corrections to temperature and density from Table D. ● Corrections to muzzle velocity for propellant temperature from Table E
8	Compute corrected values for temperature, density, entry range, crosswind, range wind and variations from standard.
9	Enter the TFT, and determine and extract the following: ● Unit corrections from Table F (Columns 8 through 19). ● Rotation corrections for range from Table H. ● Rotation corrections for azimuth from Table I.
10	Compute met deflection correction and position deflection correction.
11	Compute met range correction and position velocity error (VE).
12	Enter the TFT, and determine and extract the unit corrections from Table J by using the variations from standard determined in step 8 and the ∆V determined in step 11.
13	Compute the met fuze correction and position fuze correction.
Legend: GFT – graphical firing table TFT – tabular firing table VE – velocity error	

Table 11-3. Concurrent Met Technique (RATT Rule).

STEP	ACTION
1	Determine and record total corrections from the GFT setting.
2	Record the known data. (Refer to Table 11-2, step 2)
3	Apply the known data.
4	Record the met line number from Table B of the TFT.
5	Extract and convert the computer met message data based on the line number determined.
6	Record the met message data.
7	Apply Δh and the chart direction of wind.
8	Record complementary range from Table B.
9	Apply complementary range to chart range and determine entry range.
10	Record wind components from Table C.
11	Apply wind components, and determine crosswind and range wind.
12	Transfer range wind to MET RANGE CORRECTION section.
13	Record corrections to temperature and density from Table D.
14	Apply corrections to temperature, density and determine corrected values.
15	Transfer corrections to temperature and density to the MET RANGE CORRECTION section.
16	Record the correction to muzzle velocity for propellant temperature from Table E.
17	Record unit correction factors from Table F (Columns 8 through 19).
18	Apply unit correction factors to variations from standard.
19	Record rotation correction for range from Table H.
20	Apply rotation correction, and determine the met range correction.
21	Transfer the met range correction.
22	Apply the met range correction, and complete COMPUTATION of VE block.
23	Record rotation corrections from azimuth from Table I.
24	Apply rotation correction, drift correction, and crosswind correction, and determine met deflection correction and position deflection correction.
25	Record unit correction factors from Table J.
26	Apply unit correction factors to variations from standard, and determine met fuze correction and position fuze correction.
Legend: GFT – graphical firing table TFT – tabular firing table VE – velocity error	

SOLUTION OF A CONCURRENT MET

11-42. Table 11-4 shows a detailed solution of a concurrent met using the RATT rule. The example uses the data shown in figure 11-10 on page 11-25.

Table 11-4. Solution of a Concurrent Met.

STEP	ACTION
1	Record the known data from the registration on DA Form 4200. Use the ROF shown in Figure 11-10 (on page 11-25).
1a	Record the charge (1L).
1b	Record a line through the adjusted QE block.
1c	Record the chart range in both blocks (5140).

Table 11-4. Solution of a Concurrent Met (continued).

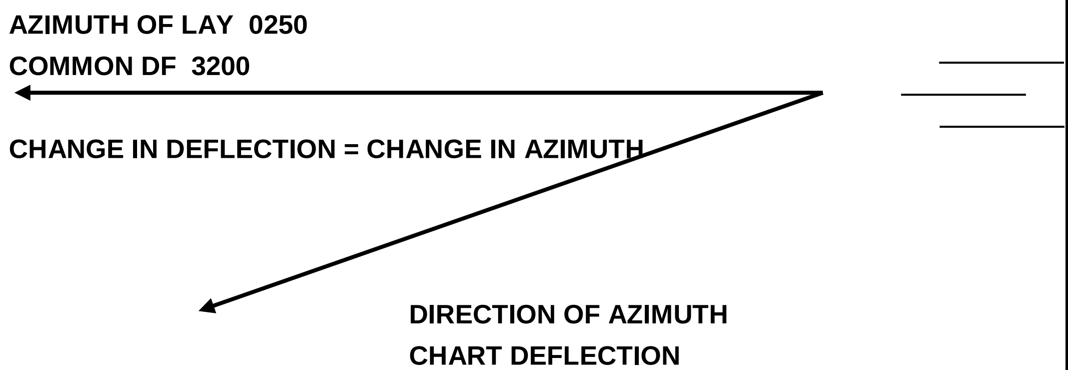
STEP	***ACTION***
1d	Record the latitude (nearest 10°) (34°N~30°N).
1e	Record the battery altitude (to the nearest 1 meter in parentheses and to the nearest 10 meters) in the block (355~360). Enter to the nearest 1 meter in the lower block (355).
1f	Record target altitude and altitude of the burst (nearest meter) (376).
1g	Record the direction of fire (to the nearest mil in parentheses and to the nearest 100 mils in the block) (0395~0400). The following diagram shows how to determine the direction of fire.  **COMMON DEFLECTION 3200** **AZIMUTH OF FIRE 0250** **- CHART DEFLECTION 3055** **+CHANGE IN AZIMUTH (+145)** **CHANGE IN DEFLECTION +145** **DIRECTION OF FIRE 0395** Note: The direction of fire can also be determined by using the LARS rule to compare the chart deflection to the common deflection and by using the RALS rule to apply the angular difference to the azimuth of fire. Keeping the algebraic sign will simplify the math step.
1h	Record the total deflection correction (R1) in the wind components and deflection computational space. Use the equation **TOT DF CORR – MET DF CORR = POS DF CORR** to determine the position deflection correction. Record it as follows: **TOTAL DF CORR L9** **- MET DF CORR** **POS DF CORR**
1i	Record in the MET RANGE CORRECTION section the [] weight of the projectile fired during the registration (3[]). Also, record the standard projectile weight, which can be determined from the introduction of the appropriate TFT (4[]).
1j	Record the MVV (-7.7) of the howitzer that fired the registration. Use the equation **VE – MVV = POS VE** in the MET RANGE CORRECTION computational block. Record it as follows: **VE – MVV = POS VE** – **(-7.7) =**

Table 11-4. Solution of a Concurrent Met (Continued).

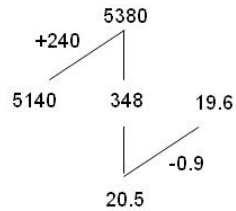
STEP	***ACTION***
1k	Record the propellant temperature at the time of the registration (+82).
1l	Divide the MV UNIT CORRECTION block in half with a diagonal line.
1m	Record the lazy Z in the bottom computational block (range, adjusted elevation, adjusted fuze setting, and total corrections [values only, no letters]). 
1n	Record the total range correction in the top block, and line out the bottom block (+240).
1o	Record the total fuze correction in the top block, and line out the bottom block (-0.9).
1p	Record the fuze setting corresponding to the adjusted elevation to the nearest 0.1, and then express it to the nearest whole fuze setting increment. Record it in the space to the left of the words “MET FUZE CORRECTION” as follows: **FS ~ ADJ EL = 20.5 ≈ 20**
1q	Record the known point number (**KN PT 1**).
1r	Record the unit designation (**E**).
1s	Record the 13 April 2016-time group.
	Note: A DA Form 4200 with the above known data is shown in figure 11-11 on page 11-26.
2	Determine the met line number of the met message from Table B and height of target above gun.
2a	Determine the height of target above gun (VI) to the nearest 1 meter, and express it to the nearest 100 meters (figure 11-14, page 11-29).
2b	Enter Table B for the appropriate charge with the chart range expressed to the nearest 100 meters and the VI (figure 11-12, page 11-27).
2c	Extract the met line number corresponding to the expressed chart range and VI. This indicates which line of data from the met message will be used in solving the met. Record the value in the **LINE NO.** block (**02**). This line number represents the needed ballistic data to solve the concurrent met.
3	Record the met message data on DA Form 4200. The computer met message is shown in Figure 11-13 on page 11-28.
3a	Determine the corresponding computer met message line for the line number determined in step 2 (**Line No. 02**) (See figure 11-7, page 11-12).
3b	Determine the corresponding weather standards for air temperature and density (**285.9, 1.1844)** at the determined line number (See figure 11-8, page 11-13).
3c	Extract the computer met air temperature (**288.2**) and air pressure (**939**).
3d	Convert the computer met air temperature and air pressure into simulated “ballistic” data with the following equations: $\frac{Air\ Temperature\ at\ CM\ line\ 02}{Temperature\ std\ (at\ ballistic\ line\ 02)} = \frac{288.2}{285.9} X\ 100\%$ **(expressed to nearest tenth of a percent)**

Table 11-4. Solution of a Concurrent Met (continued).

STEP	*ACTION*
	$\frac{Air\ Preassure\ (at\ CM\ line\ 02)}{AirTemperature\ (at\ CM\ line\ 02)} = \frac{939}{288.2}\ X\ 0.34836764$ $\frac{Density\ Conversion\ Ratio}{Density\ std\ (at\ ballistic\ line\ 02)} = \frac{1.1350}{1.1844}\ X\ 100\%\ \approx 95.8\%$ **(expressed to nearest tenth of a percent)**
3e	Extract the density weighting factor at the appropriate ballistic line number (**1.0000)** (See figure 11-9, page 11-13).
3f	Multiply the derived ballistic density by extracted weighting factor (**95.8% x 1.0000 = 95.8%**)
3g	Record the derivation computations in the MET MESSAGE section computational space.
3h	Record data from the identification line (METCM, 1, 347 985, 27, 1230, 550, 977) and the line number (02) determined in step 2c from the met message in the met message block.
3i	Record the altitude of the MDP (**550**), wind direction (**5920**), wind speed (**17**), air temperature (**100.8**), and air density (**95.8**) from the met message in the appropriate blocks. (See figure 11-14, page 11-29.) Note: Data from the met message must be decoded before being recorded on DA Form 4200 (figure 11-14, page 11-29).
4	Compute ∆h, and chart direction of wind.
4a	Determine the difference in altitude between the battery and the MDP to correct the values for air temperature and density. Circle the word “above” or “below” as appropriate. **ALT OF BTRY 360** **-ALT OF MDP (-550)** **BTRY (BELOW) MDP -190**
4b	Subtract the direction of fire from the direction of wind to determine the chart direction of wind. Add 6400 to the direction of wind if it is less than the direction of fire. Record the actual wind direction in parentheses and expressed to the nearest 100 mils in the block. **DIRECTION OF WIND 5920 ~ 5900** **- DIRECTION OF FIRE 0400** **CHART DIRECTION OF WIND 5500** Note: The chart direction of wind is used to divide the wind direction into crosswind and range wind components.
4c	Record the wind speed (**17**) in the CROSS WIND and RANGE WIND blocks.
5	Extract the complementary range from Table B.
5a	Enter Table B with the chart range expressed to the nearest 100 meters (**5140 ≈ 5100**) and the height of target above gun (VI) to the nearest 100 meters (**0**). (See figure 11-12, page 11-27.)
5b	Extract the complementary range. Record the value in the COMP RG block in the MET MESSAGE section, and apply it to the chart range. The result is the entry range to the nearest meter. Express the value to the nearest 100 meters, and record it out to the side of the ENTRY RG block. (See figure 11-15, page 11-30) **COMP RG 0** **+CHART RG 5140** **ENTRY RG 5140 ≈ 5100**
6	Extract the wind components from Table C.
6a	Enter Table C with the chart direction of wind (**5500**). Extract and record the crosswind (**L0.77**) component and range wind (**H0.63**) component. (See figure 11-15, page 11-30)
6b	Multiply the wind components by the wind speed, and express the result to the nearest 1 knot. Circle the appropriate symbol (L or R for cross wind and T or H for range wind). (See figure 11-17 on page 11-31)

Table 11-4. Solution of a Concurrent Met (continued).

STEP	***ACTION***
6c	The range wind and crosswind are now known values. The range wind is recorded in the KNOWN VALUES block under the MET RANGE CORRECTION section. (See figure 11-17, page 11-31.)
7	Determine the temperature and density corrections from Table D.
7a	Enter Table D with the Δh (**-190**) (See figure 11-16 on page 11-30.)
7b	Extract the corrections that will be applied to the temperature and density to compensate for the difference in altitude between the battery and MDP (**DT Correction +0.4; DD Correction +1.9**). Record them in the Δh CORRECTION block.
7c	Apply the corrections to the temperature and density, and record the result in the CORRECTED VALUES block and in the KNOWN VALUES column of the MET RANGE CORRECTION section. (See figure 11-17, page 11-31.) **AIR TEMP 100.8** **AIR DENSITY 95.8** **<u>Δh CORRECTION +0.4</u>** **<u>Δh CORRECTION +1.9</u>** **CORRECTED VALUE 101.2** **CORRECTED VALUE 97.7**
8	Determine the correction to muzzle velocity for propellant temperature from Table E.
8a	Enter Table E with the propellant temperature to the nearest degree Fahrenheit (**+82°F**).
8b	Interpolate the effect on muzzle velocity as required. (See figures 11-18 and 11-19, page 11-32)
8c	Record the value in the CHANGE TO MV FOR PROP TEMP block (**+0.6**).
9	Determine the variations from standard. The known values for range wind (**H11**), air temperature (**101.2**), air density (**97.7**), and projectile weight **(3[])** have been recorded in the KNOWN VALUES column under the MET RANGE CORRECTION section. Compare the known value to the standard value. Circle the (I) for an increase or the (D) for a decrease (whichever is appropriate), and record the difference in the VARIATIONS FROM STANDARD column. Transfer the values to the VARIATION FROM STANDARD column in the MET FUZE CORRECTION section. (See figure 11-17, page 11-31.)
10	Determine unit corrections for drift, crosswind, muzzle velocity, range wind, air density, air temperature, and projectile weight from Table F (see figure 11-20, page 11-33).
10a	Enter Table F with the entry range (5100). (See figure 11-21, page 11-34.)
10b	Extract the azimuth correction for drift from Column 8 (**L7.3**). (Record all unit corrections as shown in figure 11-21, page 11-34.)
10c	Extract the crosswind unit correction from Column 9 (**0.20**).
10d	Extract the range correction for muzzle velocity from Columns 10 and 11 (**DEC** +**26.6/INC -21.3**). Extract both corrections, because it is unknown at this time if the muzzle velocity effect will be an increase or a decrease.
10e	Extract the correction for range wind from Column 12 for a head wind or Column 13 for a tail wind (**+6.9**).
10f	Extract the correction for air temperature from Column 14 for a decrease or Column 15 for an increase (-**-4.4**).
10g	Extract the correction for air density from Column 16 for a decrease or Column 17 for an increase (**-6.3**).

Table 11-4. Solution of a Concurrent Met (continued).

STEP	***ACTION***
10h	Extract the correction for projectile weight from Column 18 for a decrease or Column 19 for an increase (**-29.0**). This correction will be recorded with an ending of .0.
10i	Next to the UNIT CORRECTIONS column there are two columns: PLUS and MINUS. If the unit correction is a plus, cross out the MINUS block; if the unit correction is a minus, cross out the PLUS block. (See figure 11-21, page 11-34.)
10j	Multiply the crosswind unit correction (**0.20**) by the crosswind value (**L 13**), and record the result to the nearest 0.1 in the CROSS WIND CORR block (**L 2.6**).
10k	Multiply the variations from standard by the unit corrections, and record the results to the nearest tenth (0.1) in the boxes that are not crossed out. (See figure 11-21, page 11-34.)
11	Determine the correction to range to compensate for the earth's rotation from Table H.
11a	Enter Table H with the entry range (**5100**) expressed to the nearest listed value (**nearest 500 meters**) and the exact direction of fire (**0395**) expressed to the nearest listed value (nearest 200 mils). The value extracted is for 0 degrees latitude and must be multiplied by a correction factor for latitudes other than 0. At the bottom of Table H are the correction factors for latitudes other than 0. (See figure 11-22, page 11-35.)
11b	Record the correction for range (**-7**) and the correction factor for the change in latitude (0.77) on the line titled "ROTATION" in the MET RANGE CORRECTION section. Record it as follows: **-7 x 0.87**. (See figure 11-23, page 11-36.)
	Note: Azimuth to target equals direction of fire. If the direction of fire, when expressed to the nearest mil, falls exactly between two listed values, use the correction for the higher listed value. This applies to Tables H and Table I.
11c	Cross out the appropriate column (PLUS or MINUS), and multiply the correction to range by the correction factor for the change in latitude. Record the result to the nearest tenth.
12	Determine the met range correction.
12a	Once all the multiplication is complete, total the PLUS column and total the MINUS column. (See figure 11-23, page 11-36.)
12b	Subtract the smaller column from the larger column. Express the sum to the nearest 1 meter, and record it out to the side of the MET RANGE CORRECTION block with appropriate sign. (See figure 11-23, page 11-36.)
13	Determine the ∆V range correction.
13a	Record the met range correction in the MET RANGE CORRECTION block in the COMPUTATION OF VE section. (See figure 11-23, page 11-36.)
13b	Algebraically subtract the met range correction from the total range correction to determine the ∆V range correction. (See figure 11-23, page 11-36.) **TOTAL RANGE CORRECTION +240** **- MET RANGE CORRECTION +21** **∆V RANGE CORRECTION +219**
	Note: The following is an explanation of step 14. The total range correction from the registration represents the correction for all nonstandard conditions affecting range. The met range correction represents the correction due to measurable nonstandard conditions that occur after the projectile leaves the tube. The ∆V range correction represents what is left and is determined by algebraically subtracting the met range correction from the total range correction. The symbol ∆V represents the total variation from the standard muzzle velocity. The ∆V range correction represents the magnitude of the correction, in meters, required to offset the variation in muzzle velocity. Because MV is measured in meters per second, the ∆V range correction must be converted from meters to meters per second.
	To accomplish the conversion, divide the ∆V range correction by the appropriate muzzle velocity unit conversion factor extracted from Table F. Determining which factor to use requires a complete understanding of the ∆V range correction.

Table 11-4. Solution of a Concurrent Met (continued).

STEP	***ACTION***
13b	Note: A positive ∆V range correction that shows an increase in range is needed. It follows that the velocity developed was not enough to achieve the range desired. Therefore, the MV was less than standard, or a decrease. Because the velocity was a decrease value, the decrease unit factor is used. The unit correction factor indicates the correction in meters necessary for each 1 meter-per-second **decrease** from the standard. When the MV decreases from standard, a plus range correction is needed. When the MV increases from standard, a minus range correction is needed.
14	Determine the ∆V.
14a	Divide the ∆V range correction (**+219**) by the MV unit correction (**+26.6**). If the ∆V range correction is a minus, use the increase factor. If the ∆V range correction is a plus, use the decrease factor. (See figure 11-23, page 11-36.) **∆V RANGE CORRECTION +219** **÷ MV UNIT CORRECTION +26.6** **∆V -8.2 (expressed to the nearest 0.1)**
14b	The ∆V will be expressed to the nearest 0.1 and **will have the sign opposite the MV unit correction**. Record the result in the ∆V block and the VARIATION FROM STANDARD column in the MET FUZE CORRECTION section.
	Note: The following is an explanation of step 15. ∆V is made up of propellant temperature effect, which can be measured; muzzle velocity variation, which can be measured; and the position VE, which is due to elements that cannot be easily measured (chart, material, survey errors, and so on). Since the total (∆V) is known and a part due to propellant temperature is known, the remaining part (VE) can be determined by algebraically subtracting the change to MV for propellant temperature from the ∆V. (See figure 11-23, page 11-36.) For further discussion, see TFT 155 AM-3 or any TFT (not addendums) Part I, Introduction, Sample Met Problem.
15	Determine the velocity error.
	Algebraically subtract the change to MV for propellant temperature (**+0.6**) from the ∆V (**-8.2**) (See figure 11-23, page 11-36.) **∆V -8.2** **- CHANGE TO MV FOR PROP TEMP -(+0.6)** **VE -8.8**
16	Determine the position VE.
	The position VE is determined by algebraically subtracting the value of the MVV (**-7.7**) from the VE (**-8.8**). Once the position VE is determined, circle it. (See figure 11-23, page 11-36.) **VE -8.8** **- MVV -7.7** **POS VE -1.1**
	Note: The position VE is what is left after stripping the MVV from the VE. It is an error that remains constant. The position VE is a constant for the projectile family.
17	Determine corrections for azimuth to compensate for rotation of the earth from Table I.
17a	Select the appropriate Table I on the basis of latitude (**30°N**).
17b	Enter with the entry range (**5100**) to the nearest listed value (**nearest 500 meters**) and the exact direction of fire (**0395**) expressed to the nearest listed value (nearest 400 mils **[0400]**). For northern latitudes, enter the table from the top. For southern latitudes, enter the table from the bottom. (See figure 11-24, page 11-37.)
17c	Extract the proper correction (**L0.6**), and record it in the ROTATION CORR block in the WIND COMPONENTS AND DEFLECTION section. (See figure 11-23, page 11-36.)
18	Determine the met deflection correction.

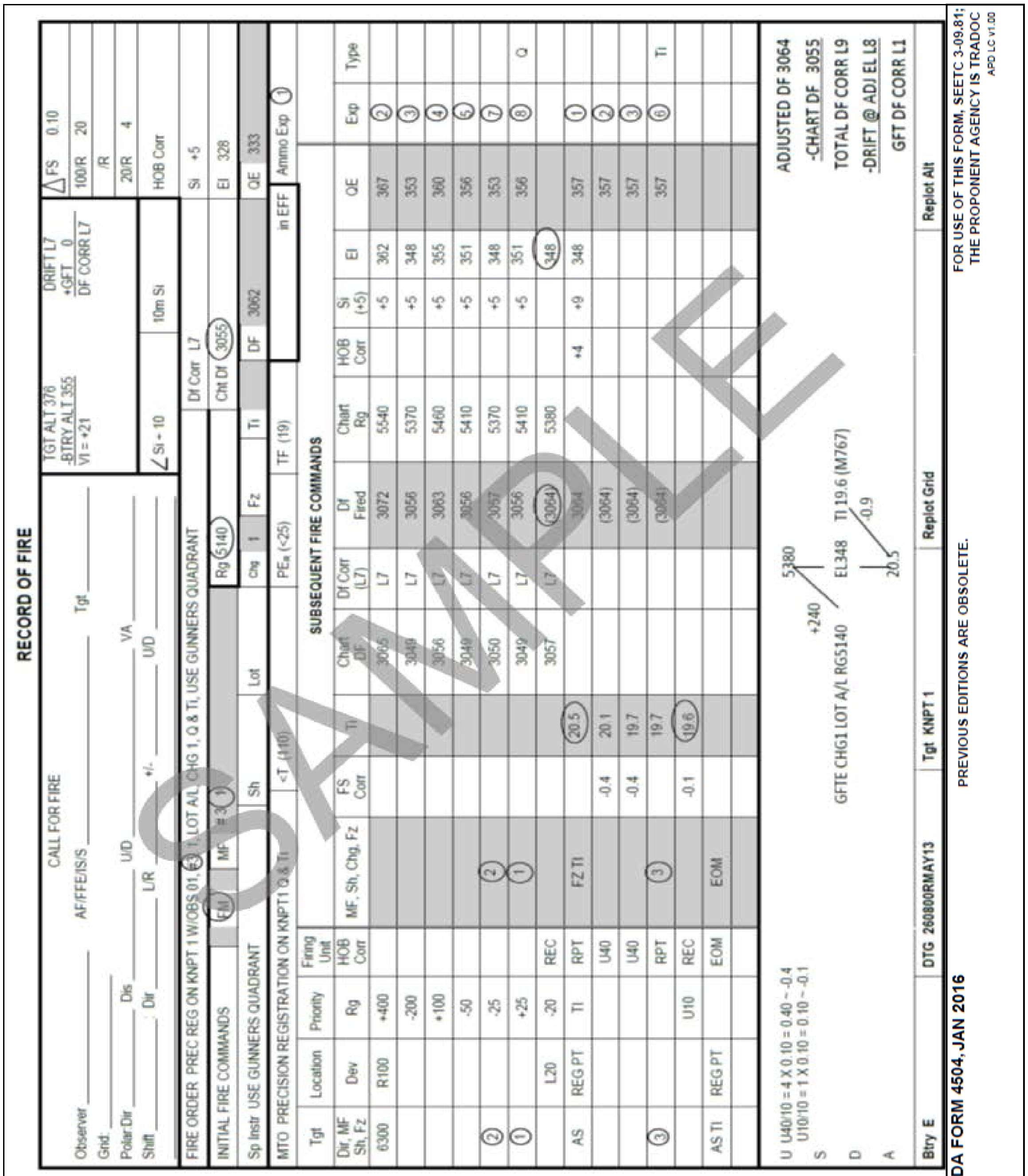
Table 11-4. Solution of a Concurrent Met (continued).

STEP	***ACTION***
18	Algebraically add the values for rotation, drift and crosswind. Express the result to the nearest 1 mil, and record it to the right of the MET DEFL CORR block as a left (L) or a right I. (See figure 11-23, page 11-36.) **ROTATION CORRECTION L0.6** **+DRIFT CORRECTION L7.3** **+CROSSWIND CORRECTION L2.6** **MET DEFLECTION CORR L10.5 ≈ L10**
	Note: This value represents that part of the total deflection correction cause by measurable nonstandard conditions.
19	Determine position deflection correction.
	Record the met deflection correction in the equation for deflection, and algebraically subtract the met deflection correction from the total deflection correction, applying the correct sign. Once the position deflection correction is determined, circle it. (See figure 11-23, page 11-36.) **TOTAL DF CORR L9** **- MET DF CORR L10** **POS DF CORR R1**
	Note: This value represents the position deflection correction, the part of the total deflection correction due to immeasurable nonstandard conditions.
20	Determine from Table J the unit corrections for fuze.
20a	Enter Table J with the fuze setting corresponding to the adjusted elevation (**20.5**) expressed to the nearest whole fuze setting increment (**20**). (See figure 11-25, page 11-38.)
20b	Extract the correction for ∆V from Column 2 for a decrease or from Column 3 for an increase (**-0.054**). (Record all unit corrections to the nearest thousandths as shown in figure 11-26, page 11-39.)
20c	Extract the correction for range wind from Column 4 for a head wind or Column 5 for a tail wind (**-0.009**).
20d	Extract the correction for air temperature from Column 6 for a decrease or Column 7 for an increase (**+0.008**).
20e	Extract the correction for air density from Column 8 for a decrease or Column 9 for an increase (**+0.008**).
20f	Extract the correction for projectile weight from Column 10 for a decrease or Column 11 for an increase (**+0.071**).
20g	Next to the UNIT CORRECTIONS column there are two columns—a PLUS column and a MINUS column. If the correction is a plus, cross out the minus block. If the correction is a minus, cross out the plus block. (See figure 11-26, page 11-39.)
21	Determine the met fuze correction.
21a	Multiply the variations from standard by unit corrections, and record the results to the nearest thousandths (0.001) in the boxes that are not crossed out. (See figure 11-26, page 11-39.)
21b	Total the PLUS column, and total the MINUS column. Subtract the smaller column from the larger column. Express the sum to the nearest 0.1, and record it in the MET FUZE CORRECTION block with the appropriate sign. (See figure 11-26, page 11-39.)

Table 11-4. Solution of a Concurrent Met (continued).

STEP	*ACTION*
22	Determine the position fuze correction. Algebraically subtract the met fuze correction (**-0.4**) from the total fuze correction (**-0.9**). The result is the position fuze correction (**-0.5**). Circle the position fuze correction. (See figure 11-26, page 11-39.) **TOTAL FUZE CORRECTION -0.9** **- MET FUZE CORRECTION -0.4** **POSITION FUZE CORRECTION -0.5**
	Note: The completed DA Form 4200 containing the concurrent met is show in figure 11-26, page 11-39.

Legend: ALT – altitude ADJ – adjusted BTRY – battery CM – computer met COMP – complementary CORR – correction DEC – decrease DF – deflection EL – elevation FS – fuze setting INC – increase KN PT – known point L – left LARS – left add right subtract MDP – meteorological datum plane MV – muzzle velocity MVV – muzzle velocity variation NO – number QE – quadrant elevation POS – position PROP – propellant R – right RALS – right add left subtract RG – range ROF – record of fire STD – standard TEMP – temperature TFT – tabular firing table TOT – total VI – vertical interval VE – velocity error



RECORD OF FIRE

CALL FOR FIRE		
Observer ____ AF/FFE/IS/S ____ Tgt ____	TGT ALT 376 -BTRY ALT 355 VI = +21	DRIFT L7 +GFT 0 DF CORR L7
Grid: ____		
Polar:Dir ____ Dis ____ U/D ____ VA ____		
Shift ____ Dir ____ L/R ____ +/- ____ U/D ____	∠ Si - 10	10m Si

△FS	0.10
100/R	20
/R	
20/R	4
HOB Corr	
Si	+5
El	328
QE	333

FIRE ORDER PREC REG ON KNPT 1 W/OBS 01, (E3) 1, LOT A/L, CHG 1, Q & Ti, USE GUNNERS QUADRANT — Df Corr L7

INITIAL FIRE COMMANDS (FM) MF #3 (1) — Rg (5140) — Cht Df (3055)

Sp Instr USE GUNNERS QUADRANT — Sh — Lot — Chg 1 — Fz — Ti — DF 3062

MTO PRECISION REGISTRATION ON KNPT1 Q & Ti — <T (110) — PE$_R$ (<25) — TF (19) — in EFF — Ammo Exp (1)

SUBSEQUENT FIRE COMMANDS

Tgt Dir, MF Sh, Fz	Location Dev	Priority Rg	Firing Unit HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart Df	Df Corr (L7)	Df Fired	Chart Rg	HOB Corr	Si (+5)	El	QE	Exp	Type
6300	R100	+400					3065	L7	3072	5540		+5	362	367	(2)	
		-200					3049	L7	3056	5370		+5	348	353	(3)	
		+100					3056	L7	3063	5460		+5	355	360	(4)	
		-50					3049	L7	3056	5410		+5	351	356	(5)	
(2)		-25		(2)			3050	L7	3057	5370		+5	348	353	(7)	
(1)		+25		(1)			3049	L7	3056	5410		+5	351	356	(8)	Q
	L20	-20	REC				3057	L7	(3064)	5380			(348)			
AS	REG PT	TI	RPT	FZ TI		(20.5)			3064		+4	+9	348	357	(1)	
			U40		-0.4	20.1			(3064)					357	(2)	
			U40		-0.4	19.7			(3064)					357	(3)	
(3)			RPT	(3)		19.7			(3064)					357	(6)	Ti
		U10	REC		-0.1	(19.6)										
AS TI	REG PT		EOM	EOM												

U U40/10 = 4 X 0.10 = 0.40 ~ -0.4
U10/10 = 1 X 0.10 = 0.10 ~ -0.1
S
D
A

GFTE CHG1 LOT A/L RG5140 — 5380 — +240 — EL348 — TI 19.6 (M767) — -0.9 — 20.5

ADJUSTED DF 3064
-CHART DF 3055
TOTAL DF CORR L9
-DRIFT @ ADJ EL L8
GFT DF CORR L1

Btry E	DTG 260800RMAY13	Tgt KNPT 1	Replot Grid	Replot Alt

DA FORM 4504, JAN 2016 — PREVIOUS EDITIONS ARE OBSOLETE. — FOR USE OF THIS FORM, SEETC 3-09.81; THE PROPONENT AGENCY IS TRADOC — APD LC v1.00

SAMPLE

Legend:
ADJ – adjusted
AF – adjust fire
ALT – altitude
APP – applied
BTRY – battery
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HA – high angle
HOB – height of burst
I/E – in effect
IS – immediate suppression
KN PT – known point
L/R – left/right
LAT – lateral
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
PREC – precision
PT – point
Q – quick
QE – quadrant elevation
REC – record
REG – registration
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 11-10. Completed ROF for a Precision Registration.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA

CHARGE	ADJ QE	CHART RG	LATITUDE
1L		5140	30° N

ALT OF BTRY (10m) (355)	360
ALT OF MDP	550
BTRY ABOVE / BELOW MDP (Δh)	-190
ALT OF TARGET (nearest meter)	376
HEIGHT OF BURST ABOVE TARGET	
ALT OF BURST	376
ALT OF BTRY (nearest meter)	
HEIGHT OF TARGET (burst) ABOVE GUN (M)	

MET MESSAGE

TYPE MESSAGE	OCTANT		AREA/UNIT	
DATE	TIME		ALT MDP	PRESSURE
LINE NO.	WIND DIR.	WIND SPEED	AIR TEMP	AIR DENSITY
Δh CORRECTION			+ / -	+ / -
CORRECTED VALUES				
COMP RG		CHART RG 5140	ENTRY RG	

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400
DIRECTION OF WIND	
DIRECTION OF FIRE (0395)	0400
CHART DIRECTION OF WIND	

TOT DF CORR L9
-MET DF CORR
POS DF CORR

ROTATION CORR L R
DRIFT CORR L
CROSS WIND — WIND SPEED ____ X COMP L R ____ L R ____ KNOTS = ____ UNIT CORR ____ CROSSWIND CORR L R
RANGE WIND — WIND SPEED ____ X COMP T H ____ TAIL HEAD ____ KNOTS — MET DEFL CORR L R

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T H	0	T H			
AIR TEMP		100%	D I			
AIR DENSITY		100%	D I			
PROJ WEIGHT		4□	D I			
ROTATION						

VE – MVV = POS VE
– -7.7 =

MET RANGE CORR

COMPUTATION OF VE

PROP TEMP +82 °F	VE	M/S	TOTAL RANGE CORRECTION	+240
	CHANGE TO MV FOR PROP TEMP	M/S	MET RANGE CORRECTION	
	ΔV	M/S — MV UNIT CORRECTION	ΔV RANGE CORRECTION	
			TOTAL RANGE CORRECTION	

OLD VE ____ + NEW VE ____ = ____ ÷ 2 = AVG VE ____ ____ M/S

FS @ ADJ EL = 20.5 ~ 20

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
ΔV	D I			
RANGE WIND	T H			
AIR TEMP	D I			
AIR DENSITY	D I			
PROJ WEIGHT	D I			

Fuze setting diagram: 5380, +240, 5140, 348, 19.6, -0.9, 20.5

TOTAL FUZE CORRECTION	-0.9
MET FUZE CORRECTION	
FUZE CORRECTION	
TOTAL FUZE CORRECTION	

TARGET NO KNPT 1 | BATTERY A | DATE/TIME 270800RMAY13

DA FORM 4200, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-11. DA Form 4200 Containing Known Data.

CHARGE 1L | TABLE B | FT 155-AM-3

COMPLEMENTARY RANGE LINE NUMBER

PROJ, HE, M107
FUZE, PD, M739A1

CHANGE IN RANGE, IN METERS TO CORRECT FOR COMPLEMENTARY ANGLE OF SITE

LINE NUMBERS OF METEOROLOGICAL MESSAGE

LINE NO.	RANGE METERS	HEIGHT OF TARGET ABOVE GUN - METERS -400	-300	-200	-100	0	100	200	300
	3500	-61	-47	-32	-16	0	17	35	54
0	3600	-64	-49	-33	-17	0	18	37	56
	3700	-66	-50	-34	-18	0	19	38	58
	3800	-68	-52	-36	-18	0	19	39	60
	3900	-70	-54	-37	-19	0	20	40	62
	4000	-73	-56	-38	-19	0	20	42	64
	4100	-75	-58	-39	-20	0	21	43	65
	4200	-77	-59	-40	-21	0	22	44	67
	4300	-80	-61	-42	-21	0	22	45	69
	4400	-82	-63	-43	-22	0	23	47	72
	4500	-85	-65	-44	-22	0	24	48	74
1	4600	-87	-67	-45	-23	0	24	50	76
	4700	-90	-69	-47	-24	0	25	51	78
	4800	-93	-71	-48	-24	0	26	52	80
	4900	-95	-73	-49	-25	0	27	54	82
	5000	-98	-75	-51	-26	0	27	55	85
	5100	-101	-77	-52	-27	0	28	57	87
	5200	-103	-79	-54	-27	0	29	59	90
	5300	-106	-81	-55	-28	0	30	60	92
	5400	-109	-84	-57	-29	0	30	62	95
	5500	-112	-86	-58	-30	0	31	64	98
	5600	-115	-88	-60	-30	0	32	66	101
	5700	-118	-91	-62	-31	0	33	67	104
	5800	-122	-93	-63	-32	0	34	69	107
	5900	-125	-96	-65	-33	0	35	72	110
	6000	-129	-98	-67	-34	0	36	74	113
2	6100	-132	-101	-69	-35	0	37	76	117
	6200	-136	-104	-71	-36	0	38	78	120
	6300	-140	-107	-73	-37	0	39	81	124
	6400	-144	-110	-75	-38	0	41	83	128
	6500	-148	-114	-78	-40	0	42	86	132
	6600	-153	-117	-80	-41	0	43	88	136
	6700	-157	-121	-82	-42	0	45	91	141
	6800	-162	-124	-85	-43	0	46	95	146
	6900	-167	-128	-88	-45	0	48	98	151
3	7000	-172	-132	-90	-46	0	49	102	157
			3						4

FT 155-AM-3 | TABLE B | CHARGE 1L

PROJ, HE, M107
FUZE, PD, M739A1

COMPLEMENTARY RANGE LINE NUMBER

CHANGE IN RANGE, IN METERS TO CORRECT FOR COMPLEMENTARY ANGLE OF SITE

LINE NUMBERS OF METEOROLOGICAL MESSAGE

HEIGHT OF TARGET ABOVE GUN - METERS 400	500	600	700	800	900	1000	RANGE METERS	LINE NO.
74	94	116	138	161	186	211	3500	
76	98	120	143	167	192	218	3600	
79	101	123	147	172	198	225	3700	
81	104	127	152	177	204	232	3800	
84	107	131	156	183	210	239	3900	
86	110	135	161	188	217	246	4000	
89	114	139	166	194	223	254	4100	3
92	117	144	171	200	230	262	4200	
95	121	148	176	206	237	270	4300	
97	124	152	182	212	244	278	4400	
100	128	157	187	219	252	286	4500	
103	132	161	192	225	259	295	4600	
106	135	166	198	232	267	303	4700	
109	139	171	204	238	275	313	4800	
112	143	176	210	245	283	322	4900	
115	147	181	216	253	291	332	5000	
119	152	186	222	260	300	342	5100	
122	156	192	229	268	309	352	5200	
126	161	197	236	276	319	363	5300	
129	166	203	243	285	328	374	5400	
133	170	209	250	293	339	386	5500	
137	176	216	258	302	349	399	5600	
141	181	222	266	312	360	412	5700	
145	186	229	274	322	372	425	5800	
150	192	236	283	332	384	440	5900	
154	198	244	292	343	397	455	6000	4
159	204	251	301	354	411	471	6100	
164	211	260	311	367	426	489	6200	
169	217	268	322	380	442	508	6300	
175	225	277	334	394	459	530	6400	
181	232	287	346	409	478	553	6500	
187	241	298	360	426	499	580	6600	5
193	250	310	374	445	524	612	6700	
201	259	322	391	467	552	652	6800	
208	270	337	410	493	588	706	6900	
217	282	353	433	524	637		7000	
	4					5		

Figure 11-12. Table B.

COMPUTER MET MESSAGE

For use of this form, see TC 3-09.81 the proponent agency is TRADOC.

IDENTIFICATION	OCTANT	LOCATION		DATE	TIME (GMT)	DURATION (HOURS)	STATION HEIGHT (10's M)	MDP PRESSURE MB
		$L_a L_a L_a$ or	$L_o L_o L_o$ or					
METCM	Q	XXX	XXX	YY	$G_o G_o G_o$	G	hhh	$P_d P_d P_d$
METCM	1	347	985	27	125	0	055	977

ZONE HEIGHT (METERS)	LINE NUMBER	ZONE VALUES			
		WIND DIRECTION (10's M)	WIND SPEED (KNOTS)	TEMPERATURE (1/10°K)	PREASURE MILLIBARS)
	ZZ	ddd	FFF	TTTT	PPPP
SURFACE	00	583	016	2911	0977
200	01	584	016	2904	0967
500	02	592	017	2882	0939
1000	03	601	025	2844	0893
1500	04	600	021	2806	0840
2000	05				
2500	06				
3000	07				
3500	08				
4000	09				
4500	10				
5000	11				
6000	12				
7000	13				
8000	14				
9000	15				
10000	16				
11000	17				
12000	18				
13000	19				
14000	20				
15000	21				
16000	22				
17000	23				
18000	24				
19000	25				
20000	26				

FROM B BTRY 1-30th FA TO: A BBRTY 1-30th FA	DATE AND TIME (GMT) 271230JUL13	DATE AND TIME (LST) 271230JUL13
MESSAGE NUMBER 1307-04	RECORDER RB	CHECKED RB

DA FORM 3677, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend: BTRY – battery FA – field artillery GMT – Greenwich Mean Time LST – local standard time MB – millibars MDP – meteorological datum plane

Figure 11-13. Computer Met Message Valid at the Time of the Registration.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA

CHARGE	ADJ QE	CHART RG	LATITUDE
1L		5140	30° N

ALT OF BTRY (10m) (355)	360
ALT OF MDP	550
BTRY ABOVE / (BELOW) MDP (Δh)	-190
ALT OF TARGET (nearest meter)	376
HEIGHT OF BURST ABOVE TARGET	
ALT OF BURST	376
ALT OF BTRY (nearest meter)	355
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+21 ~ 0

MET MESSAGE

TYPE MESSAGE	OCTANT		AREA/UNIT	
METCM	1		347 985	
DATE	TIME		ALT MDP	PRESSURE
27	1230		550	977
LINE NO.	WIND DIR.	WIND SPEED	AIR TEMP	AIR DENSITY
02	5920	17	100.8	95.8

Δh CORRECTION + - | + -

CORRECTED VALUES

288.2 / 285.9 x 100% ≈100.8% | 939 x 0.34836764 / 288.2 = 1.1350 | 1.1350 / 1.1844 x 100% ≈ 95.8%

COMP RG | CHART RG 5140 | ENTRY RG

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400
DIRECTION OF WIND (5920)	5900
DIRECTION OF FIRE (0395)	0400
CHART DIRECTION OF WIND	5500

TOT DF CORR L9
-MET DF CORR
POS DF CORR

CROSS WIND: WIND SPEED 17 X COMP L/R ____ = L/R ____ KNOTS ÷ ____ UNIT CORR = ____

RANGE WIND: WIND SPEED 17 X COMP T/H ____ = TAIL/HEAD ____ KNOTS

ROTATION CORR L R | DRIFT CORR L | CROSSWIND CORR L R | MET DEFL CORR L R

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T H	0	T H			
AIR TEMP		100%	D I			
AIR DENSITY		100%	D I			
PROJ WEIGHT		4▯	D I			
ROTATION						

VE – MVV = POS VE
– -7.7 =

MET RANGE CORR

COMPUTATION OF VE

PROP TEMP				
+82 °F	VE	M/S	TOTAL RANGE CORRECTION	+240
	CHANGE TO MV FOR PROP TEMP	M/S	MET RANGE CORRECTION	
	ΔV	M/S · MV UNIT CORRECTION	ΔV RANGE CORRECTION	
			TOTAL RANGE CORRECTION	

OLD VE ____ + NEW VE ____ = ____ ÷ 2 = AVG VE ____ M/S

FS @ ADJ EL = 20.5 ~ 20

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
ΔV	D I			
RANGE WIND	T H			
AIR TEMP	D I			
AIR DENSITY	D I			
PROJ WEIGHT	D I			

5380, +240, 5140, 348, 19.6, -0.9, 20.5

TOTAL FUZE CORRECTION	-0.9
MET FUZE CORRECTION	
FUZE CORRECTION	
TOTAL FUZE CORRECTION	

TARGET NO KNPT 1 | BATTERY A | DATE/TIME 270800RMAY13

DA FORM 4200, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-14. DA Form 4200 With Met Message Data Recorded.

CHARGE 1L | TABLE C | FT 155-AM-3

WIND COMPONENTS | PROJ, HE, M107 FUZE, PD, M739A1

COMPONENTS OF A ONE KNOT WIND

CHART DIRECTION OF WIND MIL	CROSS WIND KNOT	RANGE WIND KNOT	CHART DIRECTION OF WIND MIL	CROSS WIND KNOT	RANGE WIND KNOT
0	0	H1.00	3200	0	T1.00
100	R.10	H.99	3300	L.10	T.99
200	R.20	H.98	3400	L.20	T.98
300	R.29	H.96	3500	L.29	T.96
400	R.38	H.92	3600	L.38	T.92
500	R.47	H.88	3700	L.47	T.88
600	R.56	H.83	3800	L.56	T.83
700	R.63	H.77	3900	L.63	T.77
800	R.71	H.71	4000	L.71	T.71
900	R.77	H.63	4100	L.77	T.63
1000	R.83	H.56	4200	L.83	T.56
1100	R.88	H.47	4300	L.88	T.47
1200	R.92	H.38	4400	L.92	T.38
1300	R.96	H.29	4500	L.96	T.29
1400	R.98	H.20	4600	L.98	T.20
1500	R.99	H.10	4700	L.99	T.10
1600	R1.00	0	4800	L1.00	0
1700	R.99	T.10	4900	L.99	H.10
1800	R.98	T.20	5000	L.98	H.20
1900	R.96	T.29	5100	L.96	H.29
2000	R.92	T.38	5200	L.92	H.38
2100	R.88	T.47	5300	L.88	H.47
2200	R.83	T.56	5400	L.83	H.56
2300	R.77	T.63	5500	L.77	H.63
2400	R.71	T.71	5600	L.71	H.71
2500	R.63	T.77	5700	L.63	H.77
2600	R.56	T.83	5800	L.56	H.83
2700	R.47	T.88	5900	L.47	H.88
2800	R.38	T.92	6000	L.38	H.92
2900	R.29	T.96	6100	L.29	H.96
3000	R.20	T.98	6200	L.20	H.98
3100	R.10	T.99	6300	L.10	H.99
3200	0	T1.00	6400	0	H1.00

Figure 11-15. Table C.

FT 155-AM-3 | TABLE D | CHARGE 1L

PROJ, HE, M107 FUZE, PD, M739A1

TEMPERATURE AND DENSITY CORRECTIONS

CORRECTIONS TO TEMPERATURE (DT) AND DENSITY (DD), IN PERCENT, TO COMPENSATE FOR THE DIFFERENCE IN ALTITUDE, IN METERS, BETWEEN THE BATTERY AND THE MDP

DH		0	+10-	+20-	+30-	+40-	+50-	+60-	+70-	+80-	+90-
0	DT	0.0	0.0	0.0	-0.1+	-0.1+	-0.1+	-0.1+	-0.2+	-0.2+	-0.2+
	DD	0.0	-0.1+	-0.2+	-0.3+	-0.4+	-0.5+	-0.6+	-0.7+	-0.8+	-0.9+
+100-	DT	-0.2+	-0.2+	-0.2+	-0.3+	-0.3+	-0.3+	-0.3+	-0.4+	-0.4+	-0.4+
	DD	-1.0+	-1.1+	-1.2+	-1.3+	-1.4+	-1.5+	-1.6+	-1.7+	-1.8+	-1.9+
+200-	DT	-0.5+	-0.5+	-0.5+	-0.6+	-0.6+	-0.6+	-0.6+	-0.7+	-0.7+	-0.7+
	DD	-2.0+	-2.1+	-2.2+	-2.3+	-2.4+	-2.5+	-2.6+	-2.7+	-2.8+	-2.9+
+300-	DT	-0.7+	-0.7+	-0.7+	-0.8+	-0.8+	-0.8+	-0.8+	-0.9+	-0.9+	-0.9+
	DD	-3.0+	-3.1+	-3.2+	-3.3+	-3.4+	-3.5+	-3.6+	-3.7+	-3.8+	-3.9+

NOTES - 1. DH IS BATTERY HEIGHT ABOVE OR BELOW THE MDP.
2. IF ABOVE THE MDP, USE THE SIGN BEFORE THE NUMBER.
3. IF BELOW THE MDP, USE THE SIGN AFTER THE NUMBER.

Figure 11-16. Table D.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE			
CHARGE 1L	ADJ QE	CHART RG 5140	LATITUDE 30° N	TYPE MESSAGE METCM	OCTANT 1	AREA/UNIT 347 985	
ALT OF BTRY (10m) (355)		360		DATE 27 / TIME 1230		ALT MDP 550	PRESSURE 977
ALT OF MDP		550		LINE NO. 02 / WIND DIR. 5920	WIND SPEED 17	AIR TEMP 100.8	AIR DENSITY 95.8
BTRY ABOVE (BELOW) MDP (Δh)		-190		Δh CORRECTION		(+) 0.4	(+) 1.9
ALT OF TARGET (nearest meter)		376		CORRECTED VALUES		101.2	97.7
HEIGHT OF BURST ABOVE TARGET				288.2 / 285.9 x 100% ≈100.8%	939 x 0.34836764 / 288.2 = 1.1350	1.1350 / 1.1844 x 100% ≈ 95.8%	
ALT OF BURST		376					
ALT OF BTRY (nearest meter)		355					
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+21 ~ 0		COMP RG 0	CHART RG 5140	ENTRY RG 5140~	5100

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	TOT DF CORR L9 -MET DF CORR POS DF CORR	
DIRECTION OF WIND (5920)	5900		
DIRECTION OF FIRE (0395)	0400		ROTATION CORR L R
CHART DIRECTION OF WIND	5500		DRIFT CORR L
CROSS WIND — WIND SPEED 17 X COMP (L) R 0.77		(L) R 13 KNOTS = ___ UNIT CORR	CROSSWIND CORR L R
RANGE WIND — WIND SPEED 17 X COMP T (H) 0.63		TAIL (HEAD) 11 KNOTS	MET DEFL CORR L R

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T (H) 11	0	T (H) 11			
AIR TEMP	101.2	100%	I (D) 1.2			
AIR DENSITY	97.7	100%	I (D) 2.3			
PROJ WEIGHT	3▯	4▯	I (D) 1▯			
ROTATION						
VE – MVV = POS VE – -7.7 =				MET RANGE CORR		

COMPUTATION OF VE

PROP TEMP +82 °F	VE	M/S		TOTAL RANGE CORRECTION +240
	CHANGE TO MV FOR PROP TEMP	+0.6 M/S		MET RANGE CORRECTION
	ΔV	M/S	MV UNIT CORRECTION	ΔV RANGE CORRECTION
				TOTAL RANGE CORRECTION

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ ______ M/S

FS @ ADJ EL = 20.5 ~ 20

MET FUZE CORRECTION

ΔV	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
	D I			
RANGE WIND	T (H) 11			
AIR TEMP	I (D) 1.2			
AIR DENSITY	I (D) 2.3			
PROJ WEIGHT	I (D) 1▯			

+240 5380
5140 348 19.6
-0.9
20.5

TOTAL FUZE CORRECTION	-0.9
MET FUZE CORRECTION	
FUZE CORRECTION	
TOTAL FUZE CORRECTION	

TARGET NO KNPT 1 | BATTERY A | DATE/TIME 270800RMAY13

DA FORM 4200, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-17. DA Form 4200 With Tables A Through E Completed.

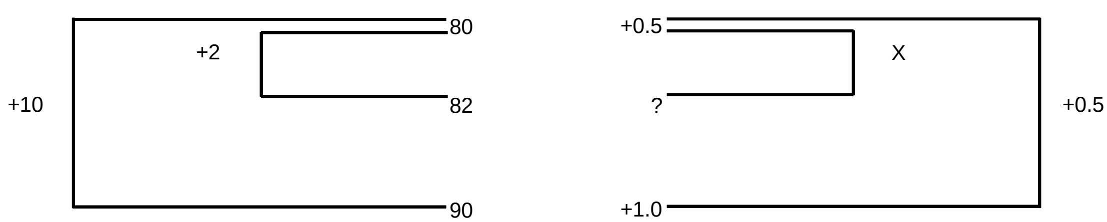
TABLE E

PROPELLANT TEMPERATURE

EFFECTS ON MUZZLE VELOCITY DUE TO PROPELLANT TEMPERATURE

TEMPERATURE OF PROPELLANT DEGREES F	EFFECT ON VELOCITY M/S	TEMPERATURE OF PROPELLANT DEGREES C
-40	-6.8	-40.0
-30	-6.0	-34.4
-20	-5.2	-28.9
-10	-4.5	-23.3
0	-3.8	-17.8
10	-3.2	-12.2
20	-2.6	-6.7
30	-2.0	-1.1
40	-1.5	4.4
50	-1.0	10.0
60	-0.5	15.6
70	0.0	21.1
80	0.5	26.7
90	1.0	32.2
100	1.4	37.8
110	1.9	43.3
120	2.4	48.9
130	3.0	54.4

Figure 11-18. Table E.



CROSS MULTIPLY $\frac{+2}{+10} = \frac{X}{+0.5}$

10X = 2(+0.5) $X = \frac{+2(+0.5)}{+10} = +0.1$

EFFECT ON VELOCITY AT 80°F	**+0.5**
ALGEBRAICALLY ADD THE VALUE OF X	**+(+0.1)**
CHANGE TO MV FOR PROP TEMP	**+0.6**

Legend: MV – muzzle velocity PROP – propellant TEMP - temperature

Figure 11-19. Interpolation.

CHARGE 1L — TABLE F — BASIC DATA — FT 155-AM-3 — PROJ, HE, M107 FUZE, PD, M739A1

1	2	3	4	5	6	7	8	9
RANGE	ELEV	FS FOR GRAZE BURST FUZE M582	DFS PER 10 M DEC HOB	DR PER 1 MIL D ELEV	FORK	TIME OF FLIGHT	AZIMUTH CORRECTIONS DRIFT (CORR TO L)	AZIMUTH CORRECTIONS CW OF 1 KNOT
M	MIL			M	MIL	SEC	MIL	MIL
3500	205.1	12.4	0.17	15	3	12.4	4.2	0.14
3600	211.9	12.8	0.16	15	3	12.8	4.4	0.14
3700	218.7	13.2	0.16	14	3	13.2	4.6	0.14
3800	225.7	13.6	0.15	14	3	13.6	4.8	0.15
3900	232.7	14.0	0.15	14	4	14.0	4.9	0.15
4000	239.8	14.4	0.15	14	4	14.4	5.1	0.15
4100	247.0	14.8	0.14	14	4	14.8	5.3	0.16
4200	254.3	15.2	0.14	14	4	15.2	5.5	0.16
4300	261.7	15.6	0.13	13	4	15.6	5.7	0.17
4400	269.2	16.1	0.13	13	4	16.1	5.9	0.17
4500	276.7	16.5	0.13	13	5	16.5	6.0	0.17
4600	284.4	16.9	0.12	13	5	16.9	6.3	0.18
4700	292.2	17.4	0.12	13	5	17.4	6.5	0.18
4800	300.1	17.8	0.12	13	5	17.8	6.7	0.18
4900	308.1	18.3	0.12	12	5	18.3	6.9	0.19
5000	316.2	18.7	0.11	12	6	18.7	7.1	0.19
5100	324.5	19.2	0.11	12	6	19.2	7.3	0.20
5200	332.9	19.6	0.11	12	6	19.6	7.6	0.20
5300	341.4	20.1	0.11	12	6	20.1	7.8	0.20
5400	350.1	20.6	0.10	11	7	20.6	8.0	0.21
5500	359.0	21.1	0.10	11	7	21.1	8.3	0.21
5600	368.0	21.6	0.10	11	7	21.6	8.5	0.22
5700	377.2	22.1	0.10	11	7	22.1	8.8	0.22
5800	386.6	22.6	0.09	11	8	22.6	9.1	0.23
5900	396.3	23.1	0.09	10	8	23.1	9.4	0.23
6000	406.1	23.6	0.09	10	9	23.6	9.7	0.23
6100	416.2	24.1	0.09	10	9	24.1	10.0	0.24
6200	426.6	24.7	0.09	10	9	24.7	10.3	0.24
6300	437.3	25.2	0.08	9	10	25.2	10.6	0.25
6400	448.3	25.8	0.08	9	10	25.8	10.9	0.25
6500	459.6	26.4	0.08	9	11	26.4	11.3	0.26
6600	471.3	27.0	0.08	8	12	27.0	11.7	0.26
6700	483.5	27.6	0.08	8	12	27.6	12.1	0.27
6800	496.2	28.3	0.08	8	13	28.3	12.5	0.27
6900	509.4	29.0	0.07	7	14	29.0	12.9	0.28
7000	523.2	29.6	0.07	7	15	29.6	13.4	0.29

FT 155-AM-3 — TABLE F — CHARGE 1L — PROJ, HE, M107 FUZE, PD, M739A1 — CORRECTION FACTORS

1	10	11	12	13	14	15	16	17	18	19
RANGE	RANGE CORRECTIONS FOR									
	MUZZLE VELOCITY 1 M/S		RANGE WIND 1 KNOT		AIR TEMP 1 PCT		AIR DENSITY 1 PCT		PROJ WT OF 1 SQ (4 SQ STD)	
	DEC	INC	HEAD	TAIL	DEC	INC	DEC	INC	DEC	INC
M	M	M	M	M	M	M	M	M	M	M
3500	18.9	-15.2	4.5	-1.7	8.9	-3.1	-3.2	3.2	-22	25
3600	19.4	-15.6	4.6	-1.8	9.2	-3.2	-3.3	3.3	-23	25
3700	19.9	-16.0	4.8	-1.9	9.4	-3.3	-3.5	3.5	-23	26
3800	20.4	-16.4	4.9	-2.0	9.7	-3.4	-3.7	3.7	-24	26
3900	20.9	-16.8	5.1	-2.0	9.9	-3.5	-3.9	3.9	-24	27
4000	21.3	-17.1	5.3	-2.1	10.2	-3.5	-4.0	4.1	-25	27
4100	21.8	-17.5	5.4	-2.2	10.4	-3.6	-4.2	4.3	-25	28
4200	22.3	-17.9	5.6	-2.3	10.6	-3.7	-4.4	4.4	-26	28
4300	22.8	-18.3	5.7	-2.4	10.9	-3.8	-4.6	4.6	-26	29
4400	23.2	-18.7	5.9	-2.4	11.1	-3.9	-4.8	4.8	-27	29
4500	23.7	-19.0	6.0	-2.5	11.3	-4.0	-5.0	5.1	-27	29
4600	24.2	-19.4	6.2	-2.6	11.5	-4.1	-5.2	5.3	-27	30
4700	24.7	-19.8	6.3	-2.7	11.7	-4.2	-5.4	5.5	-28	30
4800	25.1	-20.2	6.5	-2.8	11.9	-4.2	-5.6	5.7	-28	31
4900	25.6	-20.6	6.6	-2.9	12.1	-4.3	-5.9	5.9	-29	31
5000	26.1	-20.9	6.8	-2.9	12.3	-4.4	-6.1	6.1	-29	32
5100	26.6	-21.3	6.9	-3.0	12.5	-4.4	-6.3	6.4	-29	32
5200	27.0	-21.7	7.1	-3.1	12.7	-4.5	-6.5	6.6	-30	33
5300	27.5	-22.1	7.2	-3.2	12.9	-4.6	-6.8	6.8	-30	33
5400	28.0	-22.5	7.4	-3.3	13.1	-4.6	-7.0	7.1	-31	33
5500	28.5	-22.9	7.5	-3.4	13.2	-4.7	-7.2	7.3	-31	34
5600	29.0	-23.3	7.7	-3.5	13.4	-4.7	-7.5	7.6	-31	34
5700	29.5	-23.6	7.8	-3.6	13.6	-4.8	-7.7	7.8	-32	35
5800	29.9	-24.0	7.9	-3.7	13.7	-4.8	-8.0	8.1	-32	35
5900	30.4	-24.4	8.1	-3.7	13.9	-4.9	-8.2	8.4	-32	36
6000	30.9	-24.8	8.2	-3.8	14.0	-4.9	-8.5	8.6	-33	36
6100	31.4	-25.2	8.3	-3.9	14.1	-4.9	-8.8	8.9	-33	37
6200	31.9	-25.6	8.5	-4.0	14.2	-5.0	-9.0	9.2	-33	37
6300	32.4	-26.0	8.6	-4.1	14.3	-5.0	-9.3	9.5	-34	37
6400	32.9	-26.4	8.7	-4.2	14.4	-5.0	-9.6	9.8	-34	38
6500	33.4	-26.8	8.8	-4.3	14.5	-5.0	-9.9	10.1	-34	38
6600	33.8	-27.2	8.9	-4.4	14.6	-5.1	-10.2	10.4	-35	39
6700	34.3	-27.6	9.0	-4.5	14.6	-5.1	-10.5	10.7	-35	39
6800	34.8	-28.0	9.1	-4.6	14.7	-5.1	-10.8	11.0	-35	39
6900	35.4	-28.5	9.2	-4.7	14.8	-5.1	-11.1	11.3	-36	40
7000	35.9	-28.9	9.3	-4.8	14.8	-5.1	-11.4	11.6	-36	40

Figure 11-20. Table F.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE			
CHARGE 1L	ADJ QE	CHART RG 5140	LATITUDE 30° N	TYPE MESSAGE METCM	OCTANT 1		AREA/UNIT 347 985
ALT OF BTRY (10m) (355)		360		DATE 27	TIME 1230	ALT MDP 550	PRESSURE 977
ALT OF MDP		550		LINE NO. 02	WIND DIR. 5920	WIND SPEED 17	AIR TEMP 100.8 / AIR DENSITY 95.8
BTRY ABOVE (BELOW) MDP (Δh)		-190		Δh CORRECTION		(+) - 0.4	(+) - 1.9
ALT OF TARGET (nearest meter)		376		CORRECTED VALUES		101.2	97.7
HEIGHT OF BURST ABOVE TARGET				288.2 / 285.9 x 100% ≈100.8%	939 x 0.34836764 / 288.2 = 1.1350		1.1350 / 1.1844 x 100% ≈ 95.8%
ALT OF BURST		376					
ALT OF BTRY (nearest meter)		355					
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+21 ~ 0		COMP RG 0	CHART RG 5140	ENTRY RG	5140~ 5100

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	TOT DF CORR L9
DIRECTION OF WIND (5920)	5900	-MET DF CORR
		POS DF CORR
DIRECTION OF FIRE (0395)	0400	ROTATION CORR L R
CHART DIRECTION OF WIND	5500	DRIFT CORR (L) 7.3
CROSS WIND: WIND SPEED 17 X COMP (L) R 0.77	(L) R 13 KNOTS = 0.20 UNIT CORR	CROSSWIND CORR (L) R 2.6
RANGE WIND: WIND SPEED 17 X COMP (H) 0.63	TAIL (HEAD) 11 KNOTS	MET DEFL CORR L R

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	(H) 11	0	(H) 11	+6.9	75.9	
AIR TEMP	101.2	100%	(I) 1.2	-4.4		5.3
AIR DENSITY	97.7	100%	(D) 2.3	-6.3		14.5
PROJ WEIGHT	3▯	4▯	(D) 1▯	-29.0		29.0
ROTATION						

VE – MVV = POS VE
– -7.7 =

MET RANGE CORR

COMPUTATION OF VE

PROP TEMP +82 °F	VE	M/S	D +26.6	TOTAL RANGE CORRECTION	+240
	CHANGE TO MV FOR PROP TEMP	+0.6 M/S	I -21.3	MET RANGE CORRECTION	
	ΔV	M/S	MV UNIT CORRECTION	ΔV RANGE CORRECTION	
				TOTAL RANGE CORRECTION	

OLD VE ______ + NEW VE ______ - ______ ÷ 2 = AVG VE ______ ______ M/S

FS @ ADJ EL = 20.5 ~ 20

MET FUZE CORRECTION

ΔV	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
	D I				+240 5380 / 5140 348 19.6 / -0.9 / 20.5
RANGE WIND	(H) 11				
AIR TEMP	(I) 1.2				
AIR DENSITY	(D) 2.3				
PROJ WEIGHT	(D) 1▯				TOTAL FUZE CORRECTION -0.9
					MET FUZE CORRECTION
					FUZE CORRECTION
					TOTAL FUZE CORRECTION
TARGET NO KNPT 1	BATTERY A			DATE/TIME 270800RMAY13	

DA FORM 4200, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

SAMPLE

Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-21. DA Form 4200 with Data from Table F Complete.

FT 155-AM-3 | TABLE H | CHARGE 1L

PROJ, HE, M107
FUZE, PD, M739A1

ROTATION - RANGE

CORRECTIONS TO RANGE, IN METERS, TO COMPENSATE FOR THE ROTATION OF THE EARTH

RANGE METERS	AZIMUTH OF TARGET - MILS 0 / 3200	200 / 3000	400 / 2800	600 / 2600	800 / 2400	1000 / 2200	1200 / 2000	1400 / 1800	1600 / 1600
500	0	0	−1+	−1+	−2+	−2+	−2+	−2+	−2+
1000	0	−1+	−2+	−2+	−3+	−4+	−4+	−4+	−4+
1500	0	−1+	−2+	−4+	−5+	−5+	−6+	−6+	−6+
2000	0	−2+	−3+	−5+	−6+	−7+	−8+	−8+	−8+
2500	0	−2+	−4+	−6+	−7+	−9+	−9+	−10+	−10+
3000	0	−2+	−5+	−7+	−8+	−10+	−11+	−12+	−12+
3500	0	−3+	−5+	−8+	−10+	−11+	−13+	−13+	−14+
4000	0	−3+	−6+	−8+	−11+	−12+	−14+	−15+	−15+
4500	0	−3+	−6+	−9+	−12+	−14+	−15+	−16+	−16+
5000	0	−3+	−7+	−10+	−12+	−15+	−16+	−17+	−18+
5500	0	−4+	−7+	−10+	−13+	−15+	−17+	−18+	−18+
6000	0	−4+	−7+	−11+	−14+	−16+	−18+	−19+	−19+
6500	0	−4+	−7+	−11+	−14+	−16+	−18+	−19+	−20+
7000	0	−4+	−7+	−11+	−14+	−16+	−18+	−19+	−19+
7500	0	−4+	−7+	−10+	−13+	−15+	−17+	−18+	−18+
******	******	******	******	******	******	******	******	******	******
7500	0	−1+	−2+	−3+	−3+	−4+	−4+	−5+	−5+
7000	0	0	0	0	0	0	0	0	0
6500	0	+1−	+2−	+2−	+3−	+3−	+4−	+4−	+4−
6000	0	+1−	+3−	+4−	+5−	+6−	+7−	+7−	+8−
5500	0	+2−	+4−	+6−	+8−	+9−	+10−	+11−	+11−
5000	0	+3−	+6−	+8−	+10−	+12−	+14−	+15−	+15−
4500	0	+4−	+8−	+11−	+14−	+16−	+18−	+19−	+20−
	3200 / 6400	3400 / 6200	3600 / 6000	3800 / 5800	4000 / 5600	4200 / 5400	4400 / 5200	4600 / 5000	4800 / 4800
	AZIMUTH OF TARGET - MILS								

NOTES -
1. WHEN ENTERING FROM THE TOP USE THE SIGN BEFORE THE NUMBER.
2. WHEN ENTERING FROM THE BOTTOM USE THE SIGN AFTER THE NUMBER.
3. AZIMUTH IS MEASURED CLOCKWISE FROM NORTH.
4. CORRECTIONS ARE FOR 0 DEGREES LATITUDE. FOR OTHER LATITUDES MULTIPLY CORRECTIONS BY THE FACTOR GIVEN BELOW.

LATITUDE (DEG)	10	20	30	40	50	60	70
MULTIPLY BY	.98	.94	.87	.77	.64	.50	.34

Figure 11-22. Table H.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE				
CHARGE 1L	ADJ QE	CHART RG 5140	LATITUDE 30° N	TYPE MESSAGE METCM		OCTANT 1	AREA/UNIT 347 985	
ALT OF BTRY (10m) (355)		360		DATE 27	TIME 1230	ALT MDP 550	PRESSURE 977	
ALT OF MDP		550		LINE NO. 02	WIND DIR. 5920	WIND SPEED 17	AIR TEMP 100.8	AIR DENSITY 95.8
BTRY ABOVE / (BELOW) MDP (Δh)		-190		Δh CORRECTION			(+) - 0.4	(+) - 1.9
ALT OF TARGET (nearest meter)		376		CORRECTED VALUES			101.2	97.7
HEIGHT OF BURST ABOVE TARGET				288.2 / 285.9 x 100% ≈100.8%		939 x 0.34836764 / 288.2 = 1.1350	1.1350 / 1.1844 x 100% ≈ 95.8%	
ALT OF BURST		376						
ALT OF BTRY (nearest meter)		355						
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+21 ~ 0		COMP RG 0		CHART RG 5140	ENTRY RG 5140~	5100

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	TOT DF CORR L9 ~~MET DF CORR L10~~ (POS DF CORR R1)	
DIRECTION OF WIND (5920)	5900		
DIRECTION OF FIRE (0395)	0400		ROTATION CORR (L) R 0.6
CHART DIRECTION OF WIND	5500		DRIFT CORR (L) 7.3
CROSS WIND: WIND SPEED 17	X COMP (L) R 0.77	(L) R 13 KNOTS = 0.20 UNIT CORR	CROSSWIND CORR (L) R 2.6
RANGE WIND: WIND SPEED 17	X COMP T (H) 0.63	= TAIL (HEAD) 11 KNOTS	MET DEFL CORR (L) R 10.5 — L10

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T (H) 11	0	T (H) 11	+6.9	75.9	
AIR TEMP	101.2	100%	(I) 1.2	-4.4		5.3
AIR DENSITY	97.7	100%	(D) I 2.3	-6.3		14.5
PROJ WEIGHT	3▯	4▯	(D) 1▯	-29.0		29.0
ROTATION	-7 X	0.87				6.1
VE – MVV = POS VE -8.8 – -7.7 = -1.1					75.9	54.9
					54.9	
				MET RANGE CORR	21	~	+21

COMPUTATION OF VE

PROP TEMP +82 °F	VE	-8.8 M/S	D +26.6	TOTAL RANGE CORRECTION +240
	CHANGE TO MV FOR PROP TEMP	+0.6 M/S	I -21.3	MET RANGE CORRECTION +21
	ΔV	-8.2 M/S	MV UNIT CORRECTION +26.6	ΔV RANGE CORRECTION +219
				TOTAL RANGE CORRECTION

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

FS @ ADJ EL = 20.5 ~ 20

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
ΔV	(D) 8.2			
RANGE WIND	T (H) 11			
AIR TEMP	(I) 1.2			
AIR DENSITY	(D) 2.3			
PROJ WEIGHT	(D) 1▯			

5380 / +240 / 5140 / 348 / 19.6 / -0.9 / 20.5

TOTAL FUZE CORRECTION	-0.9
MET FUZE CORRECTION	
FUZE CORRECTION	
TOTAL FUZE CORRECTION	

TARGET NO KNPT 1 | BATTERY A | DATE/TIME 270800RMAY13

DA FORM 4200, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

SAMPLE

Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-23. DA Form 4200 With Position VE and Position Deflection Determined.

FT 155-AM-3 TABLE I CHARGE 1L

PROJ, HE, M107
FUZE, PD, M739A1

ROTATION - AZIMUTH

CORRECTIONS TO AZIMUTH, IN MILS, TO COMPENSATE FOR THE ROTATION OF THE EARTH

30 DEGREES NORTH LATITUDE

RANGE METERS	AZIMUTH OF TARGET - MILS 0 / 6400	400 / 6000	800 / 5600	1200 / 5200	1600 / 4800	2000 / 4400	2400 / 4000	2800 / 3600	3200 / 3200
500	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R
1000	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R	L0.1R
1500	L0.2R	L0.2R	L0.2R	L0.2R	L0.2R	L0.2R	L0.2R	L0.2R	L0.2R
2000	L0.2R	L0.2R	L0.2R	L0.2R	L0.2R	L0.3R	L0.3R	L0.3R	L0.3R
2500	L0.3R	L0.3R	L0.3R	L0.3R	L0.3R	L0.3R	L0.3R	L0.3R	L0.3R
3000	L0.3R	L0.3R	L0.4R	L0.4R	L0.4R	L0.4R	L0.4R	L0.4R	L0.4R
3500	L0.4R	L0.4R	L0.4R	L0.4R	L0.4R	L0.5R	L0.5R	L0.5R	L0.5R
4000	L0.4R	L0.5R	L0.5R	L0.5R	L0.5R	L0.5R	L0.6R	L0.6R	L0.6R
4500	L0.5R	L0.5R	L0.5R	L0.6R	L0.6R	L0.6R	L0.7R	L0.7R	L0.7R
5000	L0.5R	L0.6R	L0.6R	L0.6R	L0.7R	L0.7R	L0.8R	L0.8R	L0.8R
5500	L0.6R	L0.6R	L0.6R	L0.7R	L0.8R	L0.8R	L0.9R	L0.9R	L0.9R
6000	L0.6R	L0.7R	L0.7R	L0.8R	L0.8R	L0.9R	L1.0R	L1.0R	L1.0R
6500	L0.7R	L0.7R	L0.8R	L0.8R	L0.9R	L1.0R	L1.1R	L1.2R	L1.2R
7000	L0.7R	L0.7R	L0.8R	L0.9R	L1.1R	L1.2R	L1.3R	L1.4R	L1.4R
7500	L0.7R	L0.8R	L0.9R	L1.0R	L1.2R	L1.4R	L1.5R	L1.6R	L1.7R
******	******	******	******	******	******	******	******	******	******
7500	L0.4R	L0.5R	L0.7R	L1.2R	L1.7R	L2.2R	L2.6R	L2.9R	L3.0R
7000	L0.1R	L0.2R	L0.6R	L1.1R	L1.8R	L2.4R	L3.0R	L3.3R	L3.5R
6500	R0.2L	0.0	L0.4R	L1.1R	L1.8R	L2.6R	L3.3R	L3.7R	L3.9R
6000	R0.4L	R0.3L	L0.2R	L1.0R	L1.9R	L2.8R	L3.5R	L4.0R	L4.2R
5500	R0.8L	R0.5L	0.0	L0.9R	L1.9R	L2.9R	L3.8R	L4.4R	L4.6R
5000	R1.1L	R0.9L	R0.2L	L0.8R	L1.9R	L3.1R	L4.1R	L4.7R	L4.9R
4500	R1.4L	R1.2L	R0.4L	L0.6R	L1.9R	L3.2R	L4.3R	L5.0R	L5.3R
	3200 / 3200	2800 / 3600	2400 / 4000	2000 / 4400	1600 / 4800	1200 / 5200	800 / 5600	400 / 6000	0 / 6400
	AZIMUTH OF TARGET - MILS								

30 DEGREES SOUTH LATITUDE

NOTES -
1. WHEN ENTERING FROM THE TOP USE THE SIGN BEFORE THE NUMBER.
2. WHEN ENTERING FROM THE BOTTOM USE THE SIGN AFTER THE NUMBER.
3. R DENOTES CORRECTION TO THE RIGHT, L TO THE LEFT.
4. AZIMUTH IS MEASURED CLOCKWISE FROM NORTH.

Figure 11-24. Table I.

CHARGE 1L | TABLE J | FT 155-AM-3

FUZE CORRECTION FACTORS

PROJ, HE, M107
FUZE, MTSQ, M582

1	2	3	4	5	6	7	8	9	10	11
FS	FUZE CORRECTIONS FOR									
	MUZZLE VELOCITY 1 M/S		RANGE WIND 1 KNOT		AIR TEMP 1 PCT		AIR DENSITY 1 PCT		PROJ WT OF 1 SQ (4 SQ STD)	
	DEC	INC	HEAD	TAIL	DEC	INC	DEC	INC	DEC	INC
0										
1										
2	-.006	0.006	0.000	0.000	-.001	0.000	0.000	0.000	0.009	-.010
3	-.009	0.009	-.001	0.000	-.001	0.001	0.000	0.000	0.014	-.014
4	-.012	0.011	-.001	0.000	-.003	0.001	0.000	0.000	0.018	-.018
5	-.015	0.013	-.001	0.001	-.004	0.001	0.001	-.001	0.022	-.022
6	-.018	0.016	-.002	0.001	-.005	0.002	0.001	-.001	0.025	-.026
7	-.020	0.018	-.002	0.001	-.006	0.002	0.001	-.001	0.029	-.030
8	-.023	0.020	-.003	0.001	-.008	0.003	0.001	-.001	0.032	-.034
9	-.026	0.023	-.003	0.001	-.009	0.003	0.002	-.002	0.036	-.038
10	-.028	0.025	-.004	0.001	-.010	0.004	0.002	-.002	0.039	-.041
11	-.031	0.027	-.005	0.002	-.012	0.004	0.003	-.003	0.042	-.045
12	-.033	0.029	-.005	0.002	-.013	0.005	0.003	-.003	0.046	-.048
13	-.036	0.031	-.006	0.002	-.015	0.005	0.004	-.003	0.049	-.052
14	-.039	0.034	-.006	0.002	-.016	0.006	0.004	-.004	0.052	-.055
15	-.041	0.036	-.007	0.003	-.017	0.006	0.005	-.004	0.055	-.058
16	-.044	0.038	-.007	0.003	-.018	0.006	0.005	-.005	0.058	-.062
17	-.046	0.040	-.008	0.003	-.020	0.007	0.006	-.006	0.061	-.065
18	-.049	0.042	-.008	0.003	-.021	0.007	0.006	-.006	0.064	-.068
19	-.051	0.045	-.009	0.003	-.022	0.008	0.007	-.007	0.068	-.071
20	-.054	0.047	-.009	0.004	-.023	0.008	0.008	-.007	0.071	-.075
21	-.056	0.049	-.010	0.004	-.024	0.009	0.008	-.008	0.074	-.078
22	-.059	0.051	-.010	0.004	-.025	0.009	0.009	-.009	0.077	-.081
23	-.062	0.054	-.011	0.004	-.026	0.009	0.010	-.009	0.079	-.084
24	-.064	0.056	-.011	0.005	-.027	0.010	0.010	-.010	0.082	-.088
25	-.067	0.058	-.011	0.005	-.028	0.010	0.011	-.011	0.085	-.091
26	-.069	0.060	-.012	0.005	-.029	0.010	0.012	-.012	0.088	-.094
27	-.072	0.063	-.012	0.005	-.030	0.010	0.013	-.012	0.091	-.097
28	-.074	0.065	-.012	0.005	-.031	0.011	0.013	-.013	0.094	-.101
29	-.077	0.067	-.013	0.005	-.031	0.011	0.014	-.014	0.097	-.104
30	-.080	0.070	-.013	0.006	-.032	0.011	0.015	-.015	0.100	-.107
31	-.082	0.072	-.013	0.006	-.033	0.011	0.016	-.015	0.102	-.110
32	-.085	0.074	-.014	0.006	-.034	0.011	0.017	-.016	0.105	-.114
33	-.088	0.077	-.014	0.006	-.034	0.012	0.017	-.017	0.108	-.117
34	-.090	0.079	-.014	0.006	-.035	0.012	0.018	-.018	0.111	-.121
35	-.093	0.081	-.014	0.006	-.035	0.012	0.019	-.019	0.114	-.124

Figure 11-25. Table J.

MET DATA CORRECTION SHEET						
For use of this form, see TC 3.09-81; the proponent agency is TRADOC.						

BATTERY DATA

CHARGE	ADJ QE	CHART RG	LATITUDE
1L	353	5140	30° N

ALT OF BTRY (10m) (355)	360
ALT OF MDP	550
BTRY ABOVE / (BELOW) MDP (Δh)	-190
ALT OF TARGET (nearest meter)	376
HEIGHT OF BURST ABOVE TARGET	
ALT OF BURST	376
ALT OF BTRY (nearest meter)	355
HEIGHT OF TARGET (burst) ABOVE GUN (M)	+21 ~ 0

MET MESSAGE

TYPE MESSAGE		OCTANT		AREA/UNIT	
MET B 3		1		347 985	
DATE 27	TIME 1230			ALT MDP 550	PRESSURE 97.2
LINE NO. 02	WIND DIR. 5900	WIND SPEED 17		AIR TEMP 100.8	AIR DENSITY 95.8
Δh CORRECTION				(+) - 0.4	(+) - 1.9
CORRECTED VALUES				101.2	97.7
288.2 / 285.9 x 100% ≈100.8%		939 x 0.34836764 / 288.2 = 1.1350		1.1350 / 1.1844 x 100% ≈ 95.8%	
COMP RG 0		CHART RG 5140		ENTRY RG 5140 ~	5100

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	TOT DF CORR L9
DIRECTION OF WIND	5900	~~MET DF CORR L10~~
		POS DF CORR R1
DIRECTION OF FIRE (0395)	0400	ROTATION CORR R 0.6
CHART DIRECTION OF WIND	5500	DRIFT CORR L 7.3
CROSS WIND: WIND SPEED 17 X COMP (L) R 0.77	(L) R 13 KNOTS = 0.20 UNIT CORR	CROSSWIND CORR (L) R 2.6
RANGE WIND: WIND SPEED 17 X COMP (T) H 0.63	= 11 KNOTS TAIL (HEAD)	MET DEFL CORR (L) R 10.5 ~ / L10

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T (H) 11	0	T (H) 11	+6.9	75.9	
AIR TEMP	101.2	100%	I (D) 1.2	-4.4		5.3
AIR DENSITY	97.7	100%	(D) I 2.3	-6.3		14.5
PROJ WEIGHT	3▯	4▯	(D) I 1▯	-29.0		29.0
ROTATION	-7	X 0.87				6.1
VE – MVV = POS VE -8.8 - -7.7 = -1.1					75.9	54.9
					54.9	
				MET RANGE CORR	21	~ / +21

COMPUTATION OF VE

PROP TEMP +82 °F	VE -8.8 M/S	D +26.6	TOTAL RANGE CORRECTION	+240
	CHANGE TO MV FOR PROP TEMP +0.6 M/S	I -21.3	MET RANGE CORRECTION	+21
	ΔV -8.2 M/S	MV UNIT CORRECTION +26.6	ΔV RANGE CORRECTION	+219

FS @ ADJ EL = 20.5 ~ 20

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS		
ΔV	(D) I 8.2	-0.054		0.443	+240 / 5380	
RANGE WIND	T (H) 11	-0.009		0.099	5140 348	19.6
AIR TEMP	I (D) 1.2	+0.008	0.010			-0.9
AIR DENSITY	(D) I 2.3	+0.008	0.018		20.5	
PROJ WEIGHT	(D) I 1▯	+0.071	0.071		TOTAL FUZE CORRECTION	-0.9
			0.099	0.542	MET FUZE CORRECTION	-0.4
				0.099	FUZE CORRECTION	-0.5
				0.443	TOTAL FUZE CORRECTION	

TARGET NO	BATTERY	DATE/TIME
KNPT 1	A	270800RMAY13

DA FORM 4200, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-26. Completed DA Form 4200 Containing the Concurrent Met.

SECTION IV: SUBSEQUENT MET APPLICATIONS

11-43. A subsequent met is computed to determine new total corrections. Total corrections determined from a registration will remain valid only as long as the met corrections do not change. In order to maintain the accuracy gained from the registration new total corrections must be determined. These new total corrections are determined through subsequent met applications. Subsequent met applications include met to a met check gauge point, eight-direction met, met to a target, computing a GFT setting for an unregistered charge, and met + VE. These applications do not require position constants and should be used if the five requirements for accurate fire are being met or a registration cannot be performed.

OVERVIEW

11-44. Whenever a met condition (weather, propellant temperature, projectile weight, or propellant lot) changes, the GFT setting derived from the registration is no longer valid. It would not be feasible for a firing unit to register every time one of the measurable nonstandard conditions changed. To update registration corrections, a subsequent met can be solved to quantify new met corrections, which are added to the position constants determined from the concurrent met. The result is new total corrections that are used to determine a new GFT setting.

MET TO MET CHECK GAUGE POINT

11-45. The one-plot GFT setting determined by registering has limited range transfer limits. A more accurate GFT setting can be determined by using the data from a registration and one or more met + VE computations to met check gauge points. Solution of a met to met check gauge point using subsequent met principles will yield total corrections at each met check gauge point range. The met check gauge points selected should be the ones farthest away, in range, from the registration chart range.

11-46. The met to met check gauge point technique consists of the following steps:

- Solution of a concurrent met to determine the position VE, position deflection correction, and position fuze correction.
- Solving for met corrections to the selected met check gauge points and adding the position constants to determine GFT settings for these ranges. The chart ranges will be the ranges to the selected met check gauge points and the line number of the met message will be determined on the basis of that range and a height of target above gun of 0. The altitude of the target used will be the same as the battery altitude.

11-47. Combine the data from the registration and the met(s) to met check gauge points to determine a two-plot or multiplot GFT setting.

SOLUTION OF A MET TO MET CHECK GAUGE POINT

11-48. Table 11-5 on page 11-41 shows a detailed example of the solution of the met to met check gauge point subsequent met application. It uses the previously completed concurrent met (figure 11-26, page 11-38).

Table 11-5. Solution of a Met to Met Check Gauge Point.

STEP	*ACTION*
1	Record the position constants determined from the concurrent met.
1a	Record the position deflection correction **(R1)** in the WIND COMPONENTS AND DEFLECTION computational space. Use the equation below to compute the GFT deflection correction. Record it in the WIND COMPONENTS AND DEFLECTION computational space as follows: **POS DF CORR R1** **+MET DF CORR** **TOTAL DF CORR** **- DRIFT ~ ADJ EL** **GFT DF CORR**
1b	Record the position VE determined from the registration **(-1.1)** in the MET RANGE CORRECTION computational block. Use the equation POS VE + MVV = VE. Once the equation is written and the VE determined, record the VE in the COMPUTATION OF VE section VE block. **POS VE + MVV = VE -1.1 + (-6.3) = -7.4**
1c	Record the position fuze correction **(-0.5).**
2	Record the known data.
2a	Record the charge **(1L).**
2b	Select a met check gauge point based on the registration chart range. **(5480)**
2c	Determine the ballistic met line number from Table B. **(02)** Note: With the exception of met to target, all subsequent met applications determine total corrections for a selected range and not an actual target location. Since no target exists the target altitude used is zero.
2d	Determine the corresponding computer met message line for the ballistic line number determined. **(02)**
2e	Determine the corresponding weather standards for air temperature and density **(285.9, 1.1844)** at the determined line number.
2f	Extract the computer met air temperature **(269.3)** and air pressure **(963).** (See figure 11-27, page 11-47.)
2g	Convert the computer met air temperature and air pressure into simulated "ballistic" data: $\frac{\text{Air Temperature at CM line 02}}{\text{Temperature std (at ballistic line 02)}} = \frac{269.3}{285.9} X\, 100\% =\approx 94.2\%$ **(expressed to nearest tenth of a percent)** $\frac{\text{Air Preassure (at CM line 02)}}{\text{AirTemperature (at CM line 02)}} = \frac{963}{269.3}\ X\, 0.34836764$ $\frac{\text{Density Conversion Ratio}}{\text{Density std (at ballistic line 02)}} = \frac{1.2460}{1.1844} X\, 100\% \ \approx 105.2\%$ **(expressed to nearest tenth of a percent)**
2h	Extract the density weighting factor at the appropriate ballistic line number (1.0000) and multiply the derived "ballistic" density by extracted weighting factor (**105.2% x 1.0000 = 105.2%)**
2i	Record the derivation computations in the MET MESSAGE section computational space.
2j	Record data from the identification line (METCM, 1, 342 988, 27, 1430, 290, 999) and the line number (02) determined from the met message in the met message block. (See figure 11-28, page 11-48).
2k	Record the altitude of the MDP **(290),** wind direction **(0720)**, wind speed **(24),** air temperature **(94.2),** and air density **(105.2)** from the met message in the appropriate blocks. (See figure 11-28, page 11-48.)

Table 11-5. Solution of a Met to Met Check Gauge Point (continued).

STEP	*ACTION*
2l	Record the met check gauge point range in both blocks (**5480**).
2m	Record the latitude (nearest 10°) (**30°N**).
2n	Record the battery altitude (to the nearest 1 meter in parentheses and to the nearest 10 meters in the block) (**395 ≈ 400**). Enter the battery altitude to the nearest 1 meter in the lower block (**395**).
2o	Determine the difference in altitude between the battery and the MDP. **ALT OF BTRY 400** **- ALT OF MDP 290** **BTRY (ABOVE) MDP +110**
2p	Record the corrections from Table D that are applied to the temperature and density to compensate for the difference in altitude between the battery and the MDP. **DT CORRECTION -0.2 DD CORRECTION -1.1**
2q	Apply the corrections to the temperature and density, and record the result in the CORRECTED VALUES block and in the KNOWN VALUES column of the MET RANGE CORRECTION section. **AIR TEMP 94.2** **AIR DENSITY 105.2** **∆h CORRECTION -0.2** **∆h CORRECTION -1.1** **CORRECTED VALUE 94.0** **CORRECTED VALUE 104.1**
2r	Determine the variation from the standard for air temperature and air density. Circle the (I) for an increase or the (D) for a decrease (whichever is appropriate), and record the difference in the VARIATIONS FROM STANDARD column. Transfer the values to the VARIATION FROM STANDARD column in the MET FUZE CORRECTION section. Extract and record the unit corrections for the gauge point range from Table F. Line out the appropriate block (PLUS or MINUS) and record the sum of the variation from standard multiplied by the unit correction.
2s	Line out the target altitude and altitude of the burst blocks.
2t	Record the height of burst above gun (VI) (**0**) and the complementary range (**0**).
2u	Record the entry range. It will be the same as the met check gauge point range. Express this value to the nearest 100 meters, and record it out to the side of the ENTRY RG block. (**5480 ≈ 5500**).
2v	Record the direction of fire (to the nearest mil in parentheses and to the nearest 100 mils in the block) (**1600**).
2w	Subtract the direction of fire from the direction of wind, expressed to the nearest 100 mils, to determine the chart direction of wind. Add 6400 to the direction of wind if necessary. **DIRECTION OF WIND 0720 ~ 0700** **+ 6400 6400** **DIRECTION OF WIND 7100** **- DIRECTION OF FIRE 1800** **CHART DIRECTION OF WIND 5300**
2x	Record the crosswind unit correction determined from Table F (**0.21**).
2y	Record the deflection correction for rotation from Table I (**L0.8**).
2z	Record the deflection correction for drift from Table F (**L8.3**).
2aa	Record the [] weight of the projectile (**5[]**). Record the standard weight (4[]). Record the difference in the VARIATIONS FROM STANDARD column I (**1[]**). Transfer the result to the VARIATION FROM STANDARD column under the MET FUZE CORRECTION section.

Table 11-5. Solution of a Met to Met Check Gauge Point (continued).

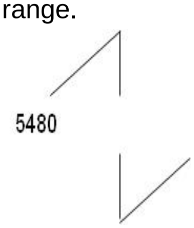
STEP	***ACTION***
2bb	Record the range correction for rotation and the correction factor for the change in latitude from Table H (**-18 x 0.87**). Line out the appropriate block (PLUS or MINUS), and record the product.
2cc	Record the current propellant temperature (**+62°F**).
2dd	Divide the MV UNIT CORRECTION block in half with a diagonal line, and record both range correction values for muzzle velocity from Table F (**DEC +28.5/INC -22.9**).
2ee	Record the lazy Z in the bottom computational block. Show only the met check gauge point range. 
2ff	Line out the top TOTAL RANGE CORRECTION block and the top TOTAL FUZE CORRECTION block.
2gg	Record (**Met Check Gauge Point**) in the TARGET NO. block.
2hh	Record the unit designation (**A**).
2ii	Record 13 April 2016-time group.
	Note: A DA Form 4200 with the above known data is shown in figure 11-28, page 11-48.
3	Determine crosswind and range components from Table C. (See figure 11-29, page 11-49)
3a	Enter Table C with the chart direction of wind (**5300**). Extract and record the crosswind (**L0.88**) component and range wind (**H0.47**) component.
3b	Multiply the wind components by the wind speed, and express the result to the nearest 1 knot. Circle the appropriate symbol (L or R for crosswind and T or H for range wind).
3c	Multiply the crosswind determined in step 3b (**L21**) by the unit correction for crosswind (**0.21**) from Table F that was already recorded. Record the sum (**L4.4**) in the CROSS WIND CORR block.
4	Determine the met deflection correction (See figure 11-29, page 11-49.) Algebraically add the values for rotation drift and cross wind. Express the result to the nearest 1 mil, and record the result to the right of the MET DEFL CORR blocks as a left (L) or a right I. **ROTATION CORRECTION L0.8** **+DRIFT CORRECTION L8.3** **+CROSSWIND CORRECTION L4.4** **MET DEFLECTION CORRECTION L13.5 ≈ L14**
5	Determine the total deflection correction (See figure 11-29, page 11-49.) Record the met deflection correction in the equation for deflection, and algebraically add the met deflection correction and the position deflection correction, applying the correct sign. **POS DF CORR R1** **+MET DF CORR L14** **TOTAL DF CORR L13**

Table 11-5. Solution of a Met to Met Check Gauge Point (continued).

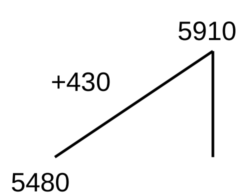
STEP	***ACTION***
6	Record the value determined for range wind (**H11**) in the KNOWN VALUES column of the MET RANGE CORRECTION section. Determine and record the variation from standard and transfer it down to the VARIATION FROM STANDARD column in the MET FUZE CORRECTION section. (See figure 11-29, page 11-49.)
7	Determine the correction to muzzle velocity for propellant temperature from Table E.
7a	Enter Table E with the propellant temperature to the nearest degree Fahrenheit (**+62°F**). (See figure 11-29, page 11-49.)
7b	Interpolate the change to muzzle velocity as required.
7c	Record the correction (**-0.4**) in the CHANGE TO MV FOR PROP TEMP block.
8	Determine the ΔV range correction.
8a	Algebraically add the VE (**-7.4**) and the change to MV for propellant temperature (**-0.4**) to determine the ΔV (**-7.8**).
8b	Multiply ΔV (**-7.8**) by the appropriate MV unit correction (**DEC +28.5**).
8c	Express the result to the nearest 1 meter, and record it in the ΔV RANGE CORRECTION block. The ΔV range correction will have the opposite sign of the ΔV (**+222**).
8d	Once the ΔV has been determined, it can be recorded in the VARIATION FROM STANDARD column under the MET FUZE CORRECTION section.
9	Determine from Table F the unit correction factors. (See figure 11-29, page 11-49.)
9a	Enter Table F with entry range (**5500**). Extract and record the unit correction for range wind (**+7.5**), air temperature (**+13.2**), and air density (**+7.3**).
9b	Multiply the variation from standard for range wind (**H11**) by the unit correction (**+7.5**), line out the appropriate block (PLUS or MINUS), and record the result (**82.5**).
9c	Multiply the variation from standard for air temperature (**6.0**) by the unit correction (**+13.2**), line out the appropriate block (PLUS or MINUS), and record the result (**79.2**).
10	Determine the met range correction. (See figure 11-29, page 11-49.)
10a	Total the PLUS column, and total the MINUS column. Subtract the smaller from the larger. Express the result to the nearest 1 meter, and record it out to the side of the MET RANGE CORR block with the appropriate sign.
10b	Record the met range correction (**+210**) in the MET RANGE CORRECTION block under the COMPUTATION OF VE section.
11	Determine the total range correction. (See figure 11-29, page 11-49.) Algebraically add the met range correction (**+210**) and the ΔV range correction (**+222**) to determine the total range correction (**+432**). Express the result to the nearest 10 meters (**+430**), and record it out to the side of the TOTAL RANGE CORRECTION block. **MET RANGE CORRECTION +210** **+ΔV RANGE CORRECTION +(+222)** **TOTAL RANGE CORRECTION +432 ≈ +430**
12	Determine the adjusted elevation. (See figure 11-30, page 11-50.)
12a	Apply the total range correction to the chart range on the lazy Z. 

Table 11-5. Solution of a Met to Met Check Gauge Point (continued).

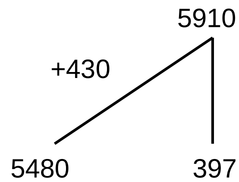
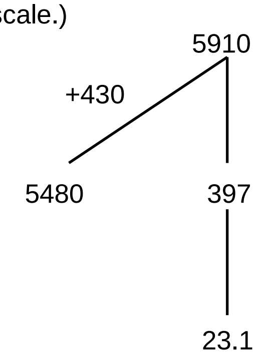
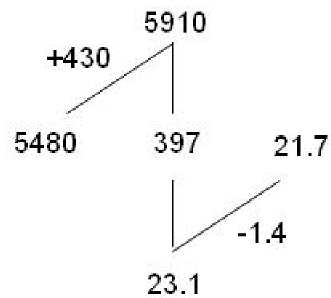
STEP	***ACTION***
12b	Place the MHL of the GFT over the range corresponding to the adjusted elevation (**5910**), and read the adjusted elevation under the MHL (**397**). 
12c	With the MHL on the adjusted elevation, determine the fuze setting corresponding to the adjusted elevation from the TF/ET/VT scale (**23.1**), and record it on the lazy Z. (If firing the M564 fuze, use the M564 scale.) 
13	Determine the GFT deflection correction. (See figure 11-30, page 11-50.)
13a	Determine the drift corresponding to the adjusted elevation, and record it in the equation for deflection (**DRIFT ~ ADJ EL = L9**).
13b	Algebraically subtract the drift corresponding to the adjusted elevation (**L9**) from the total deflection correction (**L13**) to determine the GFT deflection corresponding (**L4**). Record the result. **POS DF CORR R1** **+MET DF CORR L14** **TOTAL DF CORR L13** **-DRIFT ~ ADJ EL L9** **GFT DF CORR L4**
14	Determine the met fuze correction. (See figure 11-30, page 11-50.)
14a	All variations from standard should be entered in the MET FUZE CORRECTION section.
14b	Record the fuze setting corresponding to the adjusted elevation to the nearest 0.1, and then express it to the nearest whole fuze setting increment. Record it in the space to the left of the words "MET FUZE CORRECTION" as follows: **FS ~ ADJ EL = 23.1 ≈ 23**.
14c	Enter Table J with the fuze setting corresponding to the adjusted elevation expressed to the nearest whole increment.
14d	Extract and record the unit corrections for ∆V (**-0.062**), range wind (**-0.011**), air temperature (**-0.026**), air density (**-0.009**), and projectile weight (**-0.084**).
14e	Line out the appropriate block (PLUS or MINUS). Multiply the unit correction by the variation from standard, and record the result.
14f	Total the PLUS column, and total the MINUS column. Subtract the smaller from larger, an express the result to the nearest 0.1.

Table 11-5. Solution of a Met to Met Check Gauge Point (continued).

STEP	***ACTION***
14g	Record the met fuze correction (**-0.9**) in the MET FUZE CORRECTION block.
15	Determine the total fuze correction (See Figure 11-30 on page 11-50.) Algebraically add the position fuze correction (**-0.5**) and the met fuze correction (**-0.9**) to determine the total fuze correction (**-1.4**). Record the result.
16	Determine the adjusted time. (See Figure 11-30 on page 11-50.) Apply the total fuze correction (**-1.4**) to the fuze setting corresponding to the adjusted elevation (**23.1**) to determine the new adjusted fuze setting (**21.7**) to complete the lazy Z. 
17	Use the acronym UCARET, and determine the GFT setting. Record it on the side of DA Form 4200 as follows: **GFT A CHG 1 LOT A/L RG 5480 EL 397 TI 21.7 (M767)** **TOT DF CORR L13 GFT DF CORR L4**
	Note: Figure 11-30 (page 11-50) shows the completed met to met check gauge point application.
Legend: ALT – altitude ADJ – adjusted BTRY – battery CHG – charge CM – computer met CORR – correction DEC – decrease DF – deflection EL – elevation GFT – graphical firing table INC – increase L – left MDP – meteorological datum plane MHL – manufacturer's hair line MV – muzzle velocity MVV – muzzle velocity variation POS – position PROP – propellant R – right RG – range STD – standard TEMP – temperature TI – time TOT – total VI – vertical interval VE – velocity error VT – variable time	

COMPUTER MET MESSAGE

For use of this form, see TC 3-09.81 the proponent agency is TRADOC.

IDENTIFI-CATION	OCTANT	LOCATION		DATE	TIME (GMT)	DURATION (HOURS)	STATION HEIGHT (10's M)	MDP PRESSURE MB
		$L_a L_a L_a$ or XXX	$L_o L_o L_o$ or XXX					
METCM	Q	XXX	XXX	YY	$G_o G_o G_o$	G	hhh	$P_d P_d P_d$
METCM	1	342	988	27	145	0	029	999

ZONE HEIGHT (METERS)	LINE NUMBER	ZONE VALUES			
		WIND DIRECTION (10's M)	WIND SPEED (KNOTS)	TEMPERATURE (1/10°K)	PREASURE MILLIBARS)
	ZZ	ddd	FFF	TTTT	PPPP
SURFACE	00	631	020	2741	0999
200	01	043	022	2731	0989
500	02	072	024	2693	0963
1000	03	094	025	2666	0922
1500	04	100	026	2632	0869
2000	05				
2500	06				
3000	07				
3500	08				
4000	09				
4500	10				
5000	11				
6000	12				
7000	13				
8000	14				
9000	15				
10000	16				
11000	17				
12000	18				
13000	19				
14000	20				
15000	21				
16000	22				
17000	23				
18000	24				
19000	25				
20000	26				

FROM B BTRY 1-30th FA TO: A BBRTY 1-30th FA	DATE AND TIME (GMT) 271430JUL13	DATE AND TIME (LST) 271430JUL13
MESSAGE NUMBER 1307-04	RECORDER RB	CHECKED RB

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Legend: BTRY – battery FA – field artillery GMT – Greenwich Mean Time LST – local standard time MB – millibars MDP – meteorological datum plane

Figure 11-27. Valid Computer Met Message.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE				
CHARGE 1L	ADJ QE	CHART RG 5480	LATITUDE 30° N	TYPE MESSAGE METCM		OCTANT 1		AREA/UNIT 342 988
ALT OF BTRY (10m) (395)		400		DATE 27	TIME 1430		ALT MDP 290	PRESSURE 999
ALT OF MDP		290		LINE NO. 02	WIND DIR. 0720	WIND SPEED 24	AIR TEMP 94.2	AIR DENSITY 105.2
BTRY (ABOVE) BELOW MDP (Δh)		+110		Δh CORRECTION			+ (−) 0.2	+ (−) 1.1
ALT OF TARGET (nearest meter)				CORRECTED VALUES			94.0	104.1
HEIGHT OF BURST ABOVE TARGET				269.3 / 285.9 x 100% ≈ 94.2%		963 x 0.34836764 / 269.3 = 1.2460		1.2460 / 1.1844 x 100% ≈ 105.2%
ALT OF BURST								
ALT OF BTRY (nearest meter)								
HEIGHT OF TARGET (burst) ABOVE GUN (M)		0		COMP RG 0		CHART RG 5480		ENTRY RG 5480 / 5500

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	POS DF CORR R1 +MET DF CORR TOT DF CORR -DFT@ADJ EL GFT DF CORR
DIRECTION OF WIND (0720)	0700	
	7100	
DIRECTION OF FIRE (1800)	1800	ROTATION CORR (L) R 0.8
CHART DIRECTION OF WIND	5300	DRIFT CORR (L) 8.3
CROSS WIND	WIND SPEED 24 X COMP L R	L R KNOTS = 0.21 = UNIT CORR; CROSSWIND CORR L R
RANGE WIND	WIND SPEED 24 X COMP T H	TAIL HEAD KNOTS; MET DEFL CORR L R

MET RANGE CORRECTION

	KNOWN VALUES		STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T H		0	T H			
AIR TEMP	94.0		100%	(D) I 6.0	+13.2	79.2	
AIR DENSITY	104.1		100%	D (I) 4.1	+7.3	29.9	
PROJ WEIGHT	5▯		4▯	D (I) 1▯	+34.0	34.0	
ROTATION	-18	X	0.87				15.7

POS VE + MVV = VE
-1.1 + -6.3 = -7.4

MET RANGE CORR

COMPUTATION OF VE

PROP TEMP +62 °F	VE	-7.4 M/S	D +28.5	TOTAL RANGE CORRECTION	
	CHANGE TO MV FOR PROP TEMP	M/S	I -22.9	MET RANGE CORRECTION	
	ΔV	M/S	MV UNIT CORRECTION +28.5	ΔV RANGE CORRECTION	
				TOTAL RANGE CORRECTION	

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
ΔV	D I				
RANGE WIND	T H				5480
AIR TEMP	(D) I 6.0				
AIR DENSITY	D (I) 4.1				
PROJ WEIGHT	D (I) 1▯				TOTAL FUZE CORRECTION
					MET FUZE CORRECTION
					FUZE CORRECTION -0.5
					TOTAL FUZE CORRECTION

TARGET NO | MET CHECK GAUGE PT | BATTERY A | DATE/TIME 271000RMAY13

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Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-28. DA Form 4200 with Known Data for a Met to Met Check Gauge Point.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA

CHARGE	ADJ QE	CHART RG	LATITUDE
1L		5480	30° N

ALT OF BTRY (10m) (395)	400
ALT OF MDP	290
BTRY (ABOVE) / BELOW MDP (Δh)	+110
ALT OF TARGET (nearest meter)	
HEIGHT OF BURST ABOVE TARGET	
ALT OF BURST	
ALT OF BTRY (nearest meter)	
HEIGHT OF TARGET (burst) ABOVE GUN (M)	0

MET MESSAGE

TYPE MESSAGE		OCTANT		AREA/UNIT
METCM		1		342 988
DATE 27	TIME 1430		ALT MDP 290	PRESSURE 108.8
LINE NO. 02	WIND DIR. 0700	WIND SPEED 24	AIR TEMP 94.2	AIR DENSITY 105.2
Δh CORRECTION			+ / − 0.2	+ / − 1.1
CORRECTED VALUES			94.0	104.1

269.3 / 285.9 x 100% ≈ 94.2%

963 x 0.34836764 / 269.3 = 1.2460

1.2460 / 1.1844 x 100% ≈ 105.2%

COMP RG	CHART RG	ENTRY RG	
0	5480	5480	5500

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400
DIRECTION OF WIND (0720)	0700
	7100
DIRECTION OF FIRE (1800)	1800
CHART DIRECTION OF WIND	5300

POS DF CORR R1
+MET DF CORR L14
TOT DF CORR L13
-DFT@ADJ EL
GFT DF CORR

ROTATION CORR (L/R)	0.8	
DRIFT CORR (L)	8.3	
CROSSWIND CORR (L/R)	4.4	
MET DEFL CORR (L/R)	13.5~	L14

CROSS WIND: WIND SPEED 24 x COMP (L/R) 0.88 = (L/R) 21 KNOTS = 0.21 = UNIT CORR

RANGE WIND: WIND SPEED 24 x COMP (T/H) 0.47 = TAIL/(HEAD) 11 KNOTS

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS	
RANGE WIND	(H) 11	0	(H) 11	+7.5	82.5		
AIR TEMP	94.0	100%	(D) 6.0	+13.2	79.2		
AIR DENSITY	104.1	100%	(I) 4.1	+7.3	29.9		
PROJ WEIGHT	5▯	4▯	(I) 1▯	+34.0	34.0		
ROTATION	-18 X	0.87				15.7	
POS VE + MVV = VE; -1.1 + -6.3 = -7.4					225.6	15.7	
					15.7		
				MET RANGE CORR	209.9	~	+210

COMPUTATION OF VE

PROP TEMP +62 °F	VE	-7.4 M/S	D +28.5	TOTAL RANGE CORRECTION		
	CHANGE TO MV FOR PROP TEMP	-0.4 M/S	I -22.9	MET RANGE CORRECTION	+210	
	ΔV	-7.8 M/S	MV UNIT CORRECTION +28.5	ΔV RANGE CORRECTION	+222	
				TOTAL RANGE CORRECTION	+432	+430

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
ΔV	(D) 7.8			
RANGE WIND	(H) 11			
AIR TEMP	(D) 6.0			
AIR DENSITY	(I) 4.1			
PROJ WEIGHT	(I) 1▯			

5480

TOTAL FUZE CORRECTION	
MET FUZE CORRECTION	
FUZE CORRECTION	-0.5
TOTAL FUZE CORRECTION	

TARGET NO	MET CHECK GAUGE PT	BATTERY	DATE/TIME
		A	271000RMAY13

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Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-29. DA Form 4200 with Total Deflection and Total Range Corrections.

MET DATA CORRECTION SHEET

For use of this form, see TC 3.09-81; the proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE		
CHARGE: 1L	ADJ QE	CHART RG: 5480	LATITUDE: 30° N	TYPE MESSAGE: METCM	OCTANT: 1	AREA/UNIT: 342 988

BATTERY DATA		MET MESSAGE				
ALT OF BTRY (10m) (395)	400	DATE: 27	TIME: 1430		ALT MDP: 290	PRESSURE: 108.8
ALT OF MDP	290	LINE NO.: 02	WIND DIR.: 0700	WIND SPEED: 24	AIR TEMP: 94.2	AIR DENSITY: 105.2
BTRY (ABOVE) / BELOW MDP (Δh)	+110	Δh CORRECTION			+ / (−) 0.2	+ / (−) 1.1
ALT OF TARGET (nearest meter)		CORRECTED VALUES			94.0	104.1
HEIGHT OF BURST ABOVE TARGET		269.3 / 285.9 x 100% ≈ 94.2%		963 x 0.34836764 / 269.3 = 1.2460		1.2460 / 1.1844 x 100% ≈ 105.2%
ALT OF BURST						
ALT OF BTRY (nearest meter)						
HEIGHT OF TARGET (burst) ABOVE GUN (M)	0	COMP RG: 0		CHART RG: 5480	ENTRY RG: 5480	5500

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	POS DF CORR R1
DIRECTION OF WIND	0700	+MET DF CORR L14
	7100	TOT DF CORR L13 -DFT@ADJ EL L9 GFT DF CORR L4
DIRECTION OF FIRE (1800)	1800	ROTATION CORR (L) R: 0.8
CHART DIRECTION OF WIND	5300	DRIFT CORR (L): 8.3
CROSS WIND — WIND SPEED 24 X COMP (L) R 0.88	(L) R 21 KNOTS = 0.21 UNIT CORR	CROSSWIND CORR (L) R: 4.4
RANGE WIND — WIND SPEED 24 X COMP H (T) 0.47	TAIL / (HEAD) 11 KNOTS	MET DEFL CORR (L) R: 13.5~ — L14

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T (H) 11	0	T (H) 11	+7.5	82.5	
AIR TEMP	94.0	100%	I (D) 6.0	+13.2	79.2	
AIR DENSITY	104.1	100%	D (I) 4.1	+7.3	29.9	
PROJ WEIGHT	5▯	4▯	D (I) 1▯	+34.0	34.0	
ROTATION	-18 X	0.87				15.7
POS VE + MVV = VE -1.1 + -6.3 = -7.4					225.6	15.7
					15.7	
				MET RANGE CORR	209.9	~ +210

COMPUTATION OF VE

PROP TEMP +62 °F	VE	-7.4 M/S	D +28.5	TOTAL RANGE CORRECTION	
	CHANGE TO MV FOR PROP TEMP	-0.4 M/S	I -22.9	MET RANGE CORRECTION	+210
	ΔV	-7.8 M/S	MV UNIT CORRECTION +28.5	ΔV RANGE CORRECTION	+222
				TOTAL RANGE CORRECTION	+432 +430

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ M/S

FS@ ADJ EL 23.1 ~ 23

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
ΔV	(D) 7.8	-0.062		0.484	5910 / +430
RANGE WIND	T (H) 11	-0.011		0.121	5480 397 21.7
AIR TEMP	I (D) 6.0	-0.026		0.156	-1.4
AIR DENSITY	D (I) 4.1	-0.009		0.037	23.1
PROJ WEIGHT	D (I) 1▯	-0.084		0.084	TOTAL FUZE CORRECTION
			0	0.882	MET FUZE CORRECTION: -0.9
				0	FUZE CORRECTION: -0.5
				0.882	TOTAL FUZE CORRECTION: -1.4

TARGET NO | MET CHECK GAUGE PT | BATTERY A | DATE/TIME 271000RMAY13

GFT A CHG 1 LOT A/L RG 5480 EL 397 TI 21.7 (M767)
TOT DF CORR L13 GFT DF CORR L4

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Legend:
ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 11-30. Completed DA Form 4200 Containing the Met to Met Check Gauge Point Eight Direction Met.

11-49. Certain combat conditions may require a firing unit to provide accurate artillery support throughout a 6400-mil zone. Transfer limits define an area within which total corrections are assumed to be valid. These transfer limits place a severe limitation on a 6400-mil firing capability. Total corrections could be obtained by conducting a registration in each 800-mil sector of the unit's area of responsibility. Such registrations, however, would be costly and would endanger unit survivability. An alternative to registering in each 800-mil sector is the use of the eight-direction met technique.

11-50. The eight-direction met technique provides corrections to range, deflection, and fuze setting to compensate for the effects of ballistic wind direction and speed and for rotation of the earth throughout the firing unit's area of responsibility. These corrections are combined with the position constants determined in the concurrent met by using subsequent met procedures (starting either with position constants from a registration or allowing position constants to equal zero) in each 800-mil sector or selected 800-mil sectors. (See figure 11-31.)

11-51. Lateral transfer limits can be eliminated for ranges of 10,000 meters or less by solving an eight-direction met. For ranges greater than 10,000 meters, because the lateral transfer limits are valid 4,000 meters left and right of the battery registration point, there will be areas between the 800-mil segments that are not covered by valid corrections. When needed, corrections to cover these areas must be computed by using the met-to-target technique.

11-52. The eight-direction met technique consists of two steps:

- Solution of a concurrent met technique to determine the position VE correction, position deflection correction, and position fuze correction.
- Solving for met corrections for other 800-mil segments by use of the met + VE technique and the position constants to determine GFT settings for those octants. Eight hundred mils must be applied to the original direction of fire in order to determine corrections in each octant.

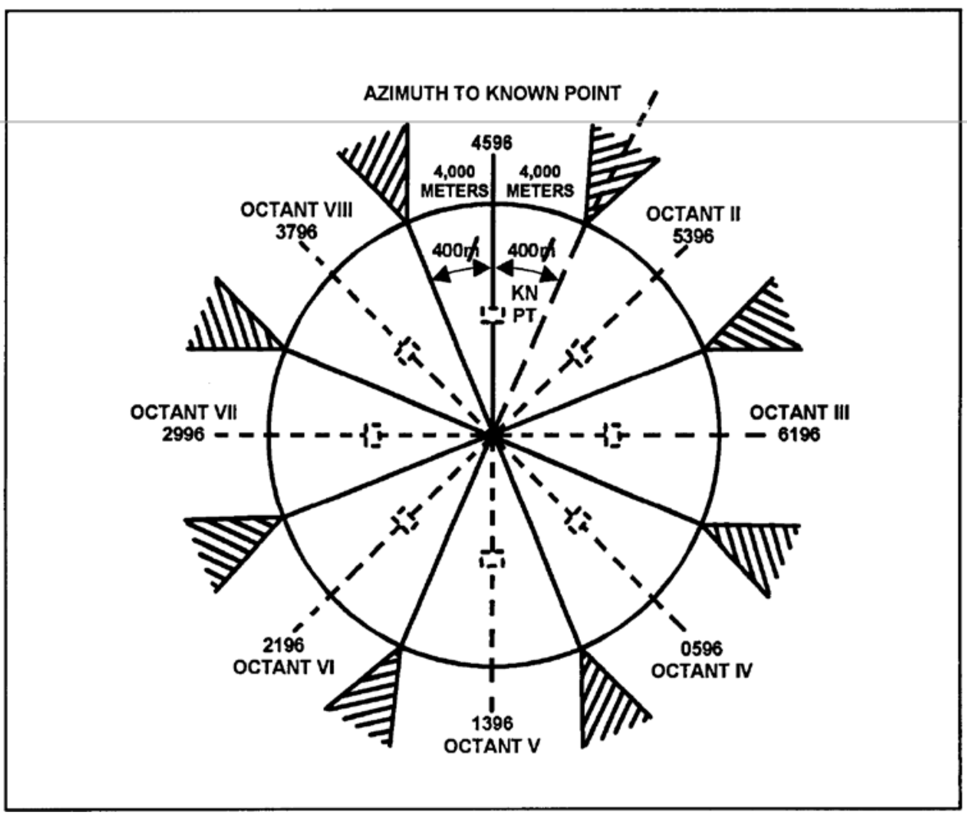

Figure 11-31. Octants.

Note: The direction of fire will be different for each octant. The value used for altitude of target is the altitude of the registration point. The **FS ~ ADJ EL** will be determined on the basis of the computed adjusted elevation. The eight-direction met technique could be solved without registering. The procedures would be identical to solving a met to met check gauge point, with the exception that all position constants would be zero.

MET TO A TARGET

11-53. Because of the restrictions of transfer limits for the total corrections represented by a GFT setting, there are areas beyond 10,000 meters that are not covered by normal eight-direction met techniques. If a target that requires accurate surprise fires appears in one of the areas, a met to the target is solved. A met to target may also be solved for situations when the unit needs to fire a projectile that they did not register with (for example, M549A1 RAP). Because of the time needed to solve a met to a target, this technique is usually reserved for those situations requiring FFE fires against a "high-payoff" target.

11-54. The met-to-target technique consists of the two steps below.

- Solution of a concurrent met to determine the position VE, position deflection correction, and position fuze correction. If position constants are not available, use zero for these values.
- Solving for met corrections by using the chart range and direction to the target and the position constants to determine a GFT setting. The chart range used is the range to the target. The direction of fire is determined on the basis of the chart direction to the target. The met line number and complementary range are determined from Table B on the basis of the chart range to the target and the height of target above gun.

COMPUTING A GFT SETTING FOR AN UNREGISTERED CHARGE

11-55. When data from a registration and concurrent met are known, the FDC can derive a GFT setting for an unregistered charge.

11-56. Total corrections for the unregistered charge are determined by applying the position constants determined for the registered charge to the met corrections for the unregistered charge. This is done by using the following steps:

11-57. Determine the range to a met check gauge point on the GFT for the unregistered charge. This will be used as the chart range on the met data correction sheet. The entry range will be the met check gauge point range expressed to the nearest 100 meters. The altitude of the target is the same as the battery altitude.

Note: All corrections from the TFT are based on the unregistered charge.

11-58. Compute the total deflection correction as follows:

- Compute the met deflection correction by use of the met data correction sheet.
- Add the position deflection correction determined from the registered charge to the newly computed met deflection correction for the unregistered charge. The sum is the total deflection-correction for the unregistered charge.

Note: The position deflection correction generally accounts for errors in survey and chart construction. These errors are independent of charge in that they remain constant regardless of the charge fired. Therefore, it is valid to apply a position deflection correction determined for one charge to other charges.

11-59. Compute the total range correction and adjusted elevation as follows:

- Add the position velocity error for the registered charge to the MVV to determine the VE.
- Add the MVV correction for propellant temperature to the VE to determine the ΔV for the unregistered charge.
- Multiply the ΔV by the appropriate MV unit correction to determine the ΔV range correction.
- Add the ΔV range correction to the met range correction for the unregistered charge to determine the total range correction.
- Add the total range correction to the chart range (range to the met check gauge point) to determine the range corresponding to adjusted elevations.
- Set the adjusted range under the MHL of the GFT, and read the adjusted elevation for the unregistered charge.

Note: Position velocity errors caused by survey and chart errors are charge independent and, therefore, can be transferred to other charges. Muzzle velocity variations can be transferred to all preferred charges within the same charge group and lot.

11-60. Compute the total fuze correction as follows:

- Determine the fuze setting corresponding to the adjusted elevation.
- Compute the met fuze correction.
- Add the met fuze correction to the position fuze correction determined for the registered charge. The sum is the total fuze correction. Apply this correction to the fuze setting corresponding the adjusted elevation to determine the adjusted fuze setting for the unregistered charge.

Note: The position fuze correction is a constant fuze characteristic. Fuze characteristics are independent of the charge fired. The position fuze correction is similar to a known fuze setting correction, which is determined historically by observing the performance of a particular lot of fuzes.

11-61. Compute the GFT deflection correction by subtracting the drift correction corresponding to the adjusted elevation for the unregistered charge from the total deflection correction. The remainder is the GFT deflection correction for the unregistered charge.

MET + VE

11-62. Registrations may not always be practical or necessary on the basis of the current tactical situation. If a battery is meeting the five requirements for accurate fire (less accurate target location), there is still a need to improve the data read from the GFT. A GFT setting can be determined by solving the subsequent met application known as a met + VE technique. The steps for working a met+ VE are similar to the other subsequent met applications. Since no registration has been conducted and position constants were not isolated, position constants are not considered (use zero for these values).

11-63. For accuracy, the chart ranges used for the met+ VE technique should correspond to met check gauge points, unless the met-to-target technique is being used. The altitude of target will be the same as the battery altitude unless the met-to-target technique is used.

11-64. The direction of fire will correspond to the chart direction to the center of the zone of responsibility or the target.

11-65. The values for position deflection correction, position velocity error, and position fuze setting will be recorded as zeros (0).

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Chapter 12

Terrain Gun Position Corrections and Special Corrections

To enhance survivability on the battlefield, a unit must take maximum advantage of the natural cover and concealment offered by the terrain and vegetation (figure 12-1). When howitzers are so positioned, corrections may be required to obtain an acceptable burst pattern (sheaf) in the target area. These corrections compensate for the differences in muzzle velocity between howitzers and terrain positioning of the weapons. When FFE rounds impact in the target area, the results, to a large extent, depend on how well the sheaf fits the size and shape of the target.

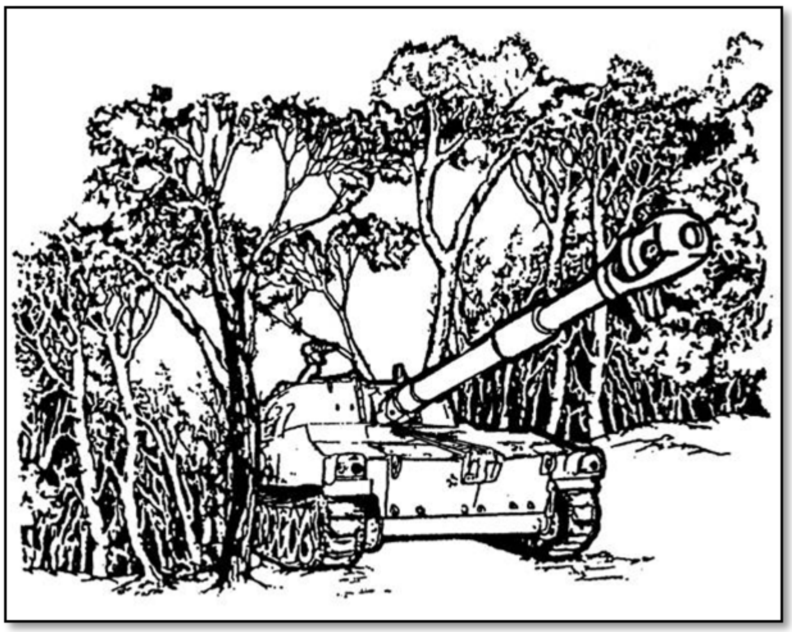


Figure 12-1. Maximum Advantage of Cover and Concealment.

SECTION I: TYPES OF CORRECTIONS

12-1. Artillery fires can be computed to fit the size and shape of the target by computing corrections for the following:

- Individual howitzers displacements (position corrections).
- Shooting strength of each howitzer (muzzle velocity corrections).
- Target size, shape, and attitude (irregularly shaped targets)

OVERVIEW

12-2. ***Terrain gun position corrections*** **(TGPCs) are individual howitzer corrections applied to the gunner's aid on the panoramic telescope (pantel), the correction counter on the range quadrant, and the fuze setting of each howitzer**.

12-3. ***Special corrections* are individual howitzer corrections applied to fuze settings, deflection, and quadrant elevation to place the FFE bursts in a precise pattern on the target**.

12-4. Special corrections and TGPCs include corrections for the location of each weapon in the firing unit area (position corrections) and for the shooting strength of each weapon (muzzle velocity corrections).

- The goal of TGPCs is to compute corrections to obtain an acceptable sheaf in the target area.
- The goal of special corrections is to compute aimpoints tailored to fit the target size, shape, and attitude.

HOWITZERS DISPLACEMENT

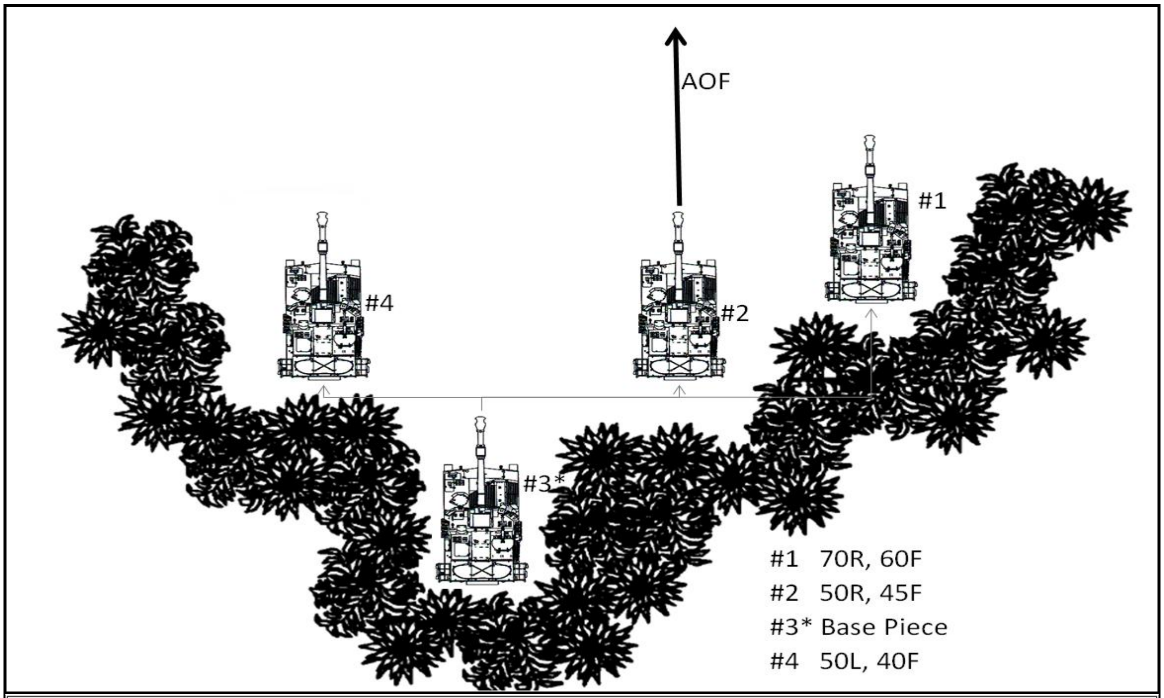
12-5. To determine position corrections, the relative position of howitzers in the firing unit area must be known (howitzers displacement). Howitzers displacement is the number of meters the howitzers is forward or behind and right or left of the base piece. It is measured on lines parallel (forward or behind) and perpendicular to (right or left) the azimuth of fire. (See figure 12-2 on page 12-3.)

12-6. Howitzers displacement (figure 12-2) can be determined by estimation and/or pacing, by hasty traverse, or by survey. Usually, estimation and pacing are not accurate enough for the large displacement distances involved in firing unit positions. The hasty traverse technique is a quick, accurate means of determining howitzers displacement by using the M17 or M19 plotting board. The survey technique provides grid coordinates for each weapon location.

12-7. Estimation is the least desirable method to determine howitzers displacement. Using this technique, the XO or platoon leader estimates the displacement of the howitzers from the base piece both parallel and perpendicular to the azimuth of lay. The pacing technique is fairly accurate in small open areas, but it is time consuming. The XO or platoon leader uses this technique to determine displacement by pacing from the base piece both parallel and perpendicular to the azimuth of lay.

12-8. The hasty traverse technique is a graphic solution of howitzers displacement that uses the M17 or M19 plotting board. The advance party provides the FDC with the initial lay deflection; distance and vertical angle to each howitzer position from the aiming circle (AC).

12-9. The survey method is the most accurate method. Field artillery survey crews provide a surveyed grid and altitude to each weapon position. Howitzers displacement is computed by determining the difference between the grid coordinates from the base piece to each weapon position.



Legend: AOF – azimuth of fire

Figure 12-2. Howitzer Displacement.

SHEAFS

12-10. A target is covered by fire through controlling the pattern of bursts (sheaf) on the target.

12-11. When firing a parallel sheaf, the rounds impact at the target in generally the same pattern formed by the howitzers in the firing unit area. The width and depth of the unit's sheaf are always measured on a line perpendicular to the line of fire. As the line of fire changes, so does the width and depth of the unit's sheaf. (See figure 12-3 on page 12-4.)

12-12. A parallel sheaf does not require TGPCs or special corrections. All weapons fire the same deflection and quadrant.

12-13. There are three basic types of sheafs that may be obtained with TGPCs and special corrections.

- **Converged sheaf.** All weapons have the same aimpoint.
- **Open sheaf.** Aimpoints are separated by one effective burst width. Figure 12-4 on page 12-4 shows sheaf widths for an open sheaf. The open sheaf width equals the number of howitzers multiplied by the projectile effective burst width.

Note**:** For manual computations of TGPCs and special corrections with an M17 plotting board, a width of 30 meters is used for the 105-mm howitzer for ease of computation.

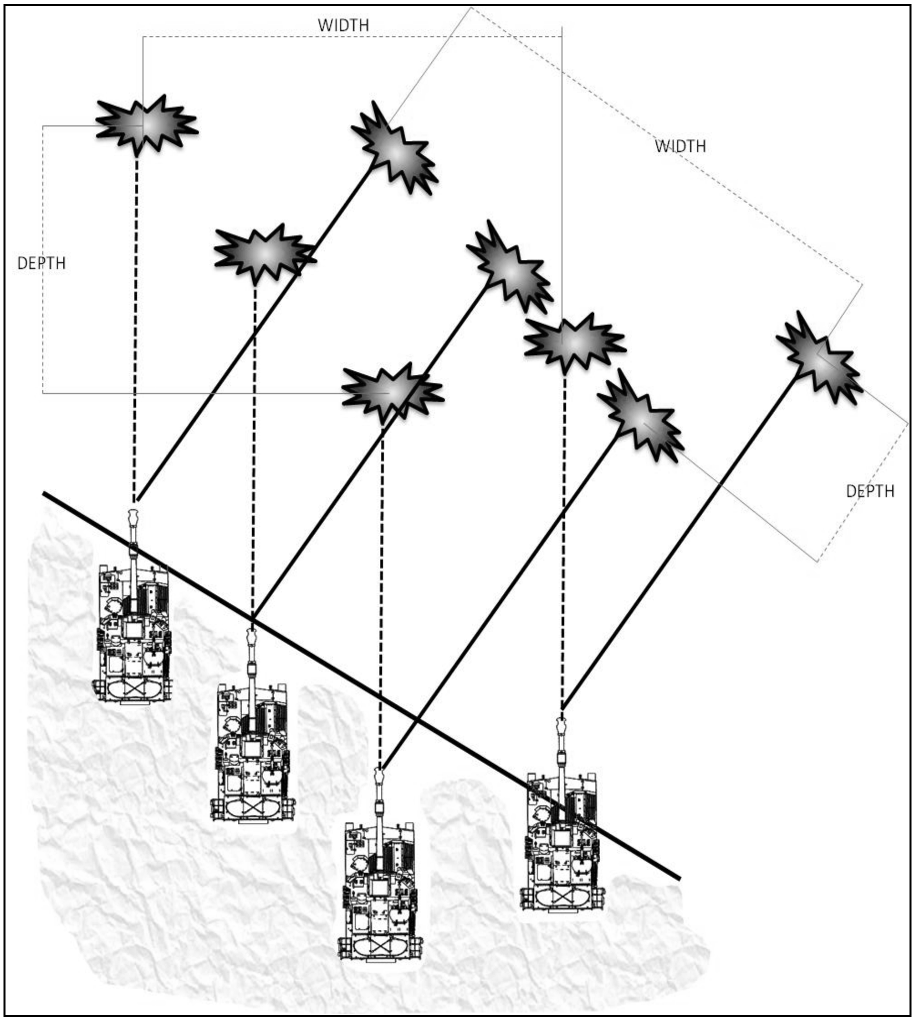


Figure 12-3. Changes in the Sheaf Caused by a Change in the Line of Fire.

- **Special sheafs.** Special sheafs are sheafs other than parallel, converged, or open.
  - **Linear**. The sheaf is described by a length and attitude, or by two grids. Aimpoints are evenly distributed along the length of the sheaf along the attitude specified.
  - **Rectangular**. The sheaf is described by a length, width, and attitude. Aimpoints are evenly distributed along two lines equal to the length and parallel to the attitude specified.
  - **Circular**. The sheaf is described by a grid and a radius. Aimpoints are evenly distributed on a concentric circle half the radius specified.
  - **Irregular.** The sheaf is described by a series of grids. Aimpoints are evenly distributed along the length of the sheaf.

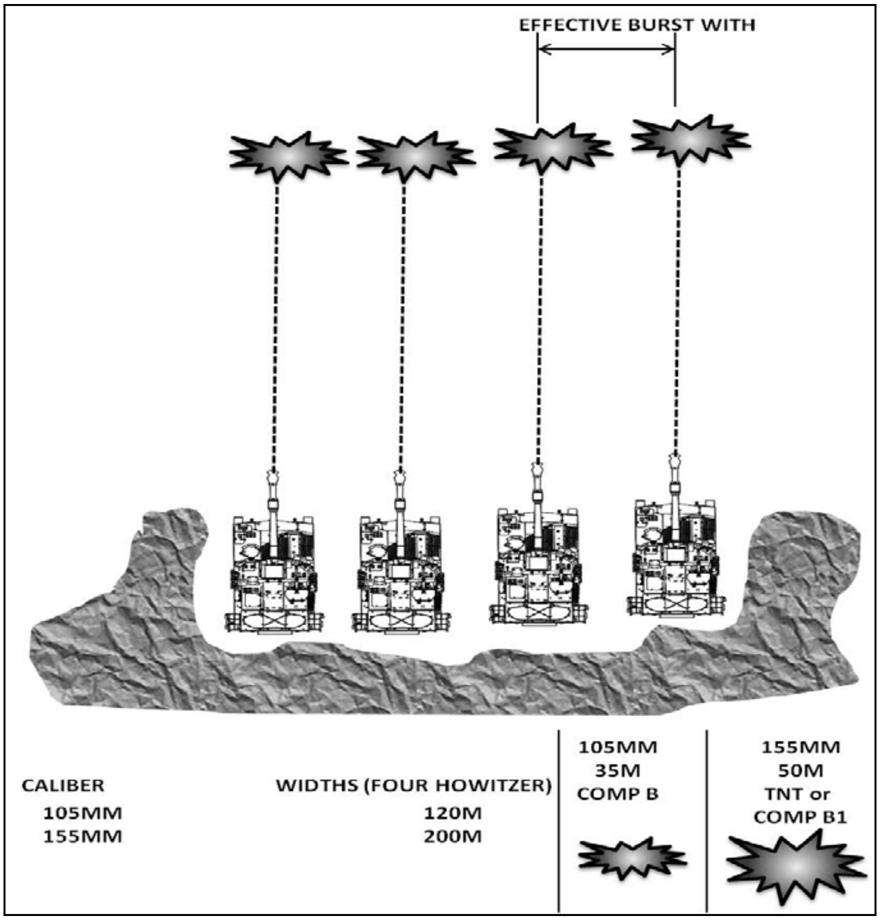


Figure 12-4. Projectile Effective Burst Widths and Open Sheaf Widths.

SECTION II: THE M17/M19 PLOTTING BOARD

12-14. The M17 and M19 plotting boards are versatile pieces of the fire direction set. The M17 and M19 plotting boards are similar and used to determine TGPCs and special corrections.

M19 PLOTTING BOARD

12-15. **General**. The M19 plotting board consists of a rotating disk of transparent plastic and a removable range arm, both attached to a flat grid base (figure 12-5, page 12-6).

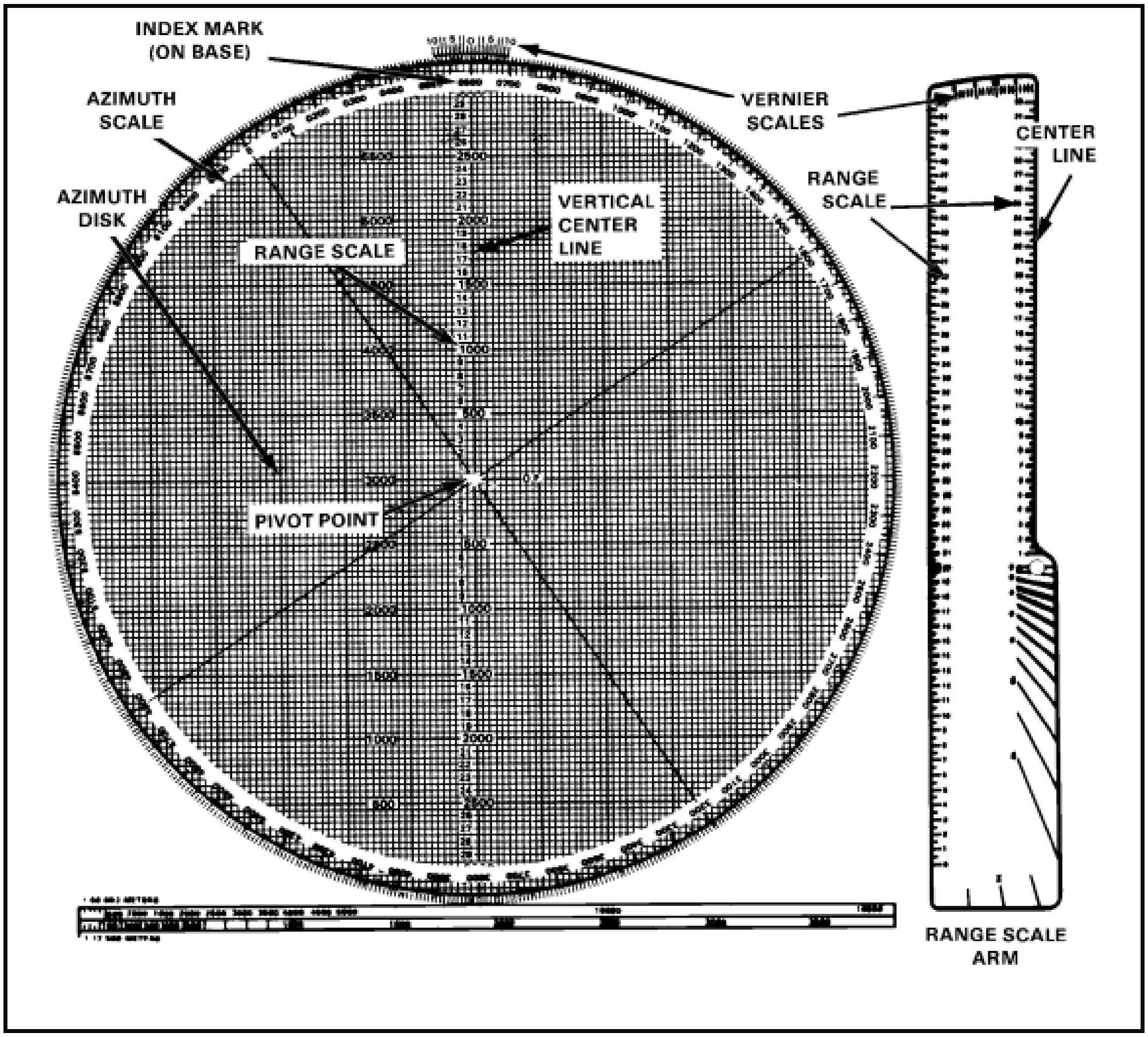


Figure 12-5. M19 Plotting Board.

THE M19 PLOTTING BOARD PARTS

12-16. **Base**. The base is a white plastic sheet bonded to a magnesium alloy backing. A grid is printed on the base in green at a scale of 1:25,000. The vertical centerline is graduated and numbered up and down from the center (pivot point) (from 0 through 32) in hundreds of meters with a maximum range of 3,200 meters. Each small grid square is 100 meters by 100 meters.

- The index mark points to the center of the □ernier scale at the top edge of the plotting board. It is the point at which deflections or azimuths may be read to the nearest 10 mils. When plotting at the pivot point, the pivot point represents the location of the base piece.
- In addition to the grid pattern, a □ernier scale is printed on the base. It is used to obtain greater accuracy when reading the mil scale on the azimuth disk. The □ernier scale permits the operator to read azimuths and deflections accurately to the nearest mil.
- On the bottom of the base, a double map scale in meters with representative fractions of 1:50,000 and 1:12,500 is used to transfer to and from a map that has one of those scales.

12-17. **Azimuth Disk**. The rotating azimuth disk is made of plastic. It is roughened on the upper surface for marking and writing. A mil scale on the outer edge is used for plotting azimuths and angles. It reads clockwise to conform to the azimuth scale of a compass. The scale is divided into 10-mil increments (from 0 to 6400) and is numbered every 100 mils. Also, the disk has two black lines called centerlines. These centerlines are printed across the center of the disk from 0 to 3200 and from 1600 to 4800 mils.

12-18. **Range Scale Arm**. The range scale arm is used when the base piece are plotted at the pivot point. It is made of plastic and can be plugged into the pivot point. Two range scales are on the range scale arm. On the right edge is a range scale that corresponds to the range scale found on the vertical centerline. An alternative range scale ranging from 0 to 6,000 meters is on the left edge of the range scale arm and is used when plotting away from the pivot point. The □ernier scale at the upper end of the range scale arm is used to read azimuths or deflection when plotting at the pivot point without rotating the disk back to the vertical centerline. The direction of the FO can be kept indexed at the index point. The □ernier scale on the range scale arm is read in reverse of the one on the grid base. The left portion is read for azimuth, and the right portion is read for deflection. The protractor lines below the range scale arm knob may be used to place a sector of fire on the disk.

- To read azimuth to 1 mil, read the left portion, starting at 0, and read to the 10 in the center.
- To read deflections, start at the right edge of the range scale arm and read to 10.

CAPABILITIES

12-19. The straightedge of the plotting board should always be on the user's right. Each plot is circled and numbered for identification. To avoid distortion, the computer should place his eye directly over the location of a plot and hold the pencil perpendicular to the board. The plot should be so small that it is difficult to see. The computer must be careful when placing a plot on the disk since a small plotting error could cause the final data to be off by as much as 25 meters in range and more than 10 mils in deflection.

12-20. To determine azimuths, read the first three numbers from the azimuth disk, left of the index mark. Read the fourth number, or the last mil, by using the azimuth disk and the right side of the □ernier scale (see figure 12-6).

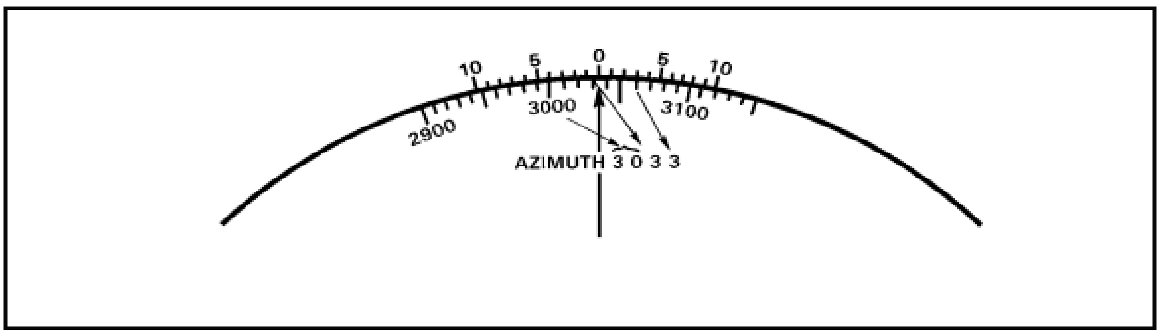


Figure 12-6. The Vernier Scale.

12-21. For example, consider the azimuth 3033 in figure 12-6. The first and second numbers are the first 100-mil indicator to the left of the index mark (30). To obtain the third number, count the 10-mil graduations between the 100-mil indicator and the index mark (3). The fourth number, or last mil, is read by counting the 1-mil graduations from 0 to the right on the □ernier scale until one of the 1-mil graduations align with one of the 10-mil graduations on the azimuth disk (3).

M17 PLOTTING BOARD

12-22. **General**. The M17 plotting board (see figure 12-7 on page 12-8) is a portable fire control instrument designed to help the operator in computing firing data for range and azimuth of a target for indirect firing of the weapon. The plotting board utilizes known range and azimuth data from the weapon to an observation post, in combination with reported data received from the post concerning location of the target with respect to the post. It is used to compute geometrically the range and azimuth of the target from the weapon.

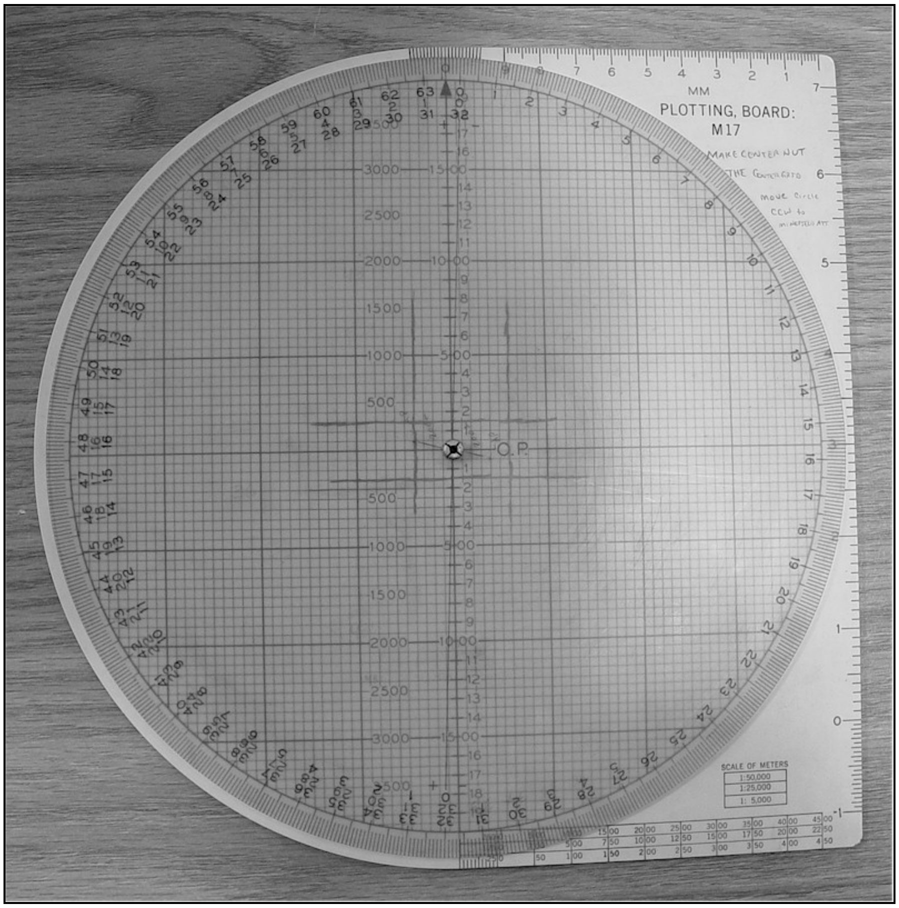


Figure 12-7. M17 Plotting Board.

THE M17 PLOTTING BOARD PARTS

12-23. Basic Components. Plotting board M17 is a two-part assembly and consists fundamentally of a base and an azimuth disk.

12-24. Base. The base is composed of white laminated plastic to which a pivot is secured to accommodate the azimuth disk. The azimuth disk is centrally mounted, and may be rotated on the pivot. The base is square on the right edge. The left edge, beginning at the index line is semicircular. The top and bottom edges are straight and parallel to each other, from the right edge to the index line. The surface of the base is roughened slightly to receive pencil markings during firing problem computation. In addition to the plotting board name and model number, the base contains those markings on its surface described below. (Printing on the base surface is black, unless otherwise stated.):

- The right edge of the base has a scale 8 inches long graduated in inches from 0 to 7 in one direction, with each graduation subdivided into tenths of an inch. The remaining 1 inch, from 0 to -1 in the opposite direction, is divided into twentieths of an inch.
- The top edge of the base has a scale 9 centimeters long graduated in centimeters from 1 to 9 and reading from right to left. Each graduation is divided into millimeters. The figures 1 through 9 and the letters MM are red.
- The Vernier scale on the top edge of the base is graduated into 20 equal spaces. The central graduation line of the scale is directly above the centrally located index mark. Ten equal divisions of the scale are located to each side of the index mark. The □ernier scale marking is red.
- At the bottom of the base is a triple map scale graduated in meters with its legend and representative ratios of 1:50,000, 1:25,000, and 1:5,000. These representative ratios refer

respectively to the top, middle, and lower scales. These scales are used to transfer data to or from a map or firing chart which has one of these scales. The triple map scale is 1 decimeter long and is divided into 10 divisions of 1 centimeter each. The first division, to the right of the index line is equally divided into 10 spaces of 1 millimeter each. The nine graduation lines in the first division and all figures in the middle scale are red.

- The grid pattern is in closed within an 8.000-inch circle. A series of l-inch vertical and horizontal squares and parts of squares are located within the circle parallel to the index and O. P. (observation post) lines. Each complete l-inch square is divided into 100 equal squares. Twenty-eight incomplete 1-inch squares, bordering on the circle, contain varying amounts of smaller squares and parts of squares. There are 78 equally spaced vertical and horizontal lines and 80 equal vertical and horizontal squares along the index and O.P. lines. All marking is red.
- The index line, passing through the center of the grid pattern, has an arrow touching the top inside diameter of the circle. The arrow points to the 0 (zero) index mark. A thin line, from the point of the arrow, intersects the index mark and extends to, and becomes the centerline of, the ernier scale. This thin line is the point on the plotting board base at which all deflections are read. The index line is graduated 2000 meters, in fifty meter increments and is numbered from 1 to 19. These numbers are spaced on every second horizontal fine line. Each small square on the grid pattern is, therefore, 50 meters on a side. The numbers to the left of the index line indicate double values for the grid squares. Each small square is, therefore, 100 meters on a side when the double value scale is used. However, any value may be assigned to the small grid square which best suits the problem at hand. All marking is red.

12-25. **Azimuth disk**. The azimuth disk is a transparent, semi-rigid, plastic disk with graduations printed around the entire outer edge and a centerline which runs through the central pivot point When the pivot point in the disk is on the pivot in the base, and the base is stationary, the disk can be rotated to all positions within 6400 mils.

- The surface of the azimuth disk, facing the operator, is slightly roughened to take pencil marks which can be erased following completion of a problem.
- A thin centerline is printed across the diameter of the disk and intersects the pivot point. Red plus and minus marks are printed near both ends of the centerline for use in computing angles of site.
- An azimuth scale graduated in mils is printed around the entire outer edge of the disk in a clockwise direction to conform to the compass and is used to plot azimuth angles. This scale is graduated in 10-mil increments from 0 to 6400 and numbered at 100-mil intervals from 0 to 63.
- A supplementary, middle mil scale having red figures is located on the plus side of the centerline, running counterclockwise from 0 to 32 and continuing on the minus side of the centerline to 5. This middle scale is numbered in hundreds of mils. It is used in computing angles of site.
- A supplementary, innermost mil scale also on the plus side of the centerline, begins at a point 180 degrees from the 0 (zero) on the middle scale. This scale runs clockwise from 0 to 32 and is numbered in hundreds of mils. It is also used in computing angles of site.

Note: In further discussions, the term “M17” will refer to the M17 and M19 plotting boards.

12-26. The gridded base is a white plastic board. The center area of the board is a circular gridded area called the target area. The grid pattern divides the target area into squares. The scale assigned to the grid pattern is at the discretion of the user, but most common scales for various operations are as follows:

OPERATION	SCALE	
Terrain Gun Position Correction	1 Square	= 10 meters
Special Corrections	1 Square	= 10 meters
Laser Adjustment of Fire	1 Square	= 100 meters
Target Location	1 Square	= 100 meters

12-27. The screw or rivet secures the disk to the base and maybe used to represent one of the following:

- Base piece.
- Target.
- Observer location.
- Location of the last burst.

Note: In the following sample problems, the M17 plotting board is viewed with the curved edge to the operator’s left and the description “top of the plotting board” refers to the side of the plotting board with the □ernier scale.

PLOTTING PIECE LOCATIONS FOR WEAPONS EQUIPPED WITH THE M100-SERIES SIGHT

12-28. Plotting Piece Locations for Weapons Equipped With the M100-Series Sight

- The following is an example of the platoon leader’s report for the M100-series sight:

HOWITZER	LAID FROM	LAY DEFLECTION	DISTANCE	VA
1	AC	2595	105	+3
2	AC	2910	55	+1
3(BP)	AC	3405	90	-2
4	AC	3950	100	-5

Note: Howitzer Number 3 is the base piece. The azimuth of lay is 4800 mils.

12-29. Table 12-1 shows the steps required to plot piece locations for weapons equipped with the M100-series sight.

Table 12-1. Plot Howitzer Location for Weapons with the M100-Series Sight.

STEP	***ACTION***
1	Plot the location of the aiming circle.
1a	Receive the XO’s report with the lay deflections, distances, and vertical angles from the aiming circle to the howitzers.
1b	Using the outer black scale, rotate the disk of the plotting board until the lay deflection of base piece is opposite the □ernier index.
1c	Count the distance from base piece (rivet) to the aiming circle from the center of the plotting board toward the **top** *of* the plotting board. Each square on the gridded base will represent 10 meters. Plot the aiming circle as a dot drawn with a soft-lead pencil at the appropriate distance. Circle the dot, and label it “AC.” (See figure 12-8, page 12-12.)
1d	The center of the plotting board represents the location of base piece. Label the rivet with the base piece number.
2	Plot the location of the pieces laid from the aiming circle.
2a	Rotate the disk of the plotting board until the lay deflection of the next howitzer on the outer black scale is opposite the □ernier index.
2b	Count the distance between the howitzers to the aiming circle **from the aiming circle location** toward the **bottom** of the plotting board. Each square on the gridded base will represent 10 meters. Plot the howitzer as a dot drawn with a soft-lead pencil at the appropriate distance. Circle the dot, and label it with the appropriate howitzer number.
2c	Plot the remainder of the howitzer(s) that were laid from the aiming circle by using the same procedures listed in steps 2 through 2b.

Table 12-1. Plot Howitzer Location for Weapons with the M100-Series Sight (continued).

STEP	*ACTION*
3	Plot the location of the howitzer laid from other howitzers.
3a	Rotate the disk of the plotting board until the lay deflection of the next howitzer on the outer black scale is opposite the □ernier index.
3b	Count the distance between the howitzer and the laying howitzer **from the laying howitzer location** toward the **bottom** of the plotting board. Each square on the gridded base will represent 10 meters. Plot the howitzer as a dot drawn with a soft-lead pencil at the appropriate distance. Circle the dot, and label it with the appropriate howitzer number.
3c	Plot the remainder of the howitzer(s) that were laid from another howitzer by using the same procedures listed in steps 3 through 3b.
4	Establish an azimuth index on the plotting board.
4a	Rotate the clear disk until 32 on the outer black scale is opposite the □ernier index.
4b	With a soft-lead pencil, draw an arrow on the outer edge of the gridded base so that it points to the azimuth of lay on the outer black scale. This arrow will be the azimuth scale.
5	Beginning at the red **32** graduation, continue the deflection scale by numbering the 100-mil graduations of the scale. Number the graduation in increasing order beginning to the left of the 32.
	NOTE: You must first line out the numbers 1 through 5 and then relabel them 33 through 37. (See figure 12-9 on page 12-13.)
6	Measure piece displacement.
6a	Rotate the disk of the plotting board until **32** of the outer black scale is opposite the □ernier index.
6b	Count the number of meters, left or right, from the base piece to the howitzer. (Each square on the gridded base represents 10 meters). This distance, measured to the nearest 5 meters, is the lateral displacement. The sign of the lateral displacement is left (L) or right I.
6c	Count the number of meters forward (toward the top of the plotting board) or back (toward the bottom of the plotting board) from the base piece to the howitzer. (Each square on the gridded base represents 10 meters.) This distance, measured to the nearest 5 meters, is the range displacement. The sign of the range displacement is + (forward) or- (back).
Legend: AC – aiming circle L – left R – right XO – executive officer	

12-30. The following data are an example of the howitzer displacement as shown in step 6 (table 12-2).

Table 12-2. Example of Howitzer Displacement.

HOWITZER	*LATERAL DISPLACEMENT*	*RANGE DISPLACEMENT*
1	R75	0
2	R35	+35
3	0	0
4	L50	+15
Legend: L – left R – right		

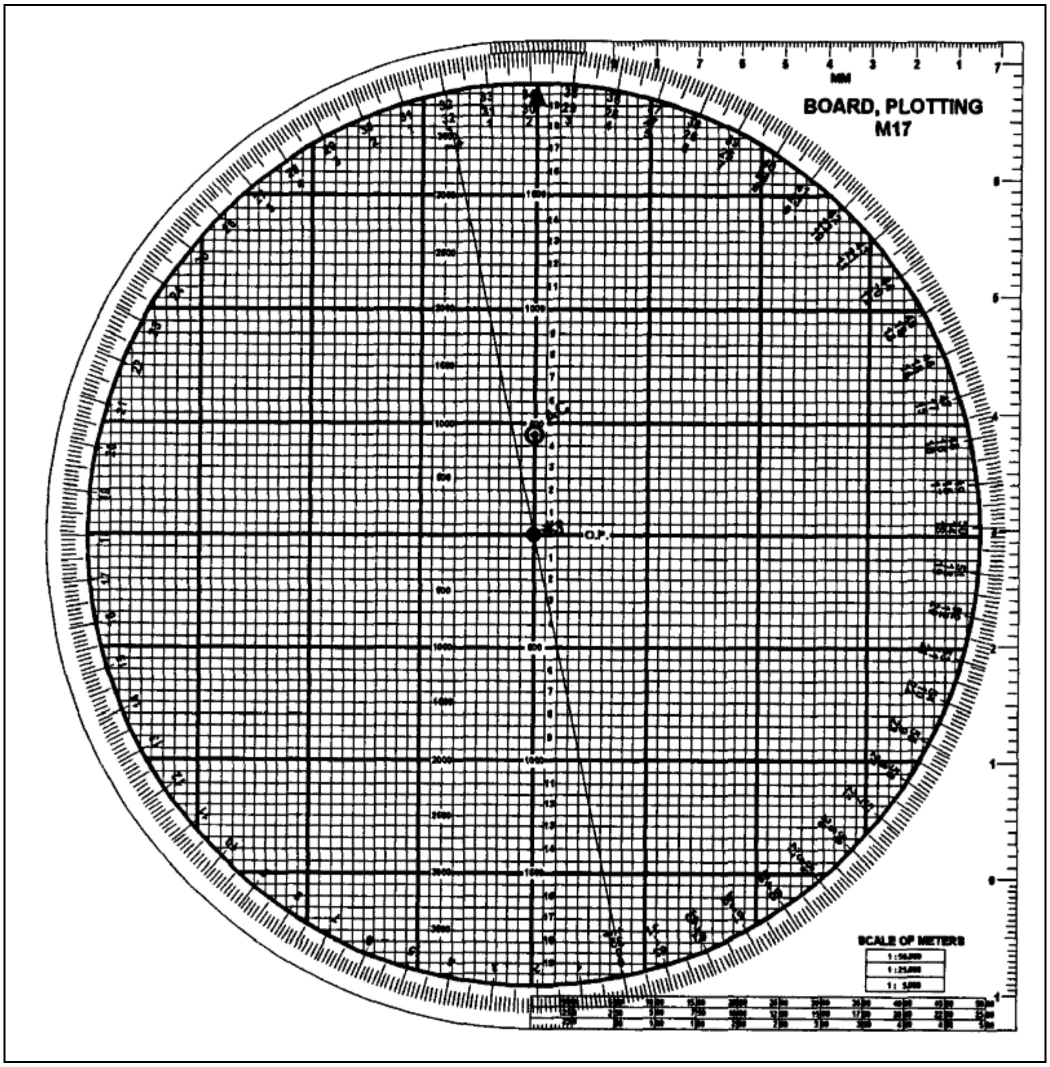


Figure 12-8. M17 Plotting Board With the Aiming Circle and Base Piece Plotted.

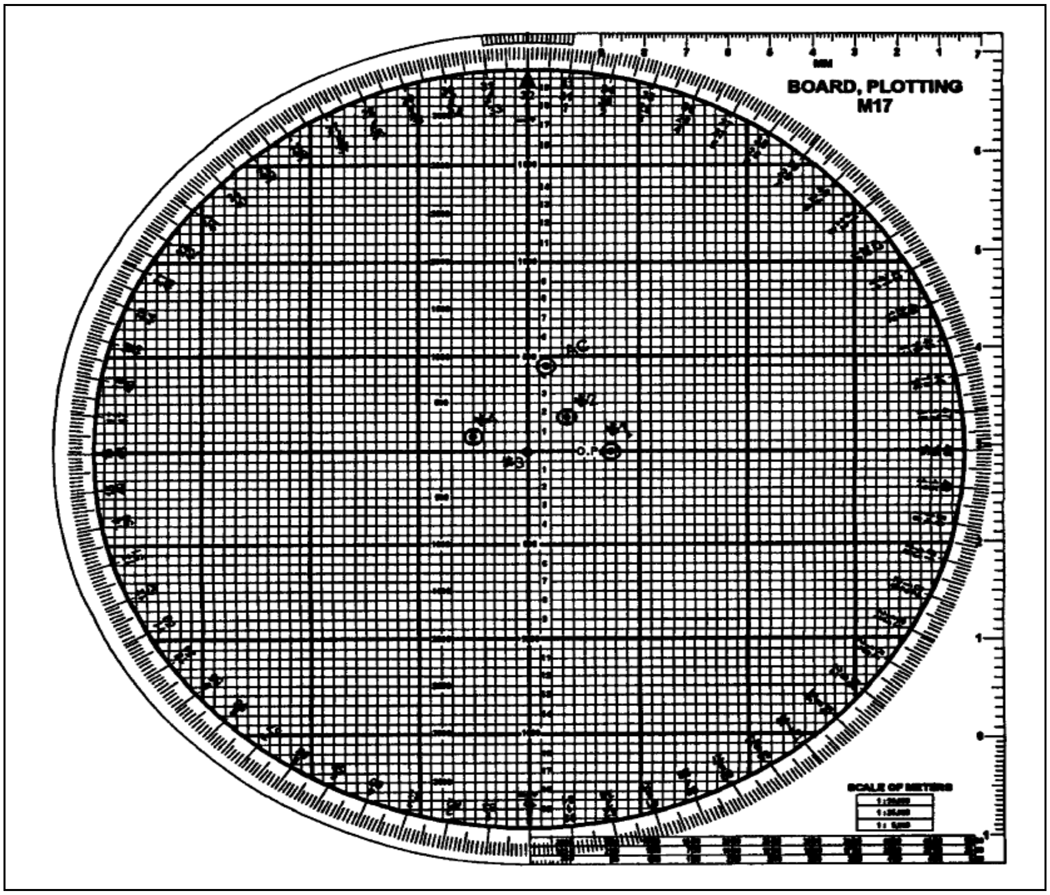


Figure 12-9. M17 Plotting Board with All Howitzers Plotted, Azimuth Index Established, and Deflection Scale Continued for the M100-Series Sight.

PLOTTING PIECE LOCATIONS FOR WEAPONS EQUIPPED WITH THE M12-SERIES SIGHT

12-31. Plotting Piece Locations for Weapons Equipped With the M12-Series Sight **a.** The M12-series sight is capable of determining deflection to a maximum value of 3,200 mils. The sight is graduated from 1 to 3200 twice to form a full circle. Consequently, every deflection has a "back deflection" of equal value in the opposite direction. This arrangement is indicated on the plotting board by the inner black scale. This scale is a lay deflection scale graduated from 0 to 3200. Care must be taken when setting up the plotting board to prevent the use of the wrong scale and thereby creating a **"mirror image"** of the battery. The use of the scales is dictated by the location of the howitzers in relationship to the position of the aiming circle. In the XO's report, the XO must indicate whether each piece is to the **left or right** of the aiming circle in respect to the azimuth of lay. If the lay deflection for a howitzer is exactly 3200, the XO's report must indicate whether that piece is forward (down range) or behind (the aiming circle is down range) in comparison to the aiming circle. The rules for the use of the scale are as follows:

- If the piece is left of the 0-3200 line as viewed from the aiming circle, **use the inner black scale.**
- If the piece is right of the 0-3200 line as viewed from the aiming circle, **use the outer black scale.**
- If the piece is on the 0-3200 line (lay deflection 3200) and behind as viewed from the aiming circle, **use the inner black scale.**
- If the piece is on the 0-3200 line (lay deflection 3200) and forward as viewed from the aiming circle, **use the outer black scale.**

12-32. For ease in determining whether a piece is left or right and forward or back, the XO need only realize that **if the piece is laid using the red graduations on the aiming circle it is to the left or forward of the aiming circle as you face the azimuth of fire.**

12-33. A simple alternative to the use of these rules is to have the XO report all lay deflections as they would be determined by using values read from the black numbered graduations of the aiming circle. **It is recommended that this method be unit SOP in an attempt to avoid confusion with the plotting board.**

12-34. The plotting of the pieces and establishment of an azimuth index are done by using the same procedures as described for the M100-series sight.

12-35. Piece displacement is determined by using the same procedures as described for the M100-series sight.

12-36. The following is an example of the platoon leader's report for the M12-series sight:

HOWITZER	LAID FROM	LAY DEFLECTION	DISTANCE	VA
1	AC	2595	105	+3
2	AC	2910	55	+1
3(BP)	AC	0205	90	-2
4	AC	0750	100	-5

Note**:** Howitzers 3 and 4 are left of the aiming circle. Azimuth of lay (AOL) equals 4800.

12-37. Use the steps in table 12-3 to plot piece locations for weapons equipped with the M12-series sight.

Table 12-3. Plot Howitzer Location for Weapons with the M100-Series Sight.

STEP	***ACTION***
1	Plot the location of the aiming circle.
1a	Receive the XO's report with the lay deflections, distances, and vertical angles from the aiming circle to the howitzers.
1b	Rotate the disk of the plotting board until the lay deflection of base piece on the outer (inner) black scale is opposite the □ernier index.
	NOTE: In this example, the aiming circle and number 4 were plotted using the **Inner black** scale. Number 1 and number 2 were plotted using the **outer black** scale.
1c	Count the distance from base piece to the aiming circle from the center of the plotting board toward the **top** of the plotting board. Each square on the gridded base will represent 10 meters. Plot the aiming circle as a dot drawn with a soft-lead pencil at the appropriate distance. Circle the dot, and label it "AC."
1d	The center of the plotting board represents the location of the base piece.
2	Plot the location of the howitzer laid from the aiming circle.
2a	Rotate the disk of the plotting board until the lay deflection of the next howitzer on the outer (inner) black scale is opposite the □ernier index.
2b	Count the distance between the howitzers to the aiming circle from the aiming circle location toward the bottom of the plotting board. Each square on the gridded base will represent 10 meters. Plot the howitzer as a dot drawn with a soft-lead pencil at the appropriate distance. Circle the dot, and label it with the appropriate howitzer number.
2c	Plot the remainder of the howitzer that were laid from the aiming circle.
3	Plot the location of the howitzer laid from other howitzers.
3a	Rotate the disk of the plotting board until the lay deflection of the next howitzer on the outer (inner) black scale is opposite the □ernier index.
3b	Plot the remainder of the howitzer that were laid from another howitzer.

Table 12-3. Plot Howitzer Location for Weapons with the M100-Series Sight (continued).

STEP	*ACTION*
4	Establish an azimuth index on the plotting board.
4a	Rotate the clear disk until 32 on the outer black scale is opposite the □ernier index.
4b	With a soft-lead pencil, draw an arrow on the outer edge of the gridded base that points to the azimuth of lay on the outer black scale and label it “AZ.” This arrow Is the azimuth index. (See figure 12-10.)
5	Establish a deflection index on the plotting board (M12-series sight).
5a	Rotate the clear disk until 32 on the outer black scale is opposite the □ernier index.
5b	With a soft-lead pencil, draw an arrow on the outer edge of the gridded base that point to the common deflection on the inner red scale and label it “OF.” This arrow Is the deflection index. (See figure 12-10.)
6	Beginning at the red 5 graduation, continued the deflection scale by numbering the 100-mil graduation of the scale. Number the graduations in increasing order beginning to the left of the 5. (See figure 12-8, page 12-11.)
Legend: AC – aiming circle AZ – azimuth XO – executive officer	

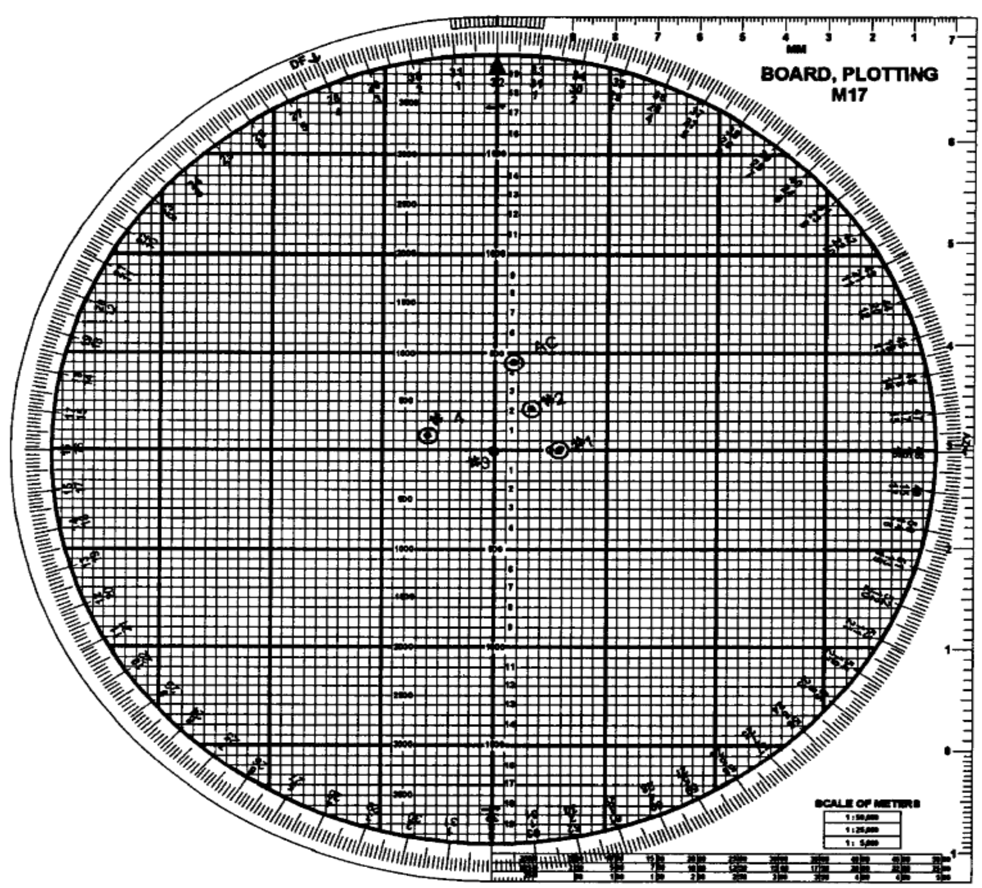


Figure 12-10. M17 Plotting Board with all Howitzers Plotted, Azimuth Index Established, and Deflection Scale Continued for the M12-Series Sight.

DETERMINATION OF BASE PIECE GRID COORDINATES

12-38. After the pieces have been plotted on the M17, the **base piece grid** can be determined by using the steps in table 12-4.

Note: The grid determined can be used to plot the base piece on the firing Chart.

Table 12-4. Determination of Base Piece Grid.

STEP	*ACTION*
1	Rotate the clear disk until the 0 on the outer black scale is opposite the azimuth Index.
2	From the aiming circle location, determine base piece displacement
3	Apply base piece displacement (displ) to the aiming circle coordinates to determine the base piece grid. LEFT DISPLACEMENT =DECREASE IN EASTING RIGHT DISPLACEMENT =INCREASE IN EASTING FORWARD DISPLACEMENT = INCREASE IN NORTHING BEHIND DISPLACEMENT = DECREASE IN NORTHING
	Note: using the example from paragraph 12-26 (page 12-8), determine the base piece grid. The advance party reported the grid to the aiming circle as E:37783 N:40821
4	Rotate the clear disk until the 0 on the outer black scale is opposite the azimuth index.
5	From the aiming circle location, determine base piece displacement (R90. B20)
6	Apply base piece displacement to the aiming circle coordinates to determine the base piece grid. RIGHT DISPLACEMENT (R90) = INCREASE IN EASTING (+90) BEHIND DISPLACEMENT (B20) = DECREASE IN NORTHING (-20) AIMING CIRCLE GRID 37783 40821 BASE PIECE DISPL +90 -20 BASE PIECE GRID 37873 40801

SECTION III: TERRAIN GUN POSITION CORRECTIONS

12-39. Terrain gun position corrections (TGPCs) are the pre-computed corrections carried on the howitzers to compensate for terrain positioning and muzzle velocity differences to achieve acceptable results in the target area. TGPCs should be computed each time the firing unit occupies a position. The use of TGPCs will allow the unit to effectively engage targets whose size and orientation requires a sheaf other than a parallel sheaf.

TRANSFER LIMITS AND SECTORS OF FIRE

12-40. Terrain gun position corrections are most accurate at the range and direction for which they are computed. They are considered valid 2,000 meters over and short of the center range and 400 mils right and left of the center azimuth of the sector. (See figure 12-11 on page 12-17.)

12-41. Terrain gun position corrections will provide an acceptable effect on the target provided the firing unit's position is within a box 400 meters wide and 200 meters deep. This box is centered over the firing unit center and oriented perpendicular to the azimuth of lay. If the firing unit is spread out more than 400 meters by 200 meters, degradation in effectiveness of sheafs can be expected as fires are shifted throughout the sector for which they were computed.

12-42. If a firing unit's area of responsibility covers an area larger than the terrain gun position corrections (TGPC) transfer limits, the unit should compute TGPCs for other sectors. Ranges to the centers of the other sectors may be different. Overlapping sectors for different charges may be necessary. (See figure 12-12.)

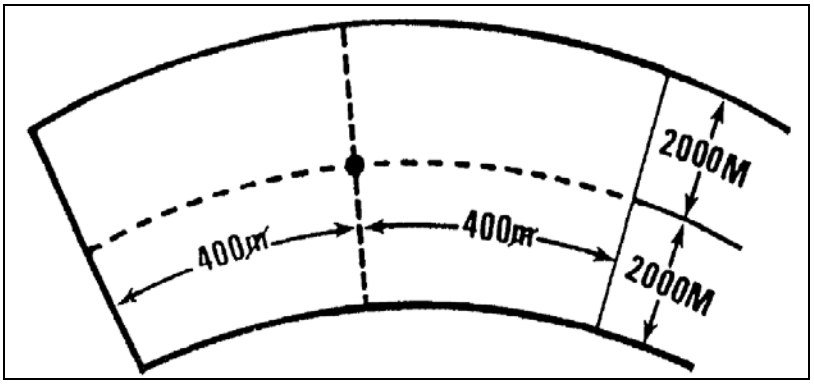


Figure 12-11. TGPC Transfer Limits.

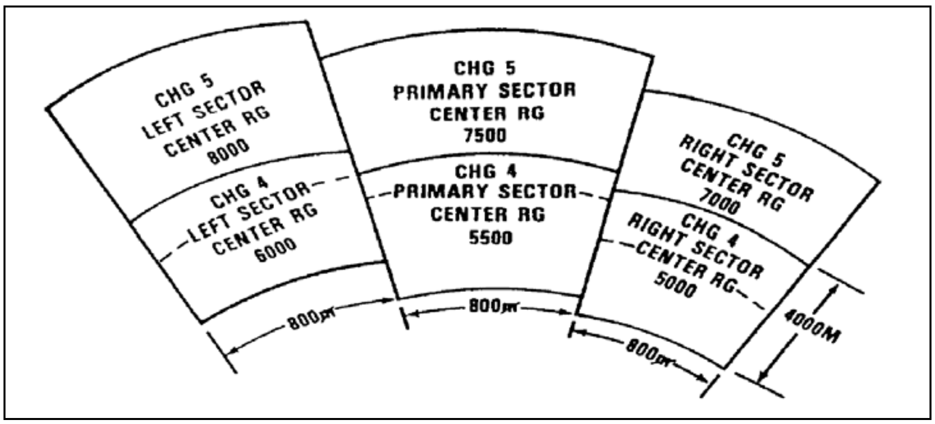


Figure 12-12. Three Sectors with Different Ranges and Overlapping for Different Charges.

FIRE ORDER AND FIRE COMMANDS

12-43. The FDO must establish a fire order SOP that indicates the corrections for the primary sector are standard. This is done in the special instructions section of the fire order SOP.

12-44. Fire command standards should direct that the primary TGPCs sector is used unless otherwise specified. The special instructions block of the fire commands will indicate which TGPC sector will be used for a mission if other than the primary sector. The absence of any instructions in the initial fire commands indicates that corrections for the primary sector will be fired. The command **LEFT (RIGHT) SECTOR** in the special instructions block of the initial fire commands indicates that the corrections for the left (right) sector are to be set on the howitzers. The command **CANCEL TERRAIN GUN POSITION CORRECTIONS** indicates that all TGPCs are to be zeroed for the mission. After end of mission is announced, the primary sector TGPCs are reapplied to the howitzers.

DETERMINATION OF TERRAIN GUN POSITION CORRECTIONS

12-45. It is recommended that TGPCs be computed for a **converged sheaf**. This will generally provide an acceptable sheaf within the transfer limits. TGPCs can be computed by using other sheafs, but the dispersion of bursts can be expected to increase as the target range varies from the range to the center of the sector. It is preferred that **base piece carry no corrections**. To do otherwise causes the base piece to "zero" the corrections on adjustment and reapply them during fire for effect, which may lead to error. Therefore, the aimpoint of the base piece should be the center pivot when computing TGPCs.

Note: DA Form 4757 (Registration/Special Corrections Work Sheet) is completed regardless of the sheaf used. Before computing any TGPCs, plot the howitzers on the M17.

12-46. Table 12-5 lists the steps for determining TGPCs and completing DA Form 4757.

Table 12-5. Determination of TGPCs.

STEP	***REFERENCE***	***ACTION***
1	(Transfer Limit Block) L/P/R	Circle the sector for which the corrections are to be computed.
2	Chg____	Record the charge used for the corrections.
3	Record deflection to the left and right limit of the sector. LEFT CENTER RIGHT CEN DF + 400 DF (min) (max) RG CEN RG + 2000M	
4	Record minimum and maximum range for the sector LEFT CENTER RIGHT CEN DF + 400 DF (min) (max) RG CEN RG + 2000M	
5	1 Pos Lateral or Corr (L/R)	Record the position lateral correction required to move each weapon to its selected burst line (open) or aimpoint to the nearest 5 meters
6	2 100/R GFT* (_____) CEN RG	Using a GFT, Determine and record 100/R for the center range.
7	3 Pos DF Corr (L/R) 1 X 2 100	The position deflection correction is determined by multiplying the position lateral correction (Col 1) by 100/R (Col 2) and dividing the result by 100 and expressing the result to the nearest mil. Assign the direction (L/R) of the lateral correction
8	4 Btry Comp VE (I/D)	Record battery comparative Ves. Record plus Ves as increases (I) and minus Ves as decreases (D). Comparative Ves (comp Ves) are determined by subtracting the base piece MVV from the other howitzer(s) MVV. Use the formula **GUN # MVV- BP MVV= COMP VE (I/D).**
9	5 MV Unit Corr Fac (TBL F) D+____ I-_____	Determine and record the muzzle velocity unit correction factors (fac) from Table F in the TFT on the basis of the center range. Record the appropriate correction factor for each howitzer on the basis of comparative VE.

Table 12-5. Determination of TGPCs (continued).

STEP	*REFERENCE*	*ACTION*
10	6 MV RG Corr 4 X 5	Determine and record the muzzle velocity range correction by multiplying the comparative (Col 1) by the muzzle velocity unit correction factor. Express the result to the nearest 1 meter.
11	7 Pos RG Corr (F= -) (B=+)	Record the required position range correction (the number of meters forward or behind the base piece) to the nearest 5 meters. If the weapon is forward (F) of the base piece, the correction is minus. If it's behind (B), the correction is plus.
12	8 Total RG Corr 6 + 7	Determine and record the change in total correction by adding the muzzle velocity range correction to the position range correction (±). Express the result to the nearest 1 meter.
13	9 Pos EL Corr 8 ÷ DR Per 1m̸ D EL (TBL F) (_____)	Determine and record the change in range for 1 mil change in elevation from Table F (Col 5) of the TFT. Determine and record the position elevation correction by dividing the total range correction by the change in range for 1 mil change in elevation. Express the result to the nearest mil (±).
14	10 8 ≈ 10M Plus CEN RG * (_____)	Determine and record the corrected range by expressing the total range correction to the nearest 10 meters and adding it to the center range.
15	11 FS≈ 10	Determine and record the fuze setting. Place the MHL (using the appropriate GFT) over the corrected range, and read the FS under the MHL.
16	12 Pos TI Corr 11 Minus FS ≈ CEN RG (_____)	Determine and record the position time correction by subtracting the fuze setting corresponding to the center range from the fuze setting corresponding to the corrected range.

Legend: BP – base piece CEN – center CHG – charge CORR – correction D – decrease DF – deflection EL – elevation FAC – factor FS – fuze setting GFT – graphical firing table I – increase L – left m̸ - mil M – meter MV – muzzle velocity MVV – muzzle velocity variation POS – position R – right RG – range TBL – table TFT – tabular firing table TI – time VE – velocity error

12-47. The note on the bottom of DA Form 4757 states to use the chart range to target wherever there is an * displayed.

12-48. The steps in table 12-6 (page 12-20) are used to determine TGPCs for all sheafs.

Note: Step 1 will be different for each type of sheaf. Steps 2 through 17 are common to all sheafs.

Table 12-6. Determination of TGPCs for all sheafs.

STEP	***ACTION***
	CONVERGED SHEAF
1	The single aimpoint for the converged sheaf will be the center of the plotting board.
	CIRCULAR SHEAF
1	Plot the piece locations, and determine piece displacement.
	NOTE: Base piece aimpoint will be the pivot in the center of the plotting board. This is done so that the base piece has no corrections.
1a	To plot the remaining aimpoints in the sheaf, the angle between aimpoints must be determined. Use the formula: $\frac{6400}{NUMBER\ OF\ WEAPONS - 1} = ANGLE\ BETWEEN\ AIMPOINTS$
1b	Rotate the clear disk until the 0 graduation of the outer black scale is opposite the **azimuth index**.
1c	Count the effective burst width from the center toward the top of the board, and mark a small **X** on the disk with a soft-lead pencil. This is the first aimpoint.
1d	Plot the next aimpoint by rotating the clear disk until the value of the angle in step 1a is opposite the azimuth index. Count the burst width from the center toward the top of the board, and mark a small **X** on the disk with a soft-lead pencil. This is the second aimpoint.
1e	Plot the remaining aimpoint by rotating the clear disk to increase the value opposite the azimuth index by the angle in step 1 a. Count the burst width from the center toward the top of the board, and mark a small **X** on the disk with a soft-lead pencil.
	OPEN SHEAF
1	Draw burst lines one burst width apart on the base of the plotting board. The burst lines are parallel to the center red arrow and are drawn from the top to the bottom of the plotting board in pencil. The first burst line will be the center line (red arrow). This line represents the burst line of the base piece. Additional burst lines are drawn for the remaining pieces, left and right of the center. Aimpoints will be the intersection of the burst line and the center horizontal red line on the base of the plotting board.
	ALL SHEAFS
2	The TGPCs must be computed for the center of the sector. Since the transfer limit for deflection is 800 mils, use the common deflection as the center of sector deflection and a range at the center of the area in which the FDO expects to engage the majority of targets. On the basis of this range, the FDO selects a charge.
3	Using the GFT, determine 100/R corresponding to the center range. Determine the change in range for a 1-mil change in elevation from the TFT, Table F, Column 5, for the appropriate charge.
4	Rotate the clear disk until the 32 graduation on the outer black scale is opposite the □ernier scale.
5	Determine, by counting, the lateral correction (to the nearest 5 meters) from the leftmost howitzer to the leftmost aimpoint and the direction (left or right) from the howitzer to the aimpoint.

Table 12-6. Determination of TGPCs for all sheafs (continued).

STEP	***ACTION***
6	To determine the deflection correction for this howitzer, multiply the lateral correction determined in step 5 by the center range 100/R determined in step 3. Divide the product (answer) by 100, and express this answer to the nearest mil. Assign the sign (L/R) for the lateral correction. This is the deflection correction.
7	Determine the comparative VE for the howitzer.
8	Enter Table F of the TFT with the center of sector range, and extract from Columns 10 and 11 the unit correction for 1 m/s change in muzzle velocity.
9	Determine the MV range correction by multiplying the comparative VE by the appropriate unit correction. (If the sign of the comparative VE is negative, use the decrease unit correction; if the sing of the comparative VE is positive, use the increase unit correction. This is the MV range correction.
	Note: if the comparative VE is within ±1.5 m/s, step 7 through 9 may be disregarded for speed, since ±1.5 m/s generally equates to ±2 probable errors in range.
10	Determine the position range correction by counting the distance from the howitzer to the assigned aimpoint toward the top or bottom of the plotting board. If the aimpoint is closer to the top of the board, the sign of the correction is a plus (+). If the howitzer is closer to the top of the board, the sing of the correction is minus (-).
11	Algebraically add the MV range correction to the position range correction. The sum is the total range correction.
12	Divide the total range correction by the change in range for a 1-mil change in elevation from step 3. Express this answer to the nearest mil, and assign the sign of the total range correction. This is the position quadrant correction.
13	Determine the fuze setting corresponding to the center range from the GFT by using the MHL.
14	Determine the fuze setting corresponding to the corrected range (center range plus the total range correction) from the GFT.
15	Determine the position time correction by using the formula **FS AT CORR RG (Step 15)- FS AT THE CEN RG (Step 14)= POS TIME CORR.**
16	Determine correction for the remainder of the howitzers as described above.
17	Determine the transfer limits. The transfer limits define the area in which the TGPCs may be expected to provide accurate corrections for the sheaf.
17a	Determine the transfer limits for the deflection as follows: **LEFT LIMIT = CENTER DF +400 MILS** **RIGHT LIMIT = CENTER DF – 400 MILS**
17b	Determine the range transfer limits as follows: **MAX RANGE LIMIT = CENTER RANGE + 2,000 METERS** **MIN RANGE LIMIT = CENTER RANGE – 2,000 METERS**
17c	The HCO draws in blue pencil on the firing chart the range and deflection limits from the battery center (Base Piece). The HCO informs the FDO if any target plots outside the transfers limits.
Legend: CEN – center CORR – correction DF – deflection FDO – fire direction officer FS – fuze setting GFT – graphical firing table HCO – horizontal control operator L – left m/s – meters per second MV – muzzle velocity R – right RG – range TFT – tabular firing table TGPC – terrain gun position correction VE – velocity error	

HASTY TERRAIN GUN POSITION CORRECTIONS

12-49. Even with well-trained FDC personnel, computing TGPCs is time-consuming. Corrections are required for firing shortly after occupation of a position. If the advance party has determined displacement and computed TGPCs, corrections will be available immediately. If the advance party has not been able to do accurate TGPCs are computed. For the hasty solution, howitzer displacement is estimated and fuze corrections are ignored.

12-50. Hasty TGPCs computations are designed to provide a converged sheaf at the center range of the TGPCs sector.

12-51. TGPCs and special corrections tables. The data presented in these tables are:

- Range in 1,000-meter increments.
- Charge most likely to be fired at the listed range.
- Deflection correction, in mils, to compensate for lateral howitzer displacement. These values have been determined to the nearest mil with the GST for each 20 meters of lateral displacement (20 to 200 meters).

$$\frac{LATERAL\ DISPLACEMENT\ (D\ SCALE)}{RANGE\ IN\ 1{,}000s\ (C\ SCALE)} = HASTY\ TGPC\ DF\ CORR$$

- Position range correction, in mils, to compensate for howitzer displacement in range. QE corrections to the nearest mil for each 20 meters of front or rear displacement (20 to 100 meters) were computed by using the range change per mil for the listed ranges.

$$\frac{DISPLACEMENT}{RANGE\ CHANGE\ PER\ MIL} = HASTY\ TGPC\ POSITION\ RG\ CORR$$

- MV correction in mils to compensate for the difference in shooting strengths (battery comparative Ves). MV corrections were determined by using the following formula.

$$\frac{MVUCF\ X\ BTRY\ COMP\ VE}{RANGE\ CHANGE\ PER\ MIL} = HASTY\ TGPC\ MV\ CORR$$

Note: MVUCF is the muzzle velocity unit correction factor from the TFT, Table F, Columns 10 and 11.

DETERMINATION OF HASTY TGPCS

12-52. Table 12-7 gives the procedures for determining hasty TGPCs, and table 12-8 gives the procedures for completing DA Form 4757. Figure 12-13 on page 12-25 shows recorded TGPCs.

Table 12-7. Determination of Hasty TGPCs.

STEP	***ACTION***
1	Enter the table at the nearest listed range to the center of the TGPC sector
2	Extract the deflection correction by visually interpolating (if necessary) between the lateral displacement listed that bracket the estimated lateral displacement of the howitzer. If the howitzer is left of the base piece (BP), the correction is to the right; if the howitzer is right of the BP, the correction is to the left. This correction is placed on the gunner's aid of the pantel.
3	Extract the position range correction, in mils, by visually interpolating between the range displacements listed that bracket the estimated lateral displacement of the howitzer. If the howitzer is behind BP, the correction is plus; if the howitzer is forward of BP, the correction is minus.
4	Extract the MV correction, in mils, for the battery comparative VE by visually interpolating between the Ves listed that bracket the VE of the howitzer. A positive VE will have a negative correction; a negative VE will have a positive correction.

Table 12-7. Determination of Hasty TGPCs (continued).

STEP	***ACTION***
5	Add the position range correction, in mils, to the MV correction, in mils. The sum is the elevation correction to be carried on the correction counter on the range quadrant.
Legend: BP – base piece MV – muzzle velocity TGPC – terrain gun position correction VE – velocity error	

Table 12-8. Completion of DA Form 4757.

STEP	***REFERENCE***	***ACTION***
1	Charge__________ Deflection________ Range___________	Record the charge, deflection, and range to the center of the sector.
2	Position Lateral Correction (L/R) a 5 Meters	Record the position lateral correction required to move each weapon to its selected burst line or aimpoint to the nearest 5meters.
3	Hasty Position Deflection Correction ~ (a) b As Listed	Determine and record the hasty position deflection correction corresponding to the lateral correction (Col a) from the hasty TGPC tables.
4	Platoon Comparative MVV c Meter Per Second	Record the comparative VE for each howitzer.
5	Hasty Muzzle Velocity Correction ~ (c) d As Listed	Determine and record the hasty muzzle velocity correction corresponding to the comparative Ves (Col c) from the hasty TGPC tables.
6	Position Range Correction (Forward – Back +) e 5 Meters	Record the required position range correction to the nearest 5 meters. If the weapon is forward of the base piece, the correction is minus; if it is behind, the correction is plus.

Table 12-8. Completion of DA Form 4757 (contined).

STEP	***REFERENCE***	***ACTION***
7	Hasty Position Quadrant Elevation Correction f As listed	Determine and record the hasty quadrant elevation correction corresponding to the position range correction.
8	Total Quadrant Elevation Correction (d) + (f) g 1 Mil	Determine and record the total quadrant correction by adding the hasty MV correction (Col d) to the hasty QE correction (Col f).
Legend: BP – base piece L – left MV – muzzle velocity MVV – muzzle velocity variation QE – quadrant elevation R – right TGPC – terrain gun position correction VE – velocity error		

REGISTRATION/SPECIAL CORRECTION WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

SECTION I. REGISTRATION COMPUTATION

	ACHIEVED RANGE			DEFLECTION CORRECTION	
1	CHART RANGE	(10 METERS)	7	CORRECTED DEFLECTION (REGISTRATION)	(1MIL)
2	REGISTERING HOWITZER DISPLACEMENT (F-/B+)	(10 METERS)	8	REGISTERING HOWITZER DISPLACEMENT CORRECTION ⑥ (L+/R)	(1MIL)
3	ACHIEVED RANGE (①-②)	(10 METERS)	9	ADJUSTED DEFLECTION (⑦+⑥)	(1MIL)
	REGISTERING HOWITZER DISPLACEMENT CORRECTION		10	CHART DEFLECTION	(1MIL)
4	LATERAL DISPLACEMENT (L/R)	(5 METERS)	11	TOTAL DEFLECTION CORRECTION (⑨-⑩) (L+/R-)	(1MIL)
5	ACHIEVED RANGE (③)	(10 METERS)	12	DRIFT CORRECTION (- ADJUSTED ELEVATION) (L)	(1MIL)
6	REGISTERING HOWITZER DIAPLACEMENT CORRECTION (④÷⑤) L+/R-	(1MIL)	13	GRAPHICAL FIRING TABLE (GFT) DEFLECTION CORRECTION (⑪-⑫)	(1MIL)

GFT SETTING (MANUAL METHOD)

							DEFLECTION CORRECTION	
14	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME	TOTAL	GFT
15	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
16	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		

GFT SETTING (COMPUTER METHOD)

17	REGISTRATION UNIT/WEAPON NUMBER	RANGE	RANGE CORRECTION	TIME CORRECTION	DEFLECTION CORRECTION
18	PROJECTILE/LOT	FUZE/LOT	PROPELLANT/LOT	ANGLE OF FIRE	TIME CORRECTION (SEC)
19	DTG	TARGET NUMBER	FUZE K	RANGE K	

TERRAIN GUN POSITION /SPECIAL CORRECTION

REMARKS

L/P/R SECTOR		TRANSFER LIMITS				CHARGE 4H M232A1
		LEFT	CENTER	RIGHT		
CEN DF +400m	DF	3600	3200	2800	DF	CEN DF -400m
CEN RG -2000M	RG	12000	14000	16000	RG	CEN RG +2000M

SECTION II. HASTY CORRECTION

INITIAL CHART DATA — DEFLECTION ___ RANGE ___ TARGET ___ DATE-TIME GROUP ___

GUN NUMBER	POSITION LATERAL CORECTION (LEFT/RIGHT)	HASTY POSITION DEFLECTION CORRECTION- ⓐ	PLATOON COMPARATIVE MUZZLE VELOCITY VARIATION	HASTY MUZZLE CORRECTION- ⓒ	POSITION RANGE CORRECTION (FORWARD- BACK +)	HASTY POSITION QUADRANT ELEVATION CORRECTION	TOTAL QUADRANT ELEVATION CORRECTION ⓓ+ⓕ	CORRECTED QUADRANT ELEVATION -SITE FIRED =ELEVATION	TIME TO FIRE (ELEVATION GAGE LINE OVER ⓗ) READ TIME
	a	b	c	d	e	f	g	h	i
	5 METERS	AS LISTED	0.1METERS PER SECOND	AS LISTED	5 METERS	AS LISTED	1 MIL	1 MIL	0.1
1									
2									
3									
4									

SECTION III. SPECIAL CORRECTIONS

INITIAL CHART DATA — DEFLECTION 3200 RANGE 14000 TARGET ___ DATE-TIME GROUP 201032ZJUN13

PLATOON	GUN NUMBER	POSITION LATERAL CORRECTION (LEFT/RIGHT)	100/R (GAPHICAL FIRING TABLE) (14000)	POSITION DEFLECTION CORRECTION (LEFT/RIGHT) ⓐ×ⓑ / 100	PLATOON COMPARATIVE VELOCITY ERROR (INCREASE/ DECREASE)	MUZZLE VELOCITY UNIT CORRECTION FACTOR (TABLE F APPROPIATE FT) D+ (+22.8) I- (-22.5)	MUZZLE VELOCITY RANGE CORRECTION ⓓ×ⓔ	POSITION RANGE CORRECTION (FORWARD - BACK+)	TOTAL RANGE CORRECTION ⓕ+ⓖ	POSITION QUADRANT ELEVATION CORRECTION (ⓙ - COLUMN 5 TABLE F APPROPIATE FT) (19)	CORRECTED RANGE (ⓙ= 10 METERS + INITIAL RANGE) (14000)	TIME TO FIRE (FUZE SETTING - ⓘ)	POSTI CORR ⓚ - Fs-CEN RG (38.1)
		a	b	c	d	e	f	g	j	h	i	k	l
		5 METERS	1 MIL	1 MIL	0.1 METER PER SECOND	0.1 METER	1 METER	5 METERS	1 METER	1 MIL	10 METERS	0.1	0.1
R	1	L75	7	L5	D 1.5	+22.8	+34	0	+34	+2	14030	38.2	+0.1
	2	L35	7	L3	D 1.0	+22.8	+23	-35	-12	-1	13990	38.0	-0.1
L	3	0	7	0	0	0	0	0	0	0	14000	38.1	0
	4	R50	7	R4	I 3.4	-22.5	-76	-15	-91	-5	13910	37.7	-0.4

DA FORM 4757, JAN 2016 — PREVIOUS EDITIONS ARE OBSOLETE. — APD LC v1.00

Legend: GFT – graphical firing table DTG – date time group CEN – center DF – deflection RG – range

Figure 12-13. DA Form 4757 (Front and Back).

SECTION IV: SPECIAL CORRECTIONS

12-53. The corrections determined by using TGPCs are valid only within the specified transfer limits and produce the sheaf for which they were computed. If a target falls outside the transfer limits or is irregularly shaped, it is necessary to compute special corrections.

DEFINITIONS AND USE

12-54. Special corrections are individual piece corrections applied to time, deflection, and quadrant elevation to place FFE bursts in precise location on a target. Special corrections are used for:

- Individual piece locations (position correction).
- Shooting strength of each piece (calculated correction).
- Target shape and size.

12-55. Knowing when to compute special corrections is as important as knowing how to compute them. Some factors that influence the use of special corrections are:

- Time available for computation.
- Target size, shape, and proximity to friendly troops.
- Accuracy of target location.

12-56. Special corrections should be applied when and where they will increase the effectiveness of fires on the target. Because of the time required for computation, they are used only for FFE missions.

12-57. The special corrections are computed in a similar manner to TGPCs, the major difference being the plotting of the target. The following types of sheafs may be computed:

- Converged sheaf.
- A target described by grid, length, and attitude.
- A target described by two grids.
- A target described by three or more grids.
- A circular target.

COMPUTATION OF SPECIAL CORRECTIONS

12-58. Table 12-9 provides the steps and procedures for the computation of special corrections

Table 12-9. Computation of Special Corrections.

STEP	***ACTION***
CONVERGED SHEAF	
1	The single aimpoint will be the center of the plotting board. To determine corrections, go to step 6.
TARGET DESCRIBED BY GRID, ATTITUDE, AND LENGTH	
2	The center of the plotting board will represent the center grid reported in the call for fire.
2a	Rotate the clear disk until the attitude reported in the call for fire is opposite the **azimuth index** on the outer black scale.
2b	Divide the length of the target by 2.
2c	Along the vertical red line, count the distance determined in step 2b from the center of the plotting board to the top. (Each square equals 10 meters.) Mark this distance with a small X. This marks the outer end of the target.
2d	Along the center vertical red line, count the distance determined in step 2c from the center of the plotting board toward the bottom. (Each square equals 10 meters.) Mark this distance with a small X. This marks the other end of the target.
2e	Divide the length of the target by one less than the number of howitzers to fire.

Table 12-9. Computation of Special Corrections (continued).

STEP	***ACTION***
2f	Starting at either end of the target, count the distance computed in step 2e. Each square represents 10 meters. At the end of the distance, mark a small X on the target. Repeat this process until the other end of the target is reached. The small Xs represent the aimpoints.
2g	Rotate the clear disk until the deflection to the center of the target (measured from the firing chart) is opposite the □ernier index on the inner red scale.
	Note: The sheaf width using this method will be one effective burst width greater than the target length. To make the sheaf width equal to the target length, subtract one effective burst width from the target length before dividing by 2 in step 2b.
2h	To compute corrections, go to step 6.
TARGET DESCRIBED BY TWO GRIDS	
3	Determine the center of the target.
3a	Subtract the eastings and northings of the grids. Use the following: FIRST EASTING COORDINATE — FIRST NORTHING COORDINATE - SECOND EASTING COORDINATE — -SECOND NORTHING COORDINATE DIFFERENCE IN EASTING (±) — DIFFERENCE IN NORTHING (±)
3b	Divide the difference in easting and the difference in northing by two.
3c	Algebraically subtract the values from step 3b above from the first grid easting and northing. This is the center grid.
3d	The HCO plots the center grid and determines chart range and deflection to the center of the target.
3e	Rotate the clear disk until 0 is opposite the **azimuth index** on the outer black scale. The top of the plotting board now represents grid north.
3f	Plot the end of the target by counting the difference in easting divided by 2 and the difference in northing divided by 2 as determined in step 3b. If the easting sign is negative, count the distance to the west (left); if the sign is positive, count the distance to the east (right). Then, if the northing sign is negative, count south (bottom); if it is positive, count north (top). At the end of this distance, mark a small X.
3g	To plot the other end of the target, reverse the signs and plot the distances in the opposite direction from the center.
3h	Rotate the clear disk until the long axis of the target is aligned with the center red line on the base of the plotting board.
3i	Divide the length of the target by one less than the number of howitzers to fire.
3j	Starting at either end of the target, count the distance computed in step 3i. Each square represents 10 meters. At the end of the distance, mark a small X on the target. Repeat this process until the other end of the target is reached. The small Xs represent the aimpoints.
3k	Rotate the clear disk until the deflection (red scale) to the center of the target (measured from the firing chart) is opposite the □ernier index.
3l	To compute corrections, go to step 6.
TARGET DESCRIBED BY THREE OR MORE GRIDS	
4	Select one of the inner grids as the center. This grid does not need to be the actual center. It will be represented by the center of the plotting board and will provide a starting point from which the remainder of the grids can be plotted.

Table 12-9. Computation of Special Corrections (continued).

STEP	***ACTION***
4a	To plot the remaining grids, subtract the easting and northing of the center grid from the first grid. Use the following: FIRST EASTING COORDINATE FIRST NORTHING COORDINATE - CENTER EASTING COORDINATE -CENTER NORTHING COORDINATE DIFFERENCE IN EASTING (±) DIFFERENCE IN NORTHING (±)
4b	Rotate the clear disk until 0 is opposite the azimuth Index on the outer black scale. The top of the plotting board now represents grid north.
4c	Plot the first grid by counting the difference in easting and the difference in northing as determined in step 4a. If the easting sign is negative, count the distance to the west (left); if the sign is positive, count the distance to the east (right). Then, if the northing sign is negative, count south (bottom); if it is positive, count north (top). At the end of this distance, mark a small X.
4d	To plot the remaining grids, repeat the procedure described in steps 4a through 4c above for each grid.
4e	Using a soft-lead pencil, connect all the grids. This is the target.
4f	Rotate the clear disk until each segment of the target is aligned with a vertical red line of the gridded base. Count the length of each segment, and add the lengths to determine a total length of the target.
4g	Divide the length of the target by one less than the number of howitzers to fire.
4h	Starting at either end of the target, count the distance computed in step 4g. Each square represents 10 meters. At the end of the distance, mark a small X on the target. Repeat this process until the other end of the target is reached. The small Xs represent the aimpoints.
4i	Rotate the clear disk until the deflection to the center of the target on the inner red scale (measured from the firing chart) is opposite the □ernier index.
4j	To compute corrections, go to step 6.
CIRCULAR TARGET	
5	The grid given in the call for fire is represented by the center of the plotting board.
5a	To plot the aimpoints in the sheaf, the angle between aimpoints must be determined. Use the formula ANGLE = 6400 ÷ THE NUMBER OF WEAPONS. This allows even distribution of aimpoints on a circle, regardless of the number of howitzers.
5b	Rotate the clear disk until the 0 graduation of the outer black scale is opposite the **azimuth index**.
5c	Count half the radius from the center toward the top of the board, and mark a small X on the disk with a soft-lead pencil. This is the first aimpoint.
5d	Plot the next aimpoint by rotating the clear disk until the value of the angle determined in step 5a is opposite the azimuth index. Count half the radius from the center toward the top of the board, and mark a small X on the disk with a soft-lead pencil. This is the second aimpoint.
5e	Plot the remaining aimpoints by rotating the clear disk to increase the value opposite the azimuth index by the angle determined in step 5a. Count half the radius from the center toward the top or the board, and mark a small X on the disk with a soft-lead pencil.
5f	The HCO determines the chart range and deflection to the center of the target.
5h	To compute corrections, go to step 6.

Table 12-9. Computation of Special Corrections (continued).

STEP	***ACTION***
COMPUTATION OF SPECIAL CORRECTIONS	
6	Using the GFT, determine 100/R corresponding to the chart range. Determine the change in range for a 1-mil change in elevation from Column 5 of Table F for the appropriate charge. Enter the TFT with chart range expressed to the nearest 100 meters.
6a	Rotate the clear disk until the chart deflection on the inner red scale is opposite the vernier scale.
6b	Determine, by counting, the lateral correction (to the nearest 5 meters) from the leftmost howitzer to the leftmost aimpoint and the direction (left or right) from the howitzer to the aimpoint.
6c	To determine the deflection correction for a howitzer, multiply the lateral correction determined in step 6b by the center range 100/R determined in step 6. Divide the product (answer) by 100, and express the result to the nearest mil. Assign the sign (L/R) of the lateral correction. This is the deflection correction.
6d	Determine the comparative VE for the howitzer. **HOWITZER MVV** **<u>-BASE PIECE MVV</u>** **COMPARATIVE VE**
6e	Enter Table F of the TFT with the center of sector range, and extract from Columns 10 and 11 the unit correction for a 1 m/s change in muzzle velocity. Enter the TFT with the chart range expressed to the nearest 100 meters.
6f	Determine the MV range correction by multiplying the comparative VE by the appropriate unit correction. (If the sign of the comparative VE is negative, use the decrease unit correction; if the sign of the comparative VE is positive, use the increase unit correction.) Express the answer to the nearest meter, and assign the sign of the unit correction. This is the MV range correction.
	Note: If the comparative VE is within 1.5 m/s, steps 6d through 6f may be disregarded.
6g	Determine the position range correction by counting the distance from the howitzer to the assigned aimpoint toward the top or bottom of the plotting board. If the aimpoint is closer to the top of the board, the sign of the correction is plus (+).If the howitzer is closer to the top of the board, the sign of the correction is minus (-).
6h	Algebraically add the muzzle velocity range correction to the position range. The sum is the total range Correction.
6i	Divide the total range correction by the change in range for a 1-mil change in elevation from step 6. Express this answer to the nearest mil, and assign the sign of the total range correction. This is the position quadrant correction.
6j	Determine the fuze setting corresponding to the chart range from the GFT by using the manufacturer's hairline.
6k	Determine the fuze setting corresponding to the corrected range (chart range plus the total range correction) from the GFT using the manufacturer's hairline.
6l	Determine the position time correction using the formula: **FS AT CORRECTED RANGE (STEP 6K) – FS AT THE CENTER RANGE (STEP 6J) = POS TIME CORRECTION**.
6m	Determine corrections for the remainder of the howitzers as described above.
Note: DA Form 4757 will be used when computing and recording special corrections. Unlike TGPCs, the FDC will apply the special corrections computed to chart range and deflection data. The special instruction SPECIAL CORRECTIONS is included in the fire commands. This special instruction will automatically cancel any TGPCs that are being carried on the howitzers for that mission.	
Legend: FDC – fire direction center FS – fuze setting GFT – graphical firing table HCO – horizontal control operator MV – muzzle velocity MVV – muzzle velocity variation TFT – tabular firing table TGPC – terrain gun position correction VE – velocity error	

SECTION V: USE OF PLOTTING BOARD FOR FIRE MISSION PROCESSING

12-59. When the use of a firing chart is not possible, the M19 or M17 plotting board and GFT or TFT may be used to compute firing data. The observer transmits the call for fire to the firing unit and describes the target location by using any of the methods of target location.

FIRE MISSION PROCESSING WITH THE M17 PLOTTING BOARD

12-60. The steps in table 12-10 are used to process fire missions with the M17 plotting board. See figure 12-14 on page 12-32 for the M17 format for processing fire missions.

Table 12-10. Processing Fire Missions with the M17.

STEP	***ACTION***
1	Plot the target location on a map.
2	Plot the firing unit on a map.
3	Determine the range to the target by using an Azimuth Range Fan or Range Deflection Protractor.
	Note: if the RDP is corrections would have to be made if the map is in a different scale.
4	Determine the gun-target azimuth
5	Determine the charge to fire.
6	Issue the initial fire commands.
6a	Determine the initial deflection by comparing the azimuth to the initial target location with the azimuth of lay. Use LARS rule, and apply the difference to the common deflection. (if this is an emergency mission, while moving or making center sector, establish the azimuth to the target as azimuth of fire so that the initial deflection will be the common deflection)
6b	Add drift to the initial deflection to determine the deflection to fire unless speed is essential and FDO decides to ignore it. Announce the deflection to the howitzer(s).
6c	Determine site unless speed is essential and FDO decides to ignore it.
6d	Determine elevation from the appropriate TFT or GFT by using the gun-target range determine in step 3.
6e	Add Site to the elevation to determine quadrant elevation. Announce QE to the howitzer(s).
7.	Determine and record the 100/R at the initial range
8	Place a mark on the clear plastic disk opposite the number on the outer black scale that corresponds to the OT line. Label the mark “O”
9	Place a mark on the clear plastic disk opposite the number that corresponds to the gun-target (GT) direction. Label the mark “G”.
	Note: the observer follows normal procedures during the adjustment so that subsequent correction can be plotted on the M17 and converted into corrections with respect to the GT line. For this procedure, the rivet (center) of the plotting board always represents the location of the burst.
10	Select an appropriate scale (assign a convenient value to the squares on the plotting board) most shifts can be plotted when a value of 10 to 20 meters is assigned to each square.
11	Rotate the clear disk so that the mark “O” representing the OT direction is over the red zero on the □ernier scale. The M17 is oriented to the OT direction. The center red arrow represents the OT line.
12	Plot the observer’s correction on the disk.
13	Rotate the clear disk until the mark “G” is over the red zero on the □ernier scale. The m17 is oriented to the GT direction. The center red arrow represents the GT line.

Table 12-10. Processing Fire Missions with the M17 (continued).

STEP	ACTION
14	Starting from the rivet, measure the observer's corrections in relation to the GT line. Determine the right or left deviation in meters.
15	Multiply the value for 100/R by the left or right deviation correction. Divide this product by 100, which is the lateral correction in mils. $\frac{\frac{100}{R} X\ GT\ DEVIATION\ CORR}{100} = L/R\ CORR\ IN\ MILS$
16	Using LARS, add the correction, in mils, to the last deflection fired to determine the new deflection to fire. Announce the new deflection to fire to the howitzers.
17	Starting from the rivet, measure the observer's corrections in relation to the GT line and determine the correction in range, add or drop, in meters.
	Note: Either the GFT or TFT can be used to determine the elevation. Steps 18 and 19 describe the procedures for using the GFT, and steps 20 through 24 describe the procedures for using the TFT.
18	Determine the adjusted range by adding or subtracting the observer's range correction along the GT line to the last range fired.
19	Move the MHL over the new range, and determine the elevation from under the MHL. If there is a current GFT setting, determine the elevation from the elevation gauge line. Go to step 25.
USING THE TFT	
20	Add the range correction to the last range fired.
21	Enter the TFT with the appropriate charge in Table F. Use the new range as the entry argument. Determine elevation from Column 2 (interpolation may be necessary). OR
22	Determine the C-factor (change in elevation for a 100-meter change in range) at the initial range by entering Table F, Column 5, with the initial range and extracting the value for the change in range for a 1-mil change in elevation. Divide 1 00 by the value extracted from Column 5. This is your C-factor.
23	Compute the change in elevation required for the range correction along the GT line by multiplying the C-factor by the change in range in hundreds. $\frac{C - FACTOR\ X\ RANGE\ CORRECTION}{100} = CHANGE\ IN\ ELEVATION$
24	Add the change in elevation to the last fired elevation to determine the new elevation.
25	Add the new elevation to the old site, and determine quadrant elevation.
	Note: The mission will continue to be processed by following steps 16 through 25 until the mission is ended.
Legend: CORR – correction FDO – fire direction officer GFT – graphical firing table GT – gun-target LARS – left add right subtract MHL – manufacturer's hair line OT – observer-target QE – quadrant elevation RDP – range deflection protractor TFT – tabular firing table	

DETERMINATION OF SUBSEQUENT CORRECTIONS FOR A LASER ADJUST-FIRE MISSION

12-61. Table 12-11 shows the steps and procedures to determine subsequent corrections for a laser adjust-fire mission.

Table 12-11. Determination of Subsequent Corrections for a Laser Adjust-Fire Mission.

STEP	ACTION
1	The first round is fired as a polar plot target location on the firing chart by using normal adjust-fire procedures.

Table 12-11. Determination of Subsequent Corrections for a Laser Adjust-Fire Mission (continued).

STEP	***ACTION***
	Note: The M19 or M17 plotting board may be used in the processing of a laser fire mission.
2	The chart operator orients his target grid over the target on the OT direction announced in the call for fire.
3	The computer rotates the clear disk on the plotting board until the OT direction on the outer black scale is opposite the □ernier index.
4	The computer, using a scale of 1 square equals 100 meters, counts toward the top of the M17 the distance announced in the call for fire. At the end of this distance, the computer marks a dot with a soft-lead pencil to represent the target.
	Note: The rivet represents the observer's location.
5	On receiving the subsequent correction, the computer must convert the polar plot location of the first rounds burst into a correction to bring the impact from the lased burst' location to the target location.
5a	The Computer/RTO records the laser polar plot data to the burst on the record of fire.
5b	The computer rotates the clear disk of the M17 until the direction (outer black scale) given in the subsequent correction is opposite the □ernier index.
5c	The computer counts the distance given in the correction from the center to the top *of* the M17 and at the appropriate distance marks a dot to represent the location of the burst.
5d	The computer rotates the clear disk until the original polar plot direction is opposite the □ernier index.
5e	The computer counts the number of meters (to the nearest 10) needed to move the burst (lateral correction) to the target. He announces the lateral correction to the HCO as LEFT or RIGHT (the direction to move from burst to target) (so many meters).
5f	The computer next counts the number of meters (to the nearest 10) to move the burst (range correction) to the target. The correction is announced to the HCO as ADD or DROP (so many meters).
6	The HCO then plots the correction by using the target grid and determines chart data. (The target grid is oriented by using the initial observer target direction.)
Legend: HCO – horizontal control operator OT – observer-target RTO – radio telephone operator	

GRID________________ GT RG ____________ = ELEVATION____________
+SITE____________
GT DIR________________ GT DIR____________ =QE____________
CHG________________ MTO________________________________
(100/R = 100 ÷RG [IN THOUSANDS] or FROM GFT) 100/R=______________
FIRE MISSION, PLT ADJ # ________ SH_____ LOT_____ CHG _____ FZ_____
TI________ DF ________ QE ________
OT CORR: L/R ________ +/- ________
GT CORR: L/R ________ +/- ________ ADJ RG ________ = EL ________
100/R ________ X GT DEVIATION CORR / 100 = ________ = ________ m L/R
+________ +LAST DF
= ____________DF
ELEVATION AT NEW RANGE ________ + SITE ________ = NEW QE________
OT CORR: L/R ________ +/- ________
GT CORR: L/R ________ +/- ________ ADJ RG ________ = EL ________
100/R ________ X GT DEVIATION CORR / 100 = ________ = ________ m L/R
+________ +LAST DF
= ____________DF
ELEVATION AT NEW RANGE ________ + SITE ________ = NEW QE________
PLT ________ SH ________ FZ ________ DF ________ QE ________

Legend: ADJ – adjust CHG – charge CORR – correction DF – deflection DIR – direction EL – elevation FZ – fuze GFT – graphical firing table GT – gun-target MTO – message to observer OT – observer-target PLT – platoon QE – quadrant elevation RG – range SH – shell TI – time

Figure 12-14. Format for Processing Fire Mission with M17.

EXAMPLES OF TGPCS

12-62. The following is an example of the platoon leader's report for the Ml00-series sight:

HOWITZER	LAID FROM	LAY DEFLECTION	DISTANCE	VA
1	AC	2595	105	+3
2	AC	2910	55	+1
3 (BP)	AC	3405	90	-2
4	AC	3950	100	-5

Note**:** Howitzer Number 3 is the base piece.

12-63. The following is an example of howitzer displacement:

HOWITZER	LATERAL DISPLACEMENT	RANGE DISPLACEMENT
1	R75	0
2	R35	+35
3	0	0
4	L50	+15

12-64. A completed DA Form 4757 for each sheaf (converged, open, and circular) containing TGPCs using the data listed above are shown in figures 12-15 through 12-17 (pages 12-34 through 12-36).

REGISTRATION/SPECIAL CORRECTION WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

SECTION I. REGISTRATION COMPUTATION

	ACHIEVED RANGE			DEFLECTION CORRECTION	
1	CHART RANGE	(10 METERS)	7	CORRECTED DEFLECTION (REGISTRATION)	(1MIL)
2	REGISTERING HOWITZER DISPLACEMENT (F-/B+)	(10 METERS)	8	REGISTERING HOWITZER DISPLACEMENT CORRECTION (6) (L+/R)	(1MIL)
3	ACHIEVED RANGE ((1)-(2))	(10 METERS)	9	ADJUSTED DEFLECTION ((7)+(6))	(1MIL)
	REGISTERING HOWITZER DISPLACEMENT CORRECTION		10	CHART DEFLECTION	(1MIL)
4	LATERAL DISPLACEMENT (L/R)	(5 METERS)	11	TOTAL DEFLECTION CORRECTION ((9)-(10)) (L+/R-)	(1MIL)
5	ACHIEVED RANGE ((3))	(10 METERS)	12	DRIFT CORRECTION (- ADJUSTED ELEVATION) (L)	(1MIL)
6	REGISTERING HOWITZER DIAPLACEMENT CORRECTION ((4)÷(5)) L+/R-	(1MIL)	13	GRAPHICAL FIRING TABLE (GFT) DEFLECTION CORRECTION ((11)-(12))	(1MIL)

GFT SETTING (MANUAL METHOD)

							DEFLECTION CORRECTION	
14	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME	TOTAL	GFT
15	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
16	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		

GFT SETTING (COMPUTER METHOD)

17	REGISTRATION UNIT/WEAPON NUMBER	RANGE	RANGE CORRECTION	TIME CORRECTION	DEFLECTION CORRECTION
18	PROJECTILE/LOT	FUZE/LOT	PROPELLANT/LOT	ANGLE OF FIRE	TIME CORRECTION (SEC)
19	DTG	TARGET NUMBER	FUZE K	RANGE K	

TERRAIN GUN POSITION /SPECIAL CORRECTION

REMARKS

L/P/R SECTOR		TRANSFER LIMITS				CHARGE 4H M232A1
		LEFT	CENTER	RIGHT		
CEN DF +400m	DF	3600	3200	2800	DF	CEN DF -400m
CEN RG -2000M	RG	12000	14000	16000	RG	CEN RG +2000M

SECTION II. HASTY CORRECTION

INITIAL CHART DATA — DEFLECTION — RANGE — TARGET — DATE-TIME GROUP

GUN NUMBER	POSITION LATERAL CORECTION (LEFT/RIGHT)	HASTY POSITION DEFLECTION CORRECTION- (a)	PLATOON COMPARATIVE MUZZLE VELOCITY VARIATION	HASTY MUZZLE CORRECTION – (c)	POSITION RANGE CORRECTION (FORWARD- BACK +)	HASTY POSITION QUADRANT ELEVATION CORRECTION	TOTAL QUADRANT ELEVATION CORRECTION (d)+(f)	CORRECTED QUADRANT ELEVATION -SITE FIRED =ELEVATION	TIME TO FIRE (ELEVATION GAGE LINE OVER (h)) READ TIME
	a	b	c	d	e	f	g	h	i
	5 METERS	AS LISTED	0.1METERS PER SECOND	AS LISTED	5 METERS	AS LISTED	1 MIL	1 MIL	0.1
1									
2									
3									
4									

SECTION III. SPECIAL CORRECTIONS

INITIAL CHART DATA — DEFLECTION 3200 — RANGE 14000 — TARGET — DATE-TIME GROUP 201032Z3UN13

PLATOON	GUN NUMBER	POSITION LATERAL CORRECTION (LEFT/RIGHT)	100/R (GAPHICAL FIRING TABLE) (14000)	POSITION DEFLECTION CORRECTION (LEFT/RIGHT) (a)×(b) / 100	PLATOON COMPARATIVE VELOCITY ERROR (INCREASE/ DECREASE)	MUZZLE VELOCITY UNIT CORRECTION FACTOR (TABLE F APPROPIATE FT) D= (+22.8) I= (-22.5)	MUZZLE VELOCITY RANGE CORRECTION (d)×(e)	POSITION RANGE CORRECTION (FORWARD – BACK+)	TOTAL RANGE CORRECTION (f)+(g)	POSITION QUADRANT ELEVATION CORRECTION ((i) ÷ COLUMN 5 TABLE F APPROPIATE FT) (19)	CORRECTED RANGE ((h)= 10 METERS + INITIAL RANGE) (14000)	TIME TO FIRE (FUZE SETTING - (j))	POS TI CORR (k) - Fs-CEN RG (38.1)
		a	b	c	d	e	f	g	j	h	j	k	l
		5 METERS	1 MIL	1 MIL	0.1 METER PER SECOND	0.1 METER	1 METER	5 METERS	1 METER	1 MIL	10 METERS	0.1	0.1
R	1	L75	7	L5	D 1.5	+22.8	+34	0	+34	+2	14030	38.2	+0.1
	2	L35	7	L3	D 1.0	+22.8	+23	-35	-12	-1	13990	38.0	-0.1
L	3	0	7	0	0	0	0	0	0	0	14000	38.1	0
	4	R50	7	R4	I 3.4	-22.5	-76	-15	-91	-5	13910	37.7	-0.4

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Legend: GFT – graphical firing table DTG – date time group CEN – center DF – deflection RG – range

Figure 12-15. Completed DA Form 4757 Containing TGPCs for a Converged Sheaf.

REGISTRATION/SPECIAL CORRECTION WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

SAMPLE

SECTION I. REGISTRATION COMPUTATION

ACHIEVED RANGE			DEFLECTION CORRECTION		
1	CHART RANGE	(10 METERS)	7	CORRECTED DEFLECTION (REGISTRATION)	(1MIL)
2	REGISTERING HOWITZER DISPLACEMENT (F-/B+)	(10 METERS)	8	REGISTERING HOWITZER DISPLACEMENT CORRECTION ⑥ (L+/R)	(1MIL)
3	ACHIEVED RANGE (①-②)	(10 METERS)	9	ADJUSTED DEFLECTION (⑦+⑥)	(1MIL)
	REGISTERING HOWITZER DISPLACEMENT CORRECTION		10	CHART DEFLECTION	(1MIL)
4	LATERAL DISPLACEMENT (L/R)	(5 METERS)	11	TOTAL DEFLECTION CORRECTION ((⑨-⑩) (L+/R-)	(1MIL)
5	ACHIEVED RANGE (③)	(10 METERS)	12	DRIFT CORRECTION (- ADJUSTED ELEVATION) (L)	(1MIL)
6	REGISTERING HOWITZER DIAPLACEMENT CORRECTION (④÷⑤) L+/R-	(1MIL)	13	GRAPHICAL FIRING TABLE (GFT) DEFLECTION CORRECTION (⑪-⑫)	(1MIL)

	GFT SETTING (MANUAL METHOD)						DEFLECTION CORRECTION	
							TOTAL	GFT
14	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
15	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
16	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		

GFT SETTING (COMPUTER METHOD)

17	REGISTRATION UNIT/WEAPON NUMBER	RANGE	RANGE CORRECTION	TIME CORRECTION	DEFLECTION CORRECTION
18	PROJECTILE/LOT	FUZE/LOT	PROPELLANT/LOT	ANGLE OF FIRE	TIME CORRECTION (SEC)
19	DTG	TARGET NUMBER	FUZE K	RANGE K	

REMARKS

TERRAIN GUN POSITION /SPECIAL CORRECTION

L/P/R SECTOR		TRANSFER LIMITS				CHARGE 4H M232A1
		LEFT	CENTER	RIGHT		
CEN DF +400 m	DF	3600	3200	2800	DF	CEN DF -400m
CEN RG -2000M	RG	12000	14000	16000	RG	CEN RG +2000M

SECTION II. HASTY CORRECTION

INITIAL CHART DATA — DEFLECTION ____ RANGE ____ TARGET ____ DATE-TIME GROUP ____

GUN NUMBER	POSITION LATERAL CORECTION (LEFT/RIGHT)	HASTY POSITION DEFLECTION CORRECTION- ⓐ	PLATOON COMPARATIVE MUZZLE VELOCITY VARIATION	HASTY MUZZLE CORRECTION- ⓒ	POSITION RANGE CORRECTION (FORWARD- BACK +)	HASTY POSITION QUADRANT ELEVATION CORRECTION	TOTAL QUADRANT ELEVATION CORRECTION ⓓ+ⓕ	CORRECTED QUADRANT ELEVATION -SITE FIRED =ELEVATION	TIME TO FIRE (ELEVATION GAGE LINE OVER ⓗ) READ TIME
	a	b	c	d	e	f	g	h	i
	5 METERS	AS LISTED	0.1METERS PER SECOND	AS LISTED	5 METERS	AS LISTED	1 MIL	1 MIL	0.1
1									
2									
3									
4									

SECTION III. SPECIAL CORRECTIONS

INITIAL CHART DATA — DEFLECTION 3200 RANGE 14000 TARGET ____ DATE-TIME GROUP 201032ZJUN13

PLATOON	GUN NUMBER	POSITION LATERAL CORRECTION (LEFT/RIGHT)	100/R (GAPHICAL FIRING TABLE) (14000)	POSITION DEFLECTION CORRECTION (LEFT/RIGHT) ⓐ×ⓑ / 100	PLATOON COMPARATIVE VELOCITY ERROR (INCREASE/ DECREASE)	MUZZLE VELOCITY UNIT CORRECTION FACTOR (TABLE F APPROPIATE FT) D= (+22.8) I= (-22.5)	MUZZLE VELOCITY RANGE CORRECTION ⓓ×ⓔ	POSITION RANGE CORRECTION (FORWARD – BACK+)	TOTAL RANGE CORRECTION ⓕ+ⓖ	POSITION QUADRANT ELEVATION CORRECTION (ⓙ ÷ COLUMN 5 TABLE F APPROPIATE FT) (19)	CORRECTED RANGE (ⓙ= 10 METERS + INITIAL RANGE) (14000)	TIME TO FIRE (FUZE SETTING - ⓙ	POS TI CORR ⓚ - Fs-CEN RG (38.1)
		a	b	c	d	e	f	g	j	h	j	k	l
		5 METERS	1 MIL	1 MIL	0.1 METER PER SECOND	0.1 METER	1 METER	5 METERS	1 METER	1 MIL	10 METERS	0.1	0.1
R	1	R25	7	R2	D 1.5	+22.8	+34	0	+34	+2	14030	38.2	+0.1
	2	R35	7	R2	D 1.0	+22.8	+23	-35	-12	-1	13990	38.0	-0.1
L	3	0	7	0	0	0	0	0	0	0	14000	38.1	0.0
	4	0	7	0	I 3.4	-22.5	-76	-15	-91	-5	13910	37.7	-0.4

DA FORM 4757, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. APD LC v1.00

Legend: GFT – graphical firing table DTG – date time group CEN – center DF – deflection RG – range

Figure 12-16. Completed DA Form 4757 Containing TGPCs for an Open Sheaf.

REGISTRATION/SPECIAL CORRECTION WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

SAMPLE

SECTION I. REGISTRATION COMPUTATION

	ACHIEVED RANGE			DEFLECTION CORRECTION	
1	CHART RANGE	(10 METERS)	7	CORRECTED DEFLECTION (REGISTRATION)	(1MIL)
2	REGISTERING HOWITZER DISPLACEMENT (F-/B+)	(10 METERS)	8	REGISTERING HOWITZER DISPLACEMENT CORRECTION ⑥ (L+/R)	(1MIL)
3	ACHIEVED RANGE (①-②)	(10 METERS)	9	ADJUSTED DEFLECTION (⑦+⑥)	(1MIL)
	REGISTERING HOWITZER DISPLACEMENT CORRECTION		10	CHART DEFLECTION	(1MIL)
4	LATERAL DISPLACEMENT (L/R)	(5 METERS)	11	TOTAL DEFLECTION CORRECTION (⑨-⑩) (L+/R-)	(1MIL)
5	ACHIEVED RANGE (③)	(10 METERS)	12	DRIFT CORRECTION (- ADJUSTED ELEVATION) (L)	(1MIL)
6	REGISTERING HOWITZER DIAPLACEMENT CORRECTION (④÷⑤) L+/R-	(1MIL)	13	GRAPHICAL FIRING TABLE (GFT) DEFLECTION CORRECTION (⑪-⑫)	(1MIL)

GFT SETTING (MANUAL METHOD)

							DEFLECTION CORRECTION	
14	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME	TOTAL	GFT
15	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
16	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		

GFT SETTING (COMPUTER METHOD)

17	REGISTRATION UNIT/WEAPON NUMBER	RANGE	RANGE CORRECTION	TIME CORRECTION	DEFLECTION CORRECTION
18	PROJECTILE/LOT	FUZE/LOT	PROPELLANT/LOT	ANGLE OF FIRE	TIME CORRECTION (SEC)
19	DTG	TARGET NUMBER	FUZE K	RANGE K	

REMARKS

TERRAIN GUN POSITION /SPECIAL CORRECTION

L/P/R SECTOR		TRANSFER LIMITS				CHARGE 4H M232A1
		LEFT	CENTER	RIGHT		
CEN DF +400 m	DF	3600	3200	2800	DF	CEN DF -400m
CEN RG -2000M	RG	12000	14000	16000	RG	CEN RG +2000M

SECTION II. HASTY CORRECTION

INITIAL CHART DATA DEFLECTION RANGE TARGET DATE-TIME GROUP

GUN NUMBER	POSITION LATERAL CORECTION (LEFT/RIGHT)	HASTY POSITION DEFLECTION CORRECTION- ⓐ	PLATOON COMPARATIVE MUZZLE VELOCITY VARIATION	HASTY MUZZLE CORRECTION – ⓒ	POSITION RANGE CORRECTION (FORWARD-BACK+)	HASTY POSITION QUADRANT ELEVATION CORRECTION	TOTAL QUADRANT ELEVATION CORRECTION ⓓ+ⓕ	CORRECTED QUADRANT ELEVATION -SITE FIRED =ELEVATION	TIME TO FIRE (ELEVATION GAGE LINE OVER ⓗ) READ TIME
	a	b	c	d	e	f	g	h	i
	5 METERS	AS LISTED	0.1METERS PER SECOND	AS LISTED	5 METERS	AS LISTED	1 MIL	1 MIL	0.1
1									
2									
3									
4									

SECTION III. SPECIAL CORRECTIONS

INITIAL CHART DATA DEFLECTION 3200 RANGE 14000 TARGET DATE-TIME GROUP 201032ZJUN13

PLATOON	GUN NUMBER	POSITION LATERAL CORRECTION (LEFT/RIGHT)	100/R (GAPHICAL FIRING TABLE) (14000)	POSITION DEFLECTION CORRECTION (LEFT/RIGHT) ⓐ×ⓑ / 100	PLATOON COMPARATIVE VELOCITY ERROR (INCREASE/ DECREASE)	MUZZLE VELOCITY UNIT CORRECTION FACTOR (TABLE F APPROPIATE FT) D+ (+22.8) I– (-22.5)	MUZZLE VELOCITY RANGE CORRECTION ⓓ×ⓔ	POSITION RANGE CORRECTION (FORWARD – BACK+)	TOTAL RANGE CORRECTION ⓕ+ⓖ	POSITION QUADRANT ELEVATION CORRECTION (ⓙ ÷ COLUMN 5 TABLE F APPROPIATE FT) (19)	CORRECTED RANGE (ⓙ= 10 METERS + INITIAL RANGE) (14000)	TIME TO FIRE (FUZE SETTING - ⓙ	POS TI CORR ⓚ - Fs-CEN RG (38.1)
		a	b	c	d	e	f	g	j	h	j	k	l
		5 METERS	1 MIL	1 MIL	0.1 METER PER SECOND	0.1 METER	1 METER	5 METERS	1 METER	1 MIL	10 METERS	0.1	0.1
R	1	L25	7	L2	D 1.5	+22.8	+34	0	+34	+2	14030	38.2	+0.1
	2	L60	7	L4	D 1.0	+22.8	+23	+10	+30	+2	14030	38.2	+0.1
L	3	0	7	0	0	0	0	0	0	0	14000	38.1	0.0
	4	R25	7	R2	I 3.4	-22.5	-76	-60	-136	-7	13860	37.5	-0.6

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Legend: GFT – graphical firing table DTG – date time group CEN – center DF – deflection RG – range

Figure 12-17. Completed DA Form 4757 Containing TGPCs for a Circular Sheaf.

EXAMPLES OF SPECIAL CORRECTIONS

12-65. Using the data listed below, determine special corrections for a linear target described by a grid, length, and attitude.

12-66. The following is an example of the platoon leader's report for the Ml00-series sight:

HOWITZER	LAID FROM	LAY DEFLECTION	DISTANCE	VA
1	AC	2595	105	+3
2	AC	2910	55	+1
3 (BP)	AC	3405	90	-2
4	AC	3950	100	-5

Note**:** Howitzer Number 3 is the base piece.

12-67. The following is an example of howitzer displacement:

HOWITZER	LATERAL DISPLACEMENT	RANGE DISPLACEMENT
1	R75	0
2	R35	+35
3	0	0
4	L50	+15

GIVEN:

- Target Grid: 432275
- Length: 300 M
- Attitude: 1,300
- $\frac{Target\ Length}{2} = \frac{300M}{2} = 150$
- $Distance\ between\ aimpoints = \frac{Target\ Lenth}{No\ Howitzer - 1} = \frac{300}{4-1} = \frac{300}{3} = 100$
- Chart data to the center grid: Chart range 14260 Chart deflection 3452

12-68. A completed DA Form 4757 for the special corrections and the Ml7 plotting board are shown in figures 12-18 through 12-20 (pages 12-38 through 12-40).

REGISTRATION/SPECIAL CORRECTION WORK SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC

SECTION I. REGISTRATION COMPUTATION

	ACHIEVED RANGE			DEFLECTION CORRECTION	
1	CHART RANGE	(10 METERS)	7	CORRECTED DEFLECTION (REGISTRATION)	(1MIL)
2	REGISTERING HOWITZER DISPLACEMENT (F-/B+)	(10 METERS)	8	REGISTERING HOWITZER DISPLACEMENT CORRECTION ⑥ (L+/R)	(1MIL)
3	ACHIEVED RANGE (①-②)	(10 METERS)	9	ADJUSTED DEFLECTION (⑦+⑧)	(1MIL)
	REGISTERING HOWITZER DISPLACEMENT CORRECTION		10	CHART DEFLECTION	(1MIL)
4	LATERAL DISPLACEMENT (L/R)	(5 METERS)	11	TOTAL DEFLECTION CORRECTION (⑨-⑩) (L+/R-)	(1MIL)
5	ACHIEVED RANGE (③)	(10 METERS)	12	DRIFT CORRECTION (- ADJUSTED ELEVATION) (L)	(1MIL)
6	REGISTERING HOWITZER DIAPLACEMENT CORRECTION (④÷⑤) L+/R-	(1MIL)	13	GRAPHICAL FIRING TABLE (GFT) DEFLECTION CORRECTION (⑪-⑫)	(1MIL)

GFT SETTING (MANUAL METHOD)

							DEFLECTION CORRECTION	
14	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME	TOTAL	GFT
15	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
16	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		

GFT SETTING (COMPUTER METHOD)

17	REGISTRATION UNIT/WEAPON NUMBER	RANGE	RANGE CORRECTION	TIME CORRECTION	DEFLECTION CORRECTION
18	PROJECTILE/LOT	FUZE/LOT	PROPELLANT/LOT	ANGLE OF FIRE	TIME CORRECTION (SEC)
19	DTG	TARGET NUMBER	FUZE K	RANGE K	

TERRAIN GUN POSITION /SPECIAL CORRECTION

REMARKS	L/P/R SECTOR	TRANSFER LIMITS				CHARGE 4H M232A1
			LEFT	CENTER	RIGHT	
	CEN DF +400 m	DF		3452		DF	CEN DF -400m
	CEN RG -2000M	RG		14260		RG	CEN RG +2000M

SECTION II. HASTY CORRECTION

INITIAL CHART DATA		DEFLECTION	RANGE	TARGET	DATE-TIME GROUP				
GUN NUMBER	POSITION LATERAL CORECTION (LEFT/RIGHT)	HASTY POSITION DEFLECTION CORRECTION- ⓐ	PLATOON COMPARATIVE MUZZLE VELOCITY VARIATION	HASTY MUZZLE CORRECTION – ⓒ	POSITION RANGE CORRECTION (FORWARD- BACK +)	HASTY POSITION QUADRANT ELEVATION CORRECTION	TOTAL QUADRANT ELEVATION CORRECTION ⓓ+ⓕ	CORRECTED QUADRANT ELEVATION -SITE FIRED =ELEVATION	TIME TO FIRE (ELEVATION GAGE LINE OVER ⓗ) READ TIME
	a	b	c	d	e	f	g	h	i
	5 METERS	AS LISTED	0.1METERS PER SECOND	AS LISTED	5 METERS	AS LISTED	1 MIL	1 MIL	0.1
1									
2									
3									
4									

SECTION III. SPECIAL CORRECTIONS

INITIAL CHART DATA — DEFLECTION 3200 — RANGE 14000 — TARGET ____ — DATE-TIME GROUP 201032ZJUN13

PLATOON	GUN NUMBER	POSITION LATERAL CORRECTION (LEFT/RIGHT)	100/R (GAPHICAL FIRING TABLE) (14260)	POSITION DEFLECTION CORRECTION (LEFT/RIGHT) ⓐ×ⓑ / 100	PLATOON COMPARATIVE VELOCITY ERROR (INCREASE/ DECREASE)	MUZZLE VELOCITY UNIT CORRECTION FACTOR (TABLE F APPROPIATE FT) D+ (+23.0) I– (-22.8)	MUZZLE VELOCITY RANGE CORRECTION ⓓ×ⓔ	POSITION RANGE CORRECTION (FORWARD – BACK+)	TOTAL RANGE CORRECTION ⓕ+ⓖ	POSITION QUADRANT ELEVATION CORRECTION (ⓘ ÷ COLUMN 5 TABLE F APPROPIATE FT) (18)	CORRECTED RANGE (ⓗ= 10 METERS + INITIAL RANGE) (14000)	TIME TO FIRE (FUZE SETTING - ⓘ	POS TI CORR ⓚ - Fs-CEN RG (39.4)
		a	b	c	d	e	f	g	j	h	j	k	l
		5 METERS	1 MIL	1 MIL	0.1 METER PER SECOND	0.1 METER	1 METER	5 METERS	1 METER	1 MIL	10 METERS	0.1	0.1
R	1	L65	7	L5	D 1.5	+23.0	+34	-135	-101	-6	14160	38.8	-0.6
	2	L40	7	L3	D 1.0	+23.0	+23	-75	-52	-3	14210	39.0	-0.4
L	3	L5	7	0	0	0	0	+50	+50	+3	14310	39.4	0.0
	4	R40	7	R3	I 3.4	-22.8	-78	+125	+47	+3	14310	39.4	0.0

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Legend: GFT – graphical firing table DTG – date time group CEN – center DF – deflection RG – range

Figure 12-18. Completed DA Form 4757 Containing Special Corrections.

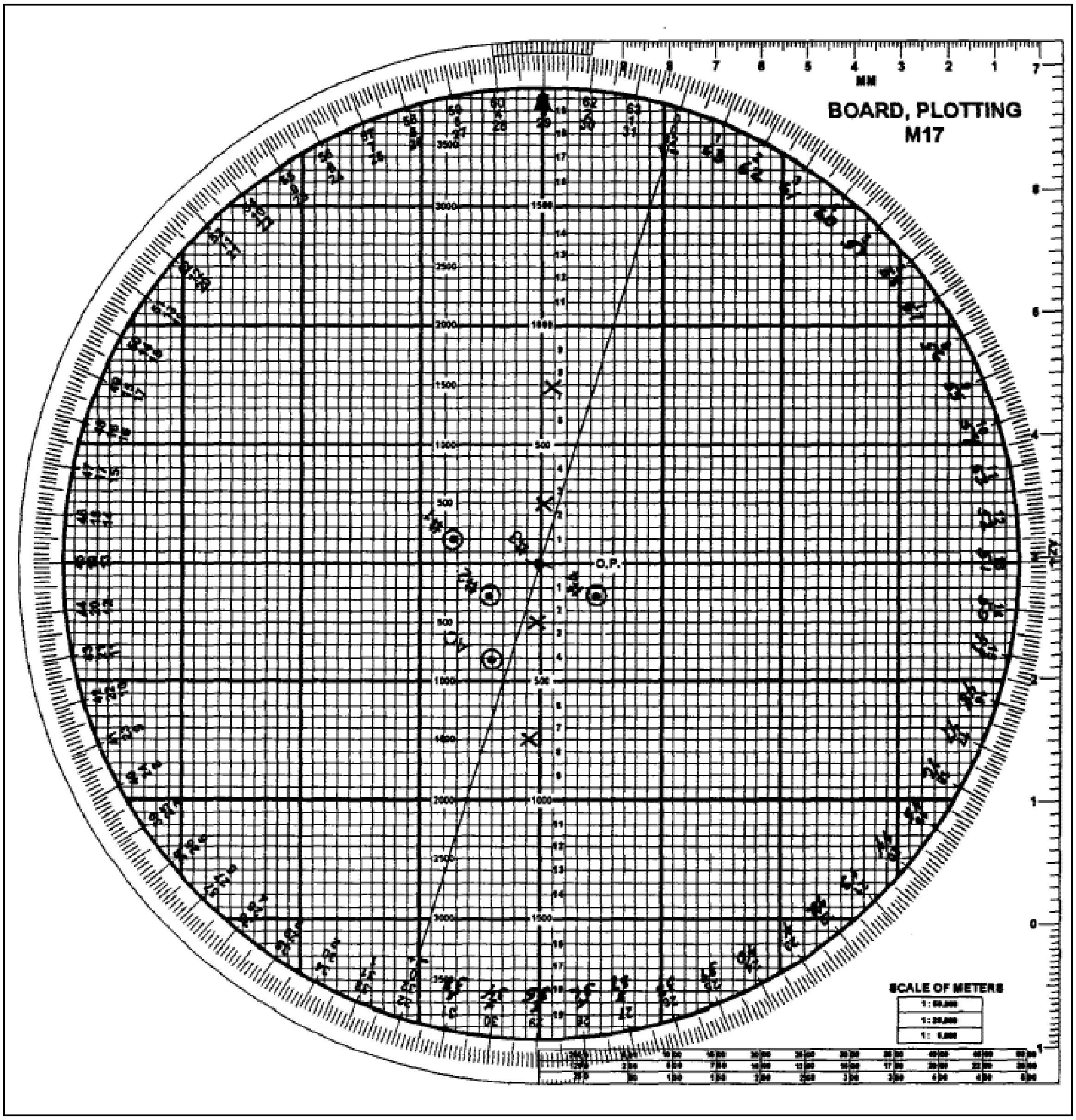

Figure 12-19. M17 Plotting Board Oriented on an Attitude 1300, with a Target and Burst Point Plotted.

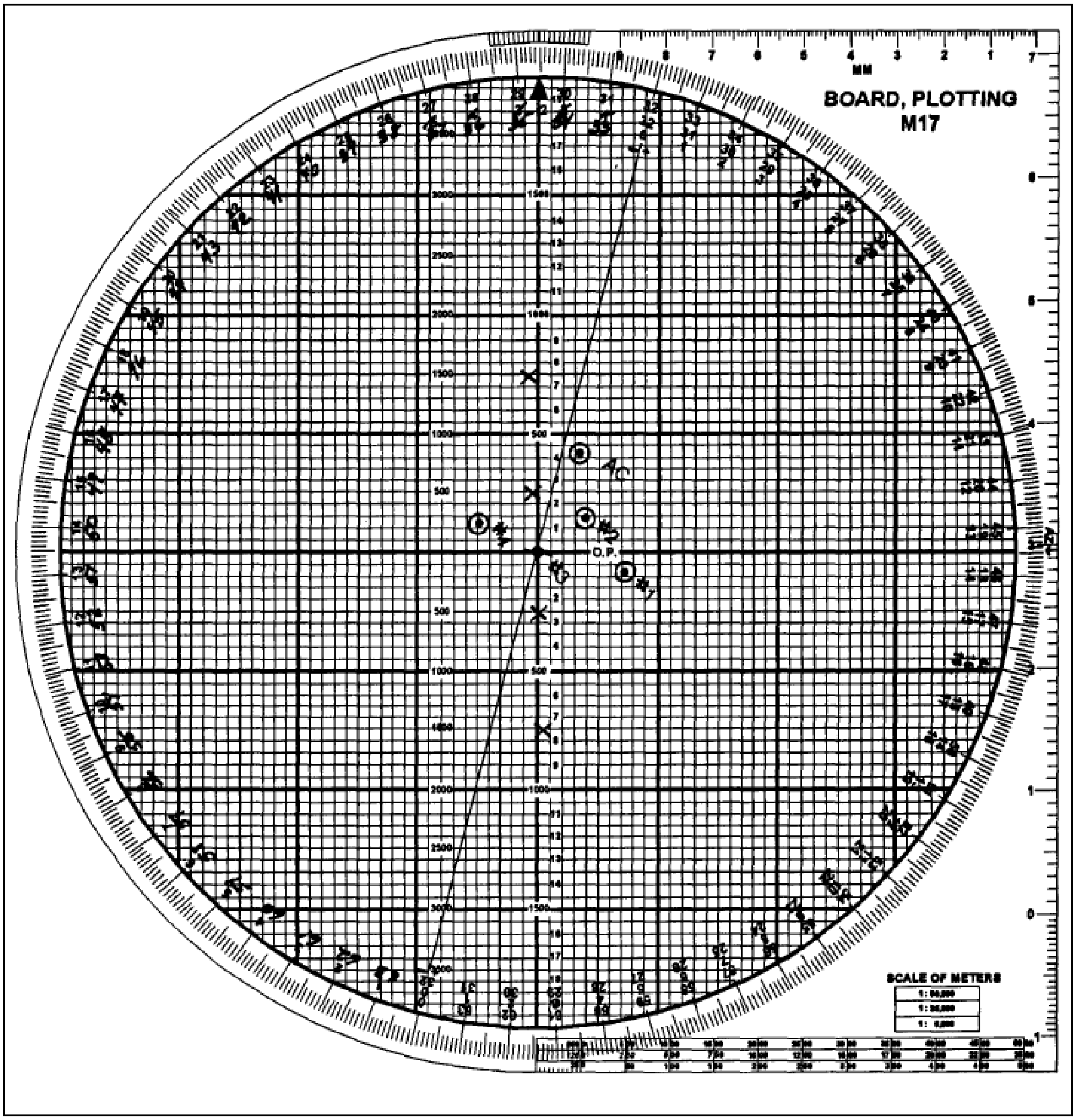

Figure 12-20. M17 Plotting Board Oriented on the Chart Deflection.

12-69. The following is an example of the platoon leader's report for the Ml00-series sight:

HOWITZER	LAID FROM	LAY DEFLECTION	DISTANCE	VA
1	AC	2595	105	+3
2	AC	2910	55	+1
3 (BP)	AC	3405	90	-2
4	AC	3950	100	-5

Note: Howitzer Number 3 is the base piece.

12-70. The following is an example of howitzer displacement:

HOWITZER	LATERAL DISPLACEMENT	RANGE DISPLACEMENT
1	**R75**	**0**
2	**R35**	**+35**
3	**0**	**0**
4	**L50**	**+15**

GIVEN:

- Target Grid: 424275 and 427273
- (Easting) (Northing)

  42400 27500
  --42700 -27300
  -300 +200
- $\frac{\Delta Easting}{2} = \frac{-300}{2} = -150$ $\frac{\Delta Northing}{2} = \frac{+200}{2} = +100$
- Center Grid:

  (Easting) (Northing)
  42400 27500
  - (-150) - (+100)
  42550 27400
- Target Length: 360
- $Distance\ between\ aimpoints = \frac{TargetLenth}{No\ Howitzer - 1} = \frac{360}{4-1} = \frac{360}{3} = 120$
- Chart data to the center grid: Chart range 14920 Chart deflection 3438

12-71. A completed DA Form 4757 for the special corrections and the Ml 7 plotting board are shown in figures 12-21 through 12-24 (pages 12-42 through 12-45).

REGISTRATION/SPECIAL CORRECTION WORK SHEET
For use of this form, see TC 3-09.81; the proponent agency is TRADOC

SECTION I. REGISTRATION COMPUTATION

	ACHIEVED RANGE			DEFLECTION CORRECTION	
1	CHART RANGE	____ (10 METERS)	7	CORRECTED DEFLECTION (REGISTRATION)	____ (1MIL)
2	REGISTERING HOWITZER DISPLACEMENT (F-/B+)	____ (10 METERS)	8	REGISTERING HOWITZER DISPLACEMENT CORRECTION ⑥ (L+/R)	____ (1MIL)
3	ACHIEVED RANGE (①-②)	____ (10 METERS)	9	ADJUSTED DEFLECTION (⑦+⑥)	____ (1MIL)
	REGISTERING HOWITZER DISPLACEMENT CORRECTION		10	CHART DEFLECTION	____ (1MIL)
4	LATERAL DISPLACEMENT (L/R)	____ (5 METERS)	11	TOTAL DEFLECTION CORRECTION ((⑨-⑩) (L+/R-)	____ (1MIL)
5	ACHIEVED RANGE (③)	____ (10 METERS)	12	DRIFT CORRECTION (- ADJUSTED ELEVATION) (L)	____ (1MIL)
6	REGISTERING HOWITZER DIAPLACEMENT CORRECTION (④÷⑤) L+/R-	____ (1MIL)	13	GRAPHICAL FIRING TABLE (GFT) DEFLECTION CORRECTION (⑪-⑫)	____ (1MIL)

GFT SETTING (MANUAL METHOD)

							DEFLECTION CORRECTION	
14	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME	TOTAL	GFT
15	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		
16	GFT	CHARGE	LOT	RANGE	ELEVATION	TIME		

GFT SETTING (COMPUTER METHOD)

17	REGISTRATION UNIT/WEAPON NUMBER	RANGE	RANGE CORRECTION	TIME CORRECTION	DEFLECTION CORRECTION
18	PROJECTILE/LOT	FUZE/LOT	PROPELLANT/LOT	ANGLE OF FIRE	TIME CORRECTION (SEC)
19	DTG	TARGET NUMBER	FUZE K	RANGE K	

TERRAIN GUN POSITION /SPECIAL CORRECTION

REMARKS
LINEAR TGT, 2 GRIDS
#1 - 424 275
#2- 427 273
CHART RANGE14920 DF 3438

L/P/R SECTOR		TRANSFER LIMITS				CHARGE 4H M232A1
		LEFT	CENTER	RIGHT		
CEN DF +400 m	DF		3438		DF	CEN DF -400m
CEN RG -2000M	RG		14920		RG	CEN RG +2000M

SECTION II. HASTY CORRECTION

INITIAL CHART DATA — DEFLECTION ____ RANGE ____ TARGET ____ DATE-TIME GROUP ____

GUN NUMBER	POSITION LATERAL CORECTION (LEFT/RIGHT)	HASTY POSITION DEFLECTION CORRECTION ⓐ	PLATOON COMPARATIVE MUZZLE VELOCITY VARIATION	HASTY MUZZLE CORRECTION – ⓒ	POSITION RANGE CORRECTION (FORWARD-BACK +)	HASTY POSITION QUADRANT ELEVATION CORRECTION	TOTAL QUADRANT ELEVATION CORRECTION ⓓ+ⓕ	CORRECTED QUADRANT ELEVATION -SITE FIRED =ELEVATION	TIME TO FIRE (ELEVATION GAGE LINE OVER ⓗ) READ TIME
	a	b	c	d	e	f	g	h	i
	5 METERS	AS LISTED	0.1METERS PER SECOND	AS LISTED	5 METERS	AS LISTED	1 MIL	1 MIL	0.1
1									
2									
3									
4									

SECTION III. SPECIAL CORRECTIONS

INITIAL CHART DATA — DEFLECTION 3200 RANGE 14000 TARGET ____ DATE-TIME GROUP 201032ZJUN13

PLATOON	GUN NUMBER	POSITION LATERAL CORRECTION (LEFT/RIGHT)	100/R (GAPHICAL FIRING TABLE) (14920)	POSITION DEFLECTION CORRECTION (LEFT/RIGHT) ⓐ×ⓑ / 100	PLATOON COMPARATIVE VELOCITY ERROR (INCREASE/ DECREASE)	MUZZLE VELOCITY UNIT CORRECTION FACTOR (TABLE F APPROPIATE FT) D+ (+23.6) I= (-23.2)	MUZZLE VELOCITY RANGE CORRECTION ⓓ×ⓔ	POSITION RANGE CORRECTION (FORWARD – BACK+)	TOTAL RANGE CORRECTION ⓕ+ⓖ	POSITION QUADRANT ELEVATION CORRECTION (ⓙ + COLUMN 5 TABLE F APPROPIATE FT) (17)	CORRECTED RANGE (ⓙ= 10 METERS + INITIAL RANGE) (14920)	TIME TO FIRE (FUZE SETTING - ⓙ	POS TI CORR ⓚ - Fs-CEN RG (42.3)
		a	b	c	d	e	f	g	j	h	j	k	l
		5 METERS	1 MIL	1 MIL	0.1 METER PER SECOND	0.1 METER	1 METER	5 METERS	1 METER	1 MIL	10 METERS	0.1	0.1
R	1	R60	7	R4	D 1.5	+23.6	+35	+140	+175	+10	15095	42.9	+0.6
	2	R5	7	0	D 1.0	+23.6	+24	+10	+34	+2	14950	42.2	-0.1
L	3	L45	7	L3	0	0	0	-45	-45	-3	14960	42.3	0.0
	4	L85	7	L6	I 3.4	-23.2	-79	-204	-283	-17	14720	41.2	-1.1

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Legend: GFT – graphical firing table DTG – date time group CEN – center DF – deflection RG – range

Figure 12-21. Completed DA Form 4757 Containing Special Corrections.

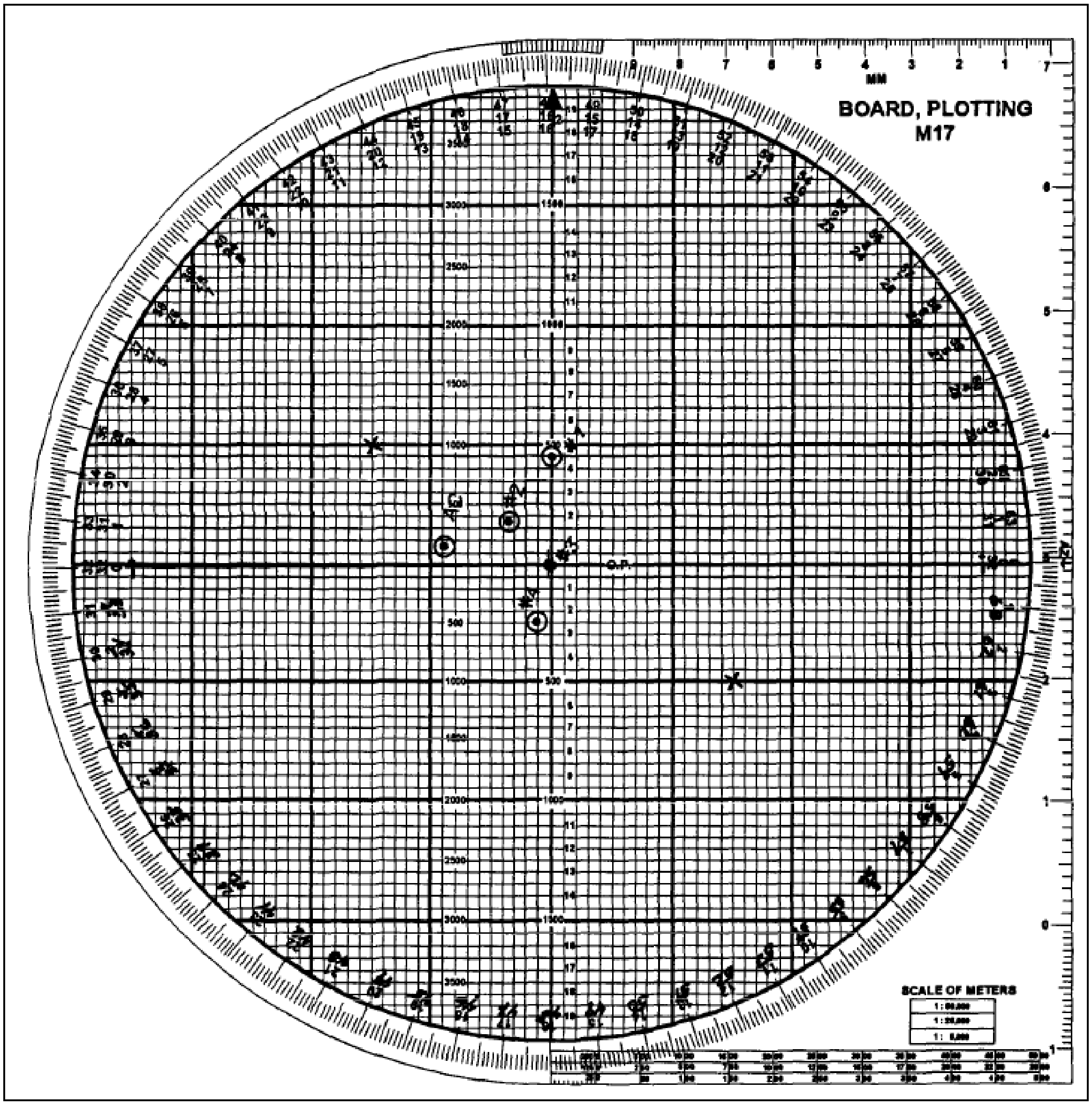

Figure 12-22. M17 Plotting Board With Both Grids Plotted.

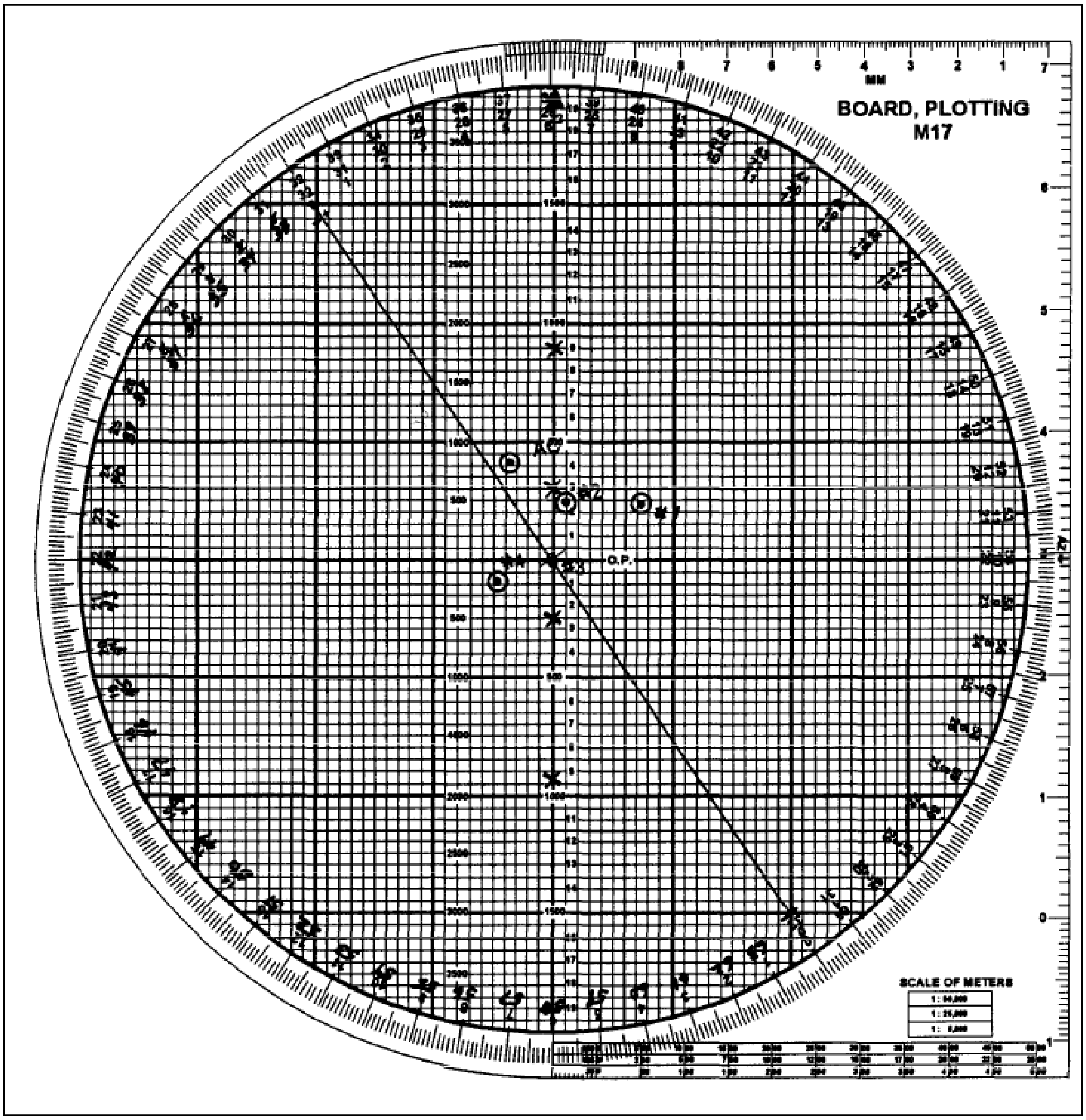

Figure 12-23. M17 Plotting Board With Burst Points Plotted.

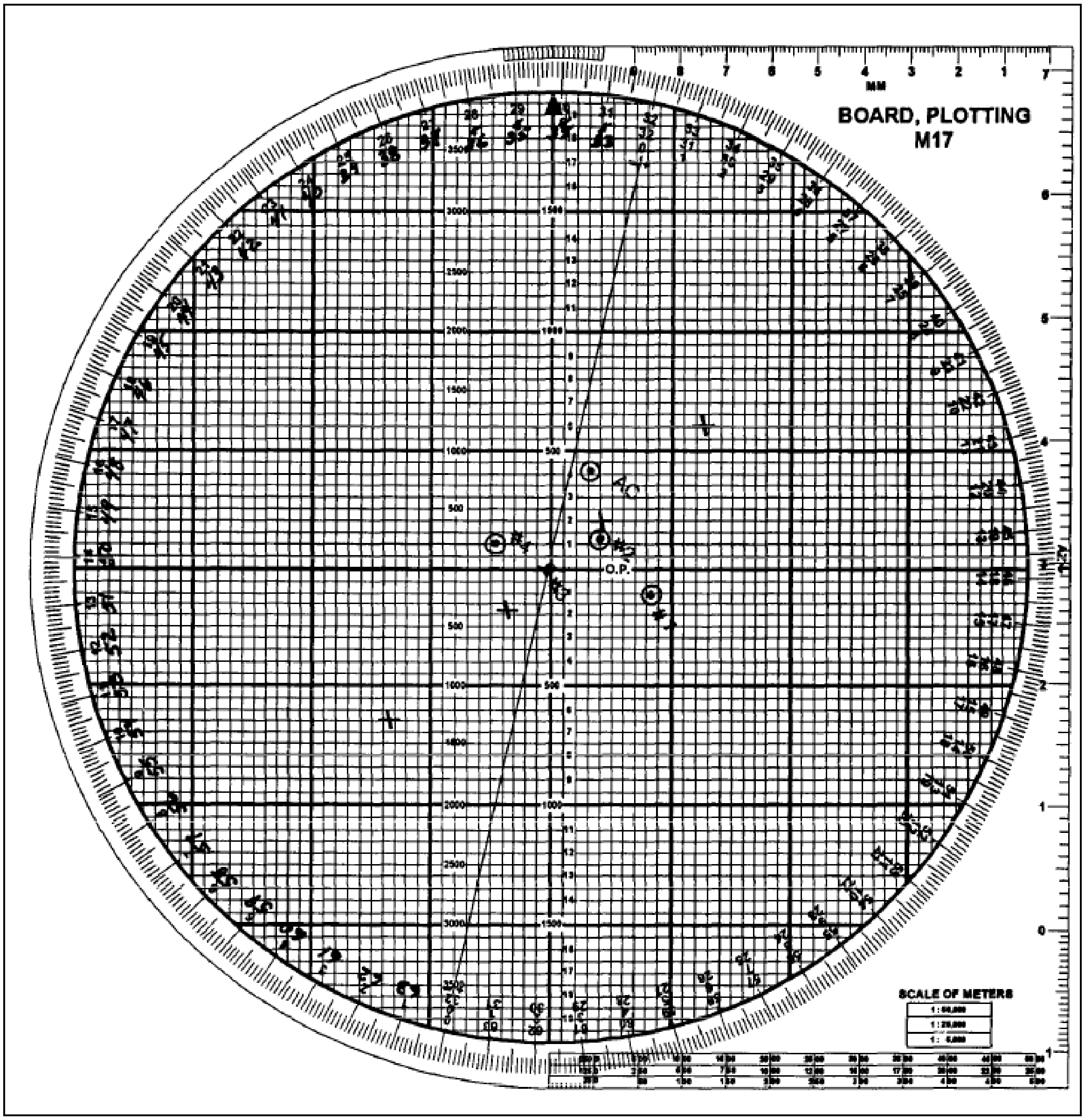

Figure 12-24. M17 Plotting Board Oriented on the Chart Deflection.

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Chapter 13

Special Munitions

This chapter describes procedures for special munition employment. Appendix G provides further information on special mission processing.

SECTION I: ROCKET-ASSISTED PROJECTILE

13-1. Rocket-assisted projectiles (RAP) are available for the 105-mm and 155-mm howitzers. They are designed to extend the range of the howitzers. The basic rocket-assisted projectiles are filled with HE material. They produce blast and fragmentation in the target area. Computation procedures for all of the HE RAPs are identical. All RAP firing tables contain data for the rocket on mode and some have data for the rocket off mode as well.

DESCRIPTION

13-2. The 105-mm RAPs are the M548, M913 and M927. The 155-mm projectile is the M549A1. M549A1 may be fired with charge 7W (M4A2), 7R (M119A2), 8S (M203A1) and 3-5H (M232/A1).

13-3. Rocket-assisted projectiles should always be fired by using current GFT settings because most RAP missions are expected to be FFE missions. The multiplot GFT setting is recommended for use with RAP. When no RAP registration data are available, a met-to-target technique should be solved by using MV data, propellant temperature, and rocket motor temperature (assumed to be the same as the propellant temperature).

MANUAL COMPUTATIONS

13-4. Procedures for computing HE RAP firing data are identical to those for conventional HE rounds. The RAP GFTs and GSTs are similar to and are read in the same way as those for conventional HE rounds. Table 13-1 shows the steps for determining firing data for the RAP.

Note: Figures 13-1 through 13-3 (pages 13-3 through 13-5) show a completed RAP fire mission. A M109A6 howitzer, propellant M232A1 and FT 155-AO-2 were used.

Table 13-1. Determining Firing Data for a RAP Fire Mission.

STEP	*ACTION*
1	Upon receipt of the observer's call for fire, the FDO issues the fire order. The RTO composes and transmits the message to observer.
2	The computer determines and sends initial fire commands.
3	The chart operator (HCO) determines and announces chart data.
4	The VCO determines and announces site by using the appropriate RAP GST.
5	The computer determines, records and, announces firing data. If a GFT setting is available, go to step 6. If a GFT setting is unavailable, go to step 7.
6	If a GFT setting is available for RAP, he determines firing data (drift, elevation and fuze setting) by using the appropriate gauge lines. Go to step 10.

Table 13-1. Determining Firing Data for a RAP Fire Mission (continued).

STEP	ACTION
7	If no GFT setting is available the computer determines deflection, range and fuze setting corrections to GFT data by using the TFT and met correction techniques (see figure 13-2, page 13-4).
8	Determine corrected chart data. Compute met data corrections on DA Form 4200, and manually apply the corrections to the chart range and deflection. All steps are the same as standard met-to-target procedures except that the rocket motor temperature correction is recorded in the upper range correction block. The rocket motor temperature is assumed to be the same as the propellant temperature, the correction is determined from the TFT Table E-1.
9	Use GFT to determine drift, elevation & time of flight corresponding to the corrected chart data. If no GFTs are available, use TFT to interpolate elevation and fuze setting from Table F.
10	Determine, record and announce remainder of the fire commands (figure 13-3, page 13-5).
Legend: FDO – fire direction officer GFT – graphical firing table HCO – horizontal control operator RAP – rocket assisted projectile RTO – radio telephone operator TFT – tabular firing table VCO – vertical control operator	

REGISTRATION AND DETERMINING A GFT SETTING

13-5. Units most likely will not register with the rocket-assisted projectile. An inferred GFT setting can be computed without registration data. Use a subsequent met technique such as met + VE, met to target, or met to met-check gauge point. Assume position constants are zero. As time allows, compute a multiplot GFT setting to improve accuracy at all ranges. Include range corrections for rocket motor temperature for solving RAP met techniques for rocket motor on mode. As time permits, total fuze setting corrections should be determined if a time fuze is to be employed. However, due to large fuze-related probable errors, the FDO may decide to ignore total fuze setting corrections if he is in a time-constrained environment when determining data. Quick and variable time fuzes generally produce the best effects on target with RAP.

13-6. In a combat environment, the unit may conduct registrations with RAP. All of the probable errors involved in firing RAP force the observer to modify a precision registration and severely degrade its accuracy. For this reason, an MPI registration is the best option. However, probable errors also affect the MPI registration. Since the observer obtains spottings of a number of impacts **without adjustment,** the effects of the probable errors are lessened in comparison to a precision registration. The determined mean point of impact most likely is not as accurate as one determined for an HE MPI registration. However, the RAP MPI registration still provides a GFT setting and increases accuracy. If the unit does register, it also solves a concurrent met and derives position constants for use with later RAP missions. Use the position constants and a subsequent met technique to determine a GFT setting for new missions. As time allows, use the position constants and subsequent met techniques to construct a multiplot GFT setting and improve accuracy at all ranges.

COMPUTER MET MESSAGE

For use of this form, see TC 3-09.81 the proponent agency is TRADOC.

IDENTIFICATION METCM	OCTANT Q	LOCATION $L_aL_aL_a$ or XXX	LOCATION $L_oL_oL_o$ or XXX	DATE YY	TIME (GMT) $G_dG_dG_o$	DURATION (HOURS) G	STATION HEIGHT (10's M) hhh	MDP PRESSURE MB $P_dP_dP_d$
METCM	1	347	984	25	138	0	036	974

ZONE HEIGHTS METERS	LINE NUMBER ZZ	ZONE VALUES: WIND DIRECTION (10s M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10 °K) TTTT	PRESSURE (MILLIBARS) PPPP
SURFACE	00	310	004	2923	0974
200	01	250	011	2931	0962
500	02	316	011	2946	0932
1000	03	361	014	2931	0893
1500	04	371	011	2871	0841
2000	05	504	007	2826	0793
2500	06	453	015	2826	0745
3000	07	473	014	2741	0702
3500	08	521	014	2669	0658
4000	09	582	019	2632	0617
4500	10	576	023	2654	0578
5000	11	568	017	2653	0544
6000	12	570	017	2633	0493
7000	13	589	011	2648	0434
8000	14	611	014	2721	0383
9000	15	256	015	2683	0338
10000	16	395	018	2658	0297
11000	17	382	019	2608	0262
12000	18	377	037	2539	0229
13000	19	394	027	2488	0201
14000	20	438	020	2460	0174
15000	21	626	023	2386	0151
16000	22	002	025	2311	0131
17000	23	634	031	2264	0113
18000	24	074	038	2267	0097
19000	25				
20000	26				

FROM FORT SILL MET TO FDC 2/2 FA	DATE AND TIME (GMT) 25 1400 NOV 04	DATE AND TIME (LST) 25 0800 NOV 04
MESSAGE NUMBER 1	RECORDER ROBERTS	CHECKED McADAMS

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Legend: BTRY – battery FA – field artillery GMT – Greenwich Mean Time LST – local standard time MB – millibars MDP – meteorological datum plane

Figure 13-1. Valid Computer Met Message (RAP Fire Mission).

MET DATA CORRECTION SHEET

For use of this form, see TC 3-09.81; the proponent agency is TRADOC.

BATTERY DATA (34.7° N)				MET MESSAGE				
CHARGE 4H(M232A1)	ADJ QE	CHART RG 17500	LATITUDE 30° N	TYPE MESSAGE METB3		OCTANT 1	AREA/UNIT 347 984	
ALT OF BTRY (10m) (482)		480		DATE 25	TIME 1348		ALT MDP 360	PRESSURE
ALT OF MDP		360		LINE NO. 05	WIND DIR. 4100	WIND SPEED 07	AIR TEMP 102.5%	AIR DENSITY 93.9%
BTRY ABOVE / BELOW MDP (Δh)		+120		Δh CORRECTION			+ - -0.2	+ - -1.2
ALT OF TARGET (nearest meter)		531		CORRECTED VALUES			102.3%	92.7%
HEIGHT OF BURST ABOVE TARGET								
ALT OF BURST		531						
ALT OF BTRY (nearest meter)		482						
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+49 ~ 0		COMP RG 0		CHART RG 17500	ENTRY RG 17500	17500

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	POS DF CORR 0 + MET DF CORR L11 TOT DF CORR L11
DIRECTION OF WIND	4100	
DIRECTION OF FIRE (1480)	1500	ROTATION CORR L R: L1.7
CHART DIRECTION OF WIND	2600	DRIFT CORR L: L11.2
CROSS WIND — WIND SPEED 07	L X COMP R R0.56 = L R R4 KNOTS = 0.48 UNIT CORR =	CROSSWIND CORR L R: R1.9
RANGE WIND — WIND SPEED 07	T X COMP H T0.83 = TAIL HEAD T6 KNOTS	MET DEFL CORR L R: L11 — L11

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS	
RANGE WIND	T H T6	0	T H T6	-14.3		85.8	
AIR TEMP	102.3	100%	D I I 2.3	+10.9	25.1		
AIR DENSITY	92.7	100%	D I D 7.3	-95.0		693.5	
PROJ WEIGHT	4[]	4[]	D I 0	0			
ROTATION	-38 X	0.87				33.1	
POS VE + MVV (PROP EFF + S.S.) = VE 0 + (-1.1 + -1.3) = -2.4					25.1	812.4	
						25.1	
				MET RANGE CORR		787.3	-787

COMPUTATION OF VE

					ROCKET MOTOR TEMP CORR		
PROP TEMP 85 °F	VE	-2.4 M/S	D 27.6		~~TOTAL RANGE CORRECTION~~	-26	
	CHANGE TO MV FOR PROP TEMP	+2.7 M/S		I -27.1	MET RANGE CORRECTION	-787	
	ΔV	+0.3 M/S	MV UNIT CORRECTION	-27.1	ΔV RANGE CORRECTION	-8	
					TOTAL RANGE CORRECTION	-821	-820

OLD VE ____ + NEW VE ____ = ____ ÷ 2 = AVG VE ____ M/S

FS @ ADJ EL = 39.6 ~ 40

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS		
ΔV	D I I 0.3	+0.042	0.013		16680 / -820 / 17500 / 335 / 40.3 / +0.7 / 39.6	
RANGE WIND	T H T6	+0.004	0.024			
AIR TEMP	D I I 2.3	-0.042		0.097		
AIR DENSITY	D I D 7.3	+0.106	0.774			
PROJ WEIGHT	D I 0	0			TOTAL FUZE CORRECTION	
			0.811	0.097	MET FUZE CORRECTION	+0.7
			0.097		FUZE CORRECTION	0.0
			0.714		TOTAL FUZE CORRECTION	+0.7

OLD FZ COMP ____ + NEW FZ CORR ____ = ____ ÷ 2 = AVG FZ CORR ____

TARGET NO ____ BATTERY ____ DATE/TIME ____

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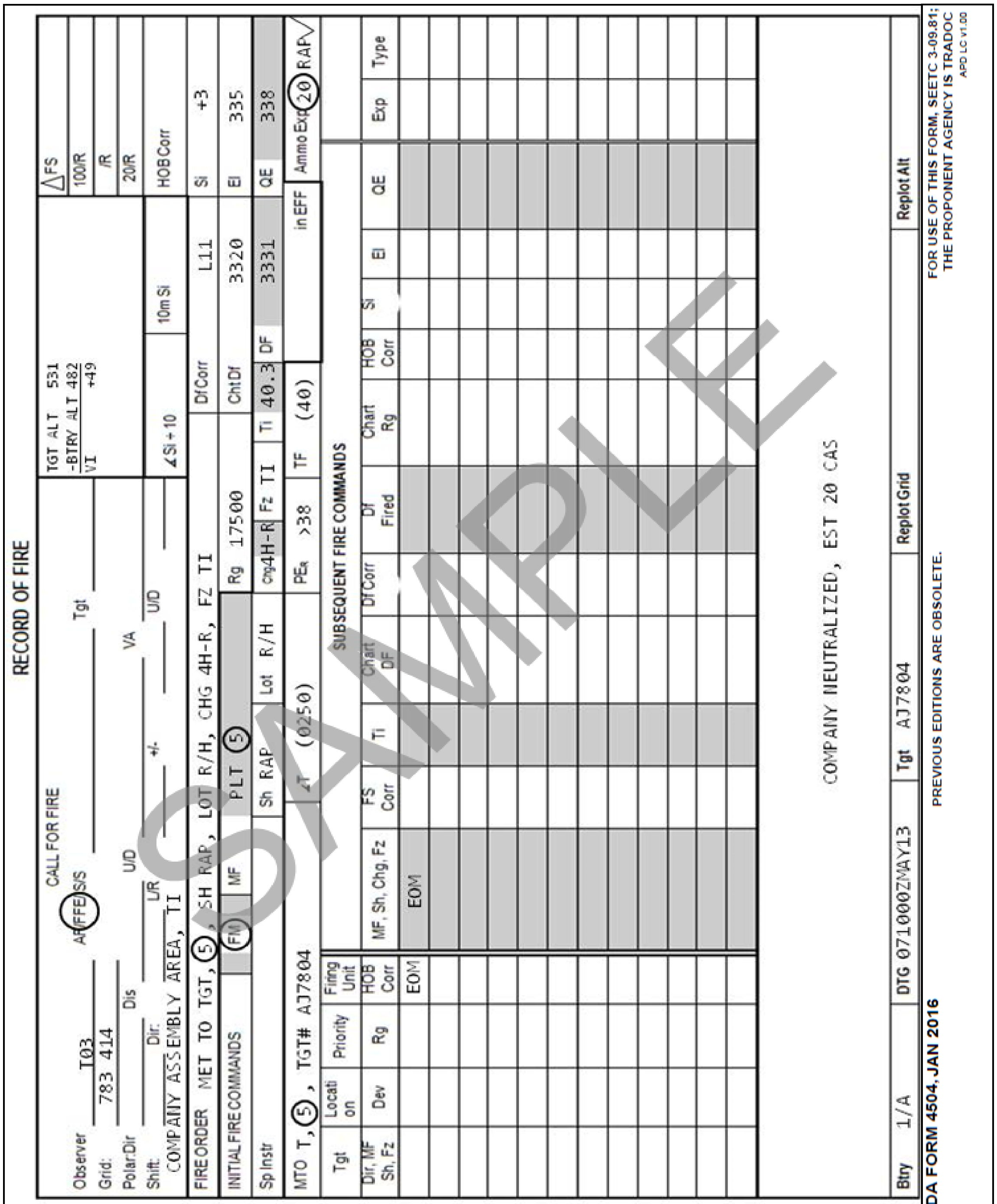
Legend:

ADJ EL – adjusted elevation
ADJ QE – adjusted quadrant elevation
ALT – altitude
AVG – average
BTRY – battery
CORR – correction
DF – deflection
DIR – direction
FS – fuze setting
KN PT – known point
MDP – met datum plane
MV – muzzle velocity
MVV – muzzle velocity variation
NO – number
POS – position
PROJ – projectile
PROP – propellant
RG – range
TEMP – temperature
VE – velocity error

Figure 13-2. Completed Met Data Correction Sheet (RAP Fire Mission).



Legend:
AF – adjust fire
ALT – altitude
BPAMC – by piece at my command
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
IS – immediate suppression
L/R – left/right
LAT – lateral
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
RAP – rocket assisted projectile
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TFT – tabular firing table
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 13-3. Completed Record of Fire (RAP Fire Mission).

SECTION II: SMOKE PROJECTILES

13-7. Smoke projectiles are used for smoke screens, obscuring smoke, and marking targets for aircraft. There are three types of smoke projectiles: Hexachloroethane, burster-type white phosphorus, and M825 white phosphorus.

DESCRIPTION

13-8. **Hexachloroethane.** Hexachloroethane (HC) smoke projectiles are available for 105-mm and 155-mm howitzers. They are used for screening, obscuration, spotting, and signaling purposes. The projectile has no casualty-producing effects. This base-ejection projectile is ballistically similar to the HE (105mm) or M107 (155mm) projectile families. It is fitted with a base ejecting time fuze. The round expels smoke canisters that emit smoke for a period of 40 to 90 seconds.

13-9. **Burster-type white phosphorus.** White phosphorus projectiles are available for 105-mm and 155-mm howitzers. They are bursting-tube type projectiles that can be fired with point-detonating (PD) or time fuzes. The projectile has an incendiary-producing effect and is ballistically similar to the HE (105mm) or M107 (155mm) projectile families. Normally, shell WP is employed for its incendiary effect. The projectile also can be used for screening, spotting, and signaling purposes.

13-10. **M825 white phosphorus.** The M825 WP projectile is an FA-delivered 155-mm base-ejection projectile designed to produce a smoke screen on the ground for a duration of 5 to15 minutes. It consists of two major components – the projectile carrier and the payload. The projectile carrier delivers the payload to the target. The payload consists of 116 WP-saturated felt wedges. The smoke screen is produced when a predetermined fuze action causes ejection of the payload from the projectile. After ejection, the WP-saturated felt wedges in the payload fall to the ground in an elliptical pattern. Each wedge then becomes a point or source of smoke. The M825 is ballistically similar to the M795 family of projectiles.

Note: The terms M825 and M825A1 are used throughout the chapter and at time interchangeably. The methods for computing firing data are generally similar between the two projectiles. Care must be exercised when using supplementary GFT scales to determine firing data as it will only apply to M825 or M825A1, whichever is annotated on the GFT. **The two projectile models have similar but different firing data.** The primary difference between the projectile models is that the M825A1 projectile contains an improved payload and a new base which have corrected the M825 flight instability issues.

Note: The preferred method for determining M825A1 firing data is to apply a GFT setting to the 155-AR-2 GFT since both the base scale (M795) and M825A1 are in the same projectile family. An acceptable alternative is to use a 155-AM-3 GFT with GFT setting applied. When using the 155-AM-3 GFT there is a small reduction in accuracy since the total corrections are being applied across projectile families (M107 to M795). If a current GFT setting for only M107 is available, the convenience gained in computing firing data from the second method more than offsets the reduction in accuracy

EMPLOYMENT

13-11. Smoke is employed by using the quick smoke and immediate smoke techniques.

13-12. **Quick smoke.** A quick smoke mission is used to build a screen 100 to 1,500 meters in length, depending on the munition selected. It may be fired as a preplanned target or as a target of opportunity. Targets greater than 250 meters in length should be preplanned because of ammunition constraints and the possible need to segment the target. Quick smoke may be processed as an adjust-fire or FFE mission. Accurate FFE mission processing on preplanned targets presupposes a positive correlation between wind direction at the screen location and that listed on line 00 of the current computer met message, in addition to meeting the five requirements for accurate fire. The following is a list of quick smoke mission characteristics:

- Delivery technique: Quick smoke.
- Type of target: Panned, or target of opportunity, 100 to 1,500 meters.
- Number of howitzers: 2 to 16. Type of ammunition: M825, HC or WP.
- Sheaf: Linear.
- Obscuration Time: 5 to 15 minutes.
- Mission command: Approval of maneuver commander.
- Computations (155 mm): FT 155-AM-2 and FT 155-AM-3 for HC and WP data, FT 155-AM-2 and FT 155-ADD-T-1 or FT 155-AM-3 and FT 155-ADD-T-2 or FT 155-AN-2 and FT 155-ADD-Q-1 or FT 155-AR-2 and FT 155-ADD-AD-1 for M825 data, and/or corresponding GFTs and GSTs.

Note: GFTs are available for 155 AM-2, 155 AM-3 and 155-AR-2 that have M825 or M825A1 supplementary scales. The M825 or M825A1 data are determined on the basis of the HE quadrant and fuze setting

13-13. **Immediate smoke.** An immediate smoke mission may be fired as a separate mission or as a follow-up to immediate suppression. Immediate smoke missions normally are fired by platoon. The initial volley may be fired with shell WP, fuze quick, or a mix of shell WP and shell HC. If additional volleys are fired, all howitzers should fire HC smoke. When firing the M825 smoke round, all howitzers should fire the M825 projectile for the initial and any subsequent volleys. Unit SOP should dictate the number of volleys and which howitzers will fire WP and which will fire HC smoke, if applicable. The following is a list of immediate smoke mission characteristics.

- Delivery technique: Immediate smoke (point suppression). The immediate smoke technique can be used in an immediate suppression mission on a target of opportunity by unit SOP. A mix of WP and HC normally will follow the initial suppression rounds when immediate smoke is requested.
- Type of target: Point or small area of 150 meters or less.
- Number of howitzers: One platoon.
- Type of ammunition: First volley, WP and/or HC; subsequent volleys, HC; or all volleys M825 smoke.
- Sheaf: Parallel.
- Obscuration time: 30 seconds to 5 minutes.
- Mission command: By SOP and/or approval of maneuver commander.
- Computations (155 mm): FT 155-AM-2 and FT 155-AM-3 for HC and WP data, FT 155-AM-2 and FT 155-ADD-T-1 or FT 155-AM-3 and FT 155-ADD-T-2 or FT 155-AN-2 and FT 155-ADD-Q-1 or FT 155-AR-2 and FT 155-ADD-AD-1 for M825 data, and/or corresponding GFTs and GSTs.

QUICK SMOKE

13-14. Quick smoke missions are fired by using linear sheafs and TGPCs or special corrections. Depending on the atmospheric conditions and the type of smoke desired, the FDC may need to determine two sets of firing data–one set for the initial rounds and one set for the sustainment rounds. The initial rounds establish the smoke screen, and the sustainment rounds ensure the smoke screen is in place for the desired duration.

13-15. For the FDC to provide an effective smoke screen, the FDO needs to obtain additional information not normally provided for other missions. From the observer, the FDO needs the following:

- The center grid of the desired smoke screen. The FDC will compute offset aimpoints on the basis of the type of munition, wind speed, and/or wind direction.
- The length of the smoke screen.
- The maneuver target (MT) direction. The direction from the point at which the maneuver element will be most susceptible to enemy observation to the target.

- Wind direction in reference to the maneuver target line. The observer must let the FDC know if the wind is a head wind, tail wind, left crosswind, or right crosswind in relation to the maneuver target line.
- The screen time (duration), in minutes.

Note: The acronym "LMDIRT" is used as a memory aid by the observer to report this information

Length of smoke screen.
Maneuver-target line direction.
DIRection of wind.
Time (duration).

13-16. From the met station, the FDO will need to know the relative humidity for line 00 of the latest met message. This should be prearranged by unit SOP.

13-17. When the call for fire is received, the FDO will use a series of tables to determine the Pasquill weather category, mean wind speed, the number of rounds to fire to establish the smoke screen (initial rounds), and the number of rounds to fire to maintain the screen for the desired duration requested (sustainment rounds). If the number of aimpoints, rounds, or guns exceeds unit capabilities, the FDO will notify higher headquarters per unit SOP.

13-18. Once the number of rounds has been determined, the FDO will go through a series of computations to determine the number of meters between rounds (separation distance) and the necessary upwind offset corrections.

13-19. The HCO will plot the center grid of the smoke screen on the firing chart and will plot the upwind offset correction on the basis of the wind direction, the maneuver target direction, and the upwind offset correction. He will then plot the aimpoints and determine chart data to each aimpoint.

Note: It is necessary to determine individual piece data to each aimpoint. Proper manual computational procedures entail the use of the M17 plotting board and the TGPC/Special Correction Worksheet. This must be prepared in advance. Different aimpoint values for the initial and sustainment volleys would normally require the computation of two sets of special corrections for each mission. An alternative method is to plot the aimpoints on the firing chart, and determine firing data for each howitzer on the basis of the base piece location. When converged sheaf TGPCs (recomputed for the appropriate sector and already relayed to each gun section) are applied, the solution approximates the previous method. Errors induced by this alternate method (that is, because of screen location at other than center of the TGPC sector) are offset by decreased computational time and complexity and the nature of the effects of smoke (large area covered per round). This latter method of computation will be used in this chapter.

13-20. The computer will determine and announce firing commands for each piece for the initial and sustainment volleys.

QUICK SMOKE TECHNIQUE

13-21. The steps in table 13-2 are used to determine firing data for the quick smoke technique.

Table 13-2. Quick Smoke Technique.

STEP	*ACTION*
1	A call for fire is received requesting quick smoke. If adjust fire is requested, the FDO will issue a partial fire order, and the adjusted fire will proceed using standard procedures. If M825 is to be the FFE projectile, the adjust-fire phase of the mission can be conducted with M107, M795 or M483A1 (in the self-registration mode). While the adjustment is being conducted, the FDO would accomplish steps 2 through 9.

Table 13-2. Quick Smoke Technique (continued).

STEP	*ACTION*
2	The FDO enters table I-1 on page I-2 with the relative humidity furnished by the met station, the screen requirement determined from the call for fire (if no screen requirement requested, use visible), and the type of smoke desired. He extracts the table (Appendix H) that will be used to develop the fire order.
3	The FDO enters the decision tree in figure H-1 on page H-3 with the atmospheric conditions and wind speed (determined from the current computer met message and personal observation) and determines the Pasquill category.
4	The FDO enters the table determined in step 2 with the wind direction, Pasquill category determined in step 3, wind speed, screen length, and screen duration. The FDO will extract the number of initial aimpoints (R1) and sustainment aimpoints (R2) for the screen. In each box, the number left of the diagonal is R1, the number right of the diagonal is R2. In some tables, there is only an R1 factor. He will also determine the firing interval at the far right of the table (time between rounds).
	Note: For R1 and R2, 1 aimpoint = 1 round = 1 gun. If R1 and R2 exceeds the number of howitzers under the control of the FDC, reinforcing fires may be necessary. It is not practical for a unit FDC to assign aimpoints to additional howitzers of another unit. Higher headquarters may segment the screen. For example, a 500-meter screen may be segmented into two 250-meter screens.
5	To determine the number of volleys to fire, the FDO divides the number of minutes smoke is required by the firing interval from the appropriate smoke table.
6	To determine the amount of ammunition required, the FDO multiplies the number of volleys to fire minus one by the number of howitzers required to sustain the screen (R2). Then the FDO adds to this total the number of howitzers firing the first volley (R1).
7	The FDO issues the fire order (or an amendment, if adjust fire). The fire order should state that the FFE rounds will be fired by round at my command.
8	Determine the offset distance for initial volley: **Projectile** / **Crosswind** / **Head or Tail Wind** M825 / 110 / 55 HC (155/105) R1 ≥ 4 / $\frac{\text{Screen Length}}{\text{R1}}$ / 120*WS R1 < 4 / $\frac{\text{Screen Length}}{\text{R1*2}}$ / 120*WS WP (155/105) / 30*WS / 15*WS
	Note: WS = mean wind speed for Pasquill category. (See table 13-7 on page 13-33.) This is an average wind speed in meters per second for the wind speed range listed for each Pasquill category. Enter the table with the Pasquill category and the wind speed in knots from line 00 of the current met message, and extract the mean WS (which is in meters per second).
	Note: Mean WS is the average of the wind speed range in the center column. The average is converted from knots to meters per second.
9	Determine the chart range to initial grid, and determine site.

Table 13-2. Quick Smoke Technique (continued).

STEP	*ACTION*
10	Determine the offset distance for subsequent volley: **Projectile** / **Crosswind** / **Head or Tail Wind** M825 / 110 / 55 HC (155/105) R1 ≥ 4 / $\frac{\text{Screen Length}}{R2}$ / 120*WS R1 < 4 / $\frac{\text{Screen Length}}{R2*2}$ / 120*WS WP (155/105) / 30*WS / 15*WS
11	The HCO determines the offset location of the initial volley.
11a	Place target grid over grid to center of the smoke screen. Orient to the north.
11b	Set off the wind direction (from line 00 of the current met message).
11c	Move pin in the direction of the arrow on the target grid the number of meters necessary to offset (from step 8 above).
11d	Relocate the target grid so that the center of the target grid is over the new offset location and oriented on the MT direction.
11e	If terrain is not relatively flat, site may be computed for each aimpoint.
	Note: Steps 11a through 11d assume that the wind direction at the screen location is the same as measured at the met station. This may be the best available data, especially for a preplanned target. However, terrain conditions and other factors may preclude this. An alternate method is to orient the target grid along the MT line, offset the pin in the direction reported by the observer in the call of fire (that is, for a left cross, move the pin L110), and then reorient as in step 11d.
12	Determine the aimpoint separation.
12a	For M825, determine the aimpoint separation as follows: CROSSWIND: INITIAL AIMPOINT SEPARATION (SEP1) = $\frac{\text{SCREEN LENGTH + 110}}{R1}$ SUSTAINING AIMPOINT SEPARATION (SEP2) = $\frac{\text{SCREEN LENGTH + 110}}{R2}$ HEAD OR TAIL WIND: INITIAL AIMPOINT SEPARATION (SEP1) = $\frac{\text{SCREEN LENGTH + 55}}{R1}$ SUSTAINING AIMPOINT SEPARATION (SEP2) = $\frac{\text{SCREEN LENGTH + 55}}{R2}$
12b	For HC (155/105), determine the aimpoint separation as follows: CROSSWIND or HEAD OR TAIL WIND: INITIAL AIMPOINT SEPARATION (SEP1) = $\frac{\text{SCREEN LENGTH}}{R1}$ SUSTAINING AIMPOINT SEPARATION (SEP2) = $\frac{\text{SCREEN LENGTH}}{R2}$

Table 13-2. Quick Smoke Technique (continued).

STEP	ACTION
12c	For WP (155/105), determine the aimpoint separation as follows: CROSSWIND: INITIAL AIMPOINT SEPARATION (SEP1) = $\frac{\text{SCREEN LENGTH + (30*WS)}}{\text{R1}}$ SUSTAINING AIMPOINT SEPARATION (SEP2) = $\frac{\text{SCREEN LENGTH + (30*WS)}}{\text{R2}}$ HEAD OR TAIL WIND: INITIAL AIMPOINT SEPARATION (SEP1) = $\frac{\text{SCREEN LENGTH}}{\text{R1}}$ SUSTAINING AIMPOINT SEPARATION (SEP2) = $\frac{\text{SCREEN LENGTH}}{\text{R2}}$
	Note: For even number of initial aimpoints, go to step 13. For odd number of initial aimpoints, go to step 14.
13	Place pins at all initial aimpoint locations on the target grid (even number of aimpoints):
13a	Ensure that the target grid is oriented on the MT direction.
13b	Place all aimpoints along the heavy line running through the center of the target grid and perpendicular to the arrow.
13c	Place pins on either side of the center of the target grid by an amount equal to SEP1 divided by two. For example when SEP1 equals 90, place one pin left 45 meters and one pin right 45 meters.
13d	Place all other pins at a distance of SEP1 from these pins.
	EXAMPLE SEP1 = 90 and Aimpoints = 4 Aimpt Aimpt Aimpt Aimpt 90 meters 45m | 45m 90 meters Center of target grid
13e	Refer to step 15.
14	Place pins at all initial aimpoint locations on the target grid (odd number of aimpoints).
14a	Ensure that the target grid is oriented on the MT direction.
14b	All aimpoints will be placed along the heavy line running through the center of the target grid and perpendicular to the arrow.
14c	Leave one pin in the center of the target grid. Place all other pins on either side of the center of the target grid by an amount equal to SEP1.
	EXAMPLE SEP1 = 90 and Aimpoints = 3 Aimpt Aimpt Aimpt 90 meters | 90 meters Center of target grid
14d	Refer to step 15.
15	Determine chart range and chart deflection to each aimpoint (pin) location.
	Note: For WP, go to step 16. For HC, go to step 17. For M825, go to step 18.

Table 13-2. Quick Smoke Technique (continued).

STEP	***ACTION***
16	Determine WP firing data to each aimpoint. Determine data with the HE (105-mm) or M107 (155-mm) GFT, remembering to add a range correction to the chart range to account for the difference in square weight between the WP round and the standard square weight. Refer to step 19.
17	Determine HC firing data to each aimpoint. Determine data with the HE (105-mm) or M107 (155-mm) GFT, remembering to subtract 2.0 seconds from the HE fuze setting. Subtracting 2.0 seconds provides the desired height of fuze functioning (approximately 100 meters) to properly deploy the smoke canisters. Refer to step 19.
18	Determine M825 firing data to each aimpoint.
18a	**M825/A1 GFT METHOD**. (The following procedures are identical for graze data determined from either M107 (155-AM-2 and 155-AM-3), M795 (155-AR-1 and 155-AR-2) or M483A1 (155-AN-2).) Determine HE graze burst time and quadrant with the respective GFT. Place the MHL over the HE time and read up to the M825/A1 FS M577/M762 scale to determine the M825/A1 time. This is the M825/A1 time to fire. Then place the MHL over the HE QE and read up to the M825/A1 QE and DEFL CORR scales. Read the drift (DEFL CORR), apply it to the GFT deflection correction, and apply the sum to the chart deflection. This is the M825/A1 deflection to fire. Then read the M825/A1 QE. This is the M825/A1 QE to fire. It should be noted that if a subsequent height of burst correction for M825/A1 is required, the appropriate firing table addendum must be referenced instead of the GFT. Table A will be used to make an adjustment to the QE, and Table B will be used to make an adjustment to the fuze setting.
18b	**M825/A1 TFT METHOD**. (The following procedures are identical for graze data determined from either M107 (155-AM-2 and 155-AM-3), M795 (155-AR-2) or M483A1 (155-AN-2).) Determine HE or DPICM graze burst time and quadrant with the respective GFT or TFT. Enter Table A of the respective firing table addendum at the appropriate charge and projectile model with the graze burst quadrant expressed to the nearest 5 mils. Extract the correction to quadrant elevation for the appropriate projectile model from Column 2. Apply this correction to the graze burst QE to determine the M825/A1 QE to fire. Extract the correction to deflection for the appropriate projectile model from Column 8. Apply this correction to the HE drift and GFT deflection correction to determine the M825/A1 total deflection correction. Apply this total deflection correction to the chart deflection to determine the deflection to fire. Enter Table B with the graze burst fuze setting. Extract the correction to fuze setting for the appropriate projectile model from Column 2. Apply this correction to the graze burst setting to determine the fuze setting to fire.
	Note: for even number of sustaining aimpoints, refer to step 19. For odd number of sustaining aimpoints, refer to step 20.
18c	Place pins at all sustaining aimpoint locations on the target grid (even number of aimpoints).
19	Set off MT direction on target grid.
19a	All aimpoints will be placed along the heavy line running through the center of the target grid and perpendicular to the arrow.
19b	Place pins on either side of the center of the target grid by an amount equal to SEP2 divided by two. For example when SEP2 equals 180, place one pin to the left 90 meters and one pin to the right 90 meters.
19c	Place all other pins at a distance of SEP2 from these pins.

Table 13-2. Quick Smoke Technique (continued).

STEP	*ACTION*
19d	EXAMPLE SEP2 = 180 and Aimpoints = 2 Aimpt Aimpt 90 m | 90 m Center of target grid
	Refer to step 21.
19e	Place pins at all sustaining aimpoint locations on the target grid (odd number of aimpoints).
20	Ensure that the target grid is set on the MT direction.
20a	All aimpoints will be placed along the heavy line running through the center of the target grid and perpendicular to the arrow.
20b	Leave one pin in the center of the target grid. Place all other pins on either side of the center of the target grid by an amount equal to SEP2.
20c	EXAMPLE SEP2 = 120 and Aimpoints = 3 Aimpt Aimpt Aimpt 120 meters | 120 meters Center of target grid
	Refer to step 21.
20d	Determine chart range and chart deflection to each aimpoint (pin) location.
21	Determine firing data as previously described in steps 16 through 18.
Legend: CORR – correction DEFL – deflection DPICM – dual-purpose improved conventional munition FDC – fire direction center FDO – fire direction officer FFE – fire for effect GFT – graphical firing table HCO – horizontal control operator HE – high explosive MHL – manufacturer's hair line MT – maneuver target QE – quadrant elevation RTO – radio telephone operator TFT – tabular firing table VCO – vertical control operator WP – white phosphorus WS – wind speed	

Note: A study of the R1 and R2 factors for HC and WP under poor conditions for smoke (calm, clear, warm, daylight) reveals an excessive number of aimpoints for a given screen width. The use of M825 or other means of screening should be considered in those instances.

SMOKE MUNITIONS EXPENDITURE TABLES AND EQUATIONS

13-22. Smoke munitions (M825, M116, and M110) are used to establish and maintain smoke screens. The following tables and equations can help you determine data when firing M825, M116, or M110 smoke munitions. (See table 13-3 on page 13-14.)

Table 13-3. Shell Separation and Upwind Offset for Smoke Munitions.

Definitions (Legend)	
R1	Initial rounds
R2	Sustaining rounds
UW1	Initial upwind adjustment
UW2	Sustaining upwind adjustment
SEP1	Initial volley shell separation
SEP2	Sustaining volley shell separation
SL	Screen Length (meters)
WS	Wind speed (meters per second
M825 Smoke Munitions	
Crosswind Cases	
UW = 110 meters	
SEP1 = (SL + 110) ÷ R1	
SEP2 = (SL + 110) ÷ R2	
Headwind or Tailwind Cases	
UW = 55 meters	
SEP1 = (SL + 55) ÷ R1	
SEP2 = (SL + 55) ÷ R2	
Hexachloroethane (HC) Smoke Munitions	
Crosswind Cases	
For R1 or R2 ≥ 4 Rounds: UW1 = SL ÷ R1 SEP1 = SL ÷ R1 UW2 = SL ÷ R2 SEP2 = SL ÷ R2	For R1 or R2 < 4 Rounds: UW1 = SL ÷ R1 * 2 SEP1 = SL ÷ R1 UW2 = SL ÷ R2 * 2 SEP2 = SL ÷ R2
Headwind or Tailwind Cases	
UW1 = 120 * WS	
SEP1 = SL ÷ R1	
UW2 = 120 * WS	
SEP2 = SL ÷ R2	
White Phosphorous (WP) Smoke Munitions	
Crosswind cases	
UW = 30 * WS	
SEP1 = (SL + UW1) ÷ R1	
UW2 = 30 * WS	
SEP2 = (SL + UW2) ÷ R2	
Headwind or Tailwind Cases	
UW1 = 15 * WS	
SEP1 = SL ÷ R1	
UW2 = 15 * WS	
SEP2 = SL ÷ R2	

M825 SMOKE PROCEDURES

13-23. The steps in table 13-4 are used to determine firing data for shell M825.

Table 13-4. M825 Smoke Technique.

STEP	*ACTION*
1	Observer transmits a call for fire after target description. Use the acronym "LMDIRT" as a memory aid. **L**ength of smoke screen. **M**aneuver target line direction. **DIR**ection of wind: ● Head: Blowing from target along the maneuver target line (MTL). ● Tail: Blowing toward the target along the MTL. ● Right Cross: Blowing from the right in relation to the MTL. ● Left Cross: Blowing from the left in relation to the MTL. **T**ime smoke is required (duration).
2	Request relative humidity for line 00 to be transmitted with the met message.
3	Determine the appropriate smoke table to use (See Appendix H).
4	Determine the Pasquill category. (Figure H-1, page H-3)
5	Enter the smoke table determined from step 3 with the following: Direction of wind. ● Pasquill category. ● Wind speed. ● Screen width. ● Screen time. Determine the following: ● R1 = number of aimpoints and rounds to fire in initial volley (1 aimpoint = 1 round). ● R2 = number of aimpoints and rounds to fire for each sustaining volley (1 aimpoint = 1 round). ● The firing interval.
6	Determine the number of volleys to fire and ammunition required. ● Duration ÷ firing interval = number of volleys ● R2 (number of volleys – 1) + R1 = amount of ammunition required.
7	Issue the fire order.
8	Adjust with M107, M795 or M483A1 to center of desired screen if necessary.
9	Offset the FFE aimpoint into the wind in relation to the MTL by using the following: ● Crosswind = 110 meters. ● Tail wind and/or head wind = 55 meters.
10	Determine aimpoint separation as follows: ● SEP1 = initial volley shell separation ● SEP2 = sustaining volley shell separation ● SL = screen length (meters)
10a	Crosswind cases are as follows: ● SEP1 = (SL + 110) ÷ R1 ● SEP2 = (SL + 110) ÷ R2

Table 13-4. M825 Smoke Technique (continued).

STEP	*ACTION*
10b	Head wind and/or tail wind cases are as follows: ● SEP1 = (SL + 55) ÷ R1 ● SEP2 = (SL + 55) ÷ R2
11	Plot aimpoints with the M17 plotting board or target grid.
11a	If using the target grid, determine chart data to each aimpoint. Use converged sheaf TGPCs.
11b	If using the M17 plotting board, determine chart data to aimpoint grid and apply special corrections.
12	Determine the graze burst data by using the appropriate TFT or GFT.
13	Firing data are determined by applying the appropriate ballistic corrections to graze burst data for shell M825/A1. Use the supplementary scales on the appropriate GFT or the appropriate firing table addendum in order to determine and apply the HOB correction.
Legend: GFT – graphical firing table HOB – height of burst R1 – Initial rounds R2 – Sustaining rounds SEP1 – Initial volley shell separation SEP2 – Sustaining volley shell separation SL – Screen Length (meters) TFT – tabular firing table TGPC – terrain gun position correction UW1 – Initial upwind adjustment UW2 – Sustaining upwind adjustment WS – Wind speed (meters per second	

M825 EXAMPLES

13-24. The following data are used in the examples shown in figures 13-4 through 13-5 (pages 13-17 and 13-18):

Known Data:

- Unit: 1/A, four-gun platoon
- Azimuth of fire: 5500
- Altitude: 1062

Conditions:

- Completely overcast afternoon
- Wind speed: 10 knots
- Humidity: 50 percent
- Wind direction: 2200 (left crosswind)
- Met line number: 00
- Assumed screening: Normal visibility
- Screen length: 250 meters
- Duration: 15 minutes

Tactical Solution:

- Pasquill category: D
- Table: I-5
- R1: 4
- R2: 2
- Firing interval: 5 min
- Number of volleys: 15/5 = 3

Aimpoint Separation:

- SEP1: 90 meters
- SEP2: 180 meters
- Offset aimpoint: 110 meters

RECORD OF FIRE

CALL FOR FIRE

Observer T03 AF (FFE) IS/S Tgt

Grid: 3736 5041

Polar:Dir Dis U/D VA

Shift: Dir: L/R +/- U/D

SCREEN MOVEMENT, LENGTH 250, MTL 0200, LEFT CROSS, 15 MIN

TGT ALT 1030
-PLT ALT 1062
VI = -32

M825A1 DRIFT L9
+GFT DF CORR R7
M825A1 DF CORR L2

∆FS | 100/R | /R | 20/R | HOB Corr

∡Si ÷ 10 | 10m Si

FIRE ORDER R PLT (3) L PLT (1) APPLY CONV TGPCS, BRAMC, SH M825A1, LOT S/H | Df Corr | Si -3

INITIAL FIRE COMMANDS (FM) MF PLT (1) RD | Rg 11330 | Cht Df | El

Sp Instr APPLY CONV TGPCS, BRAMC, SPEC CORR | Sh M825A1 | Lot S/H | Chg 4 | Fz TI | Ti | DF | QE

MTO H (3) TGT# AJ7805 | ∡T | PE_R | TF | in EFF | Ammo Exp

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L2)	Df Fired	Chart Rg	HOB Corr	Si (-3)	El	QE	Exp	Type
			#1	(HE DATA)		(27.2)	3168			11110		-3	247	(244)		
				(M825A1 DATA)		27.0		L2	3170					257		
			#2			(27.5)	3172			11180		-3	250	(247)		
						27.3		L2	3174					260		
			#3			(27.7)	3176			11250		-3	253	(250)		
						27.5		L2	3178					263		
			#4			(28.0)	3180			11330		-3	256	(253)		
						27.8		L2	3182					266	(4)	
				L PLT EOM R PLT (2)												
			#1			(27.3)	3170			11140		-3	248	(245)		
						27.1		L2	3172					258		
			#2			(27.9)	3178			11300		-3	255	(252)		
						27.7		L2	3180					265	(8)	M825A1
			EOM	EOM												

GFT 1/A CHG 4H LOT A/H RG 14500 EL 416 TI 40.9 (M582)
TOT DF CORR L8 GFT DF CORR R7

Btry 1/A | DTG 051340ZJUN13 | Tgt AJ7805 | Replot Grid | Replot Alt

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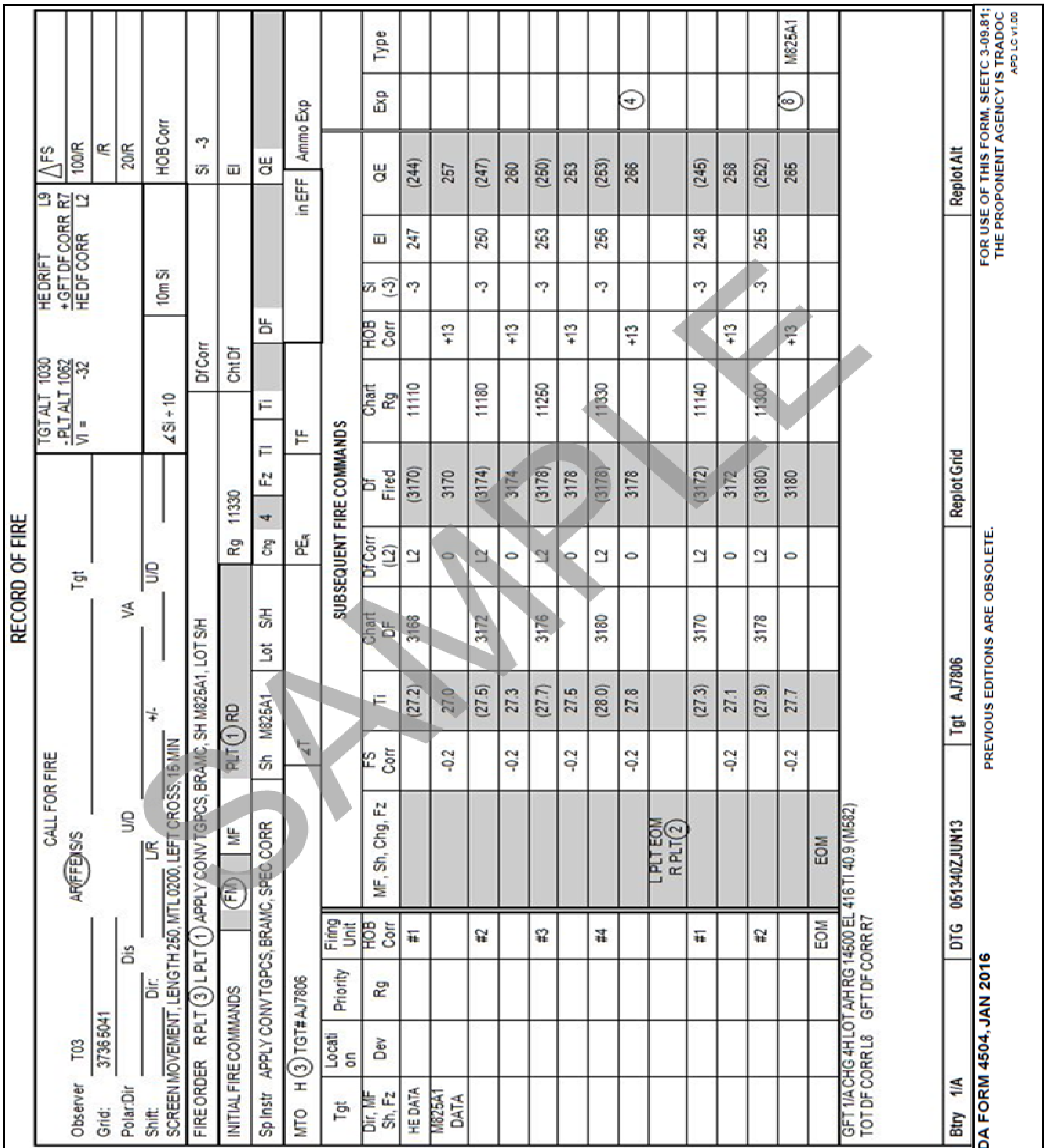
APD LC v1.00

Legend:

AF – adjust fire
ALT – altitude
BRAMC – by round at my command
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CONV – converged
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
IS – immediate suppression
L – left
L/R – left/right
LAT – lateral
MF – method of fire
MTL – maneuver-target line
MTO – message to observer
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
R – right
RD – round
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
SPEC – special
TF – time of flight
TGPCs – terrain gun position constants
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 13-4. Completed ROF for Shell M825A1, Using a 155-AM-3 GFT with Supplementary M825A1 Scales.



RECORD OF FIRE

CALL FOR FIRE	TGT ALT 1030 / -PLT ALT 1062 / VI = -32	HE DRIFT L9 / +GFT DF CORR R7 / HE DF CORR L2
Observer T03 — AF (FFE) IS/S — Tgt		△FS: 100/R, /R, 20/R
Grid: 3736 5041	∡Si + 10	10m Si
Polar:Dir — Dis — U/D — VA		HOB Corr
Shift: — Dir: — L/R — +/- — U/D		
SCREEN MOVEMENT, LENGTH 250, MTL 0200, LEFT CROSS, 15 MIN		
FIRE ORDER R PLT (3) L PLT (1) APPLY CONV TGPCS, BRAMC, SH M825A1, LOT S/H	Df Corr	Si -3
INITIAL FIRE COMMANDS (FM) MF PLT (1) RD — Rg 11330	Cht Df	El
Sp Instr APPLY CONV TGPCS, BRAMC, SPEC CORR — Sh M825A1 — Lot S/H — Chg 4 — Fz TI — Ti	DF	QE
MTO H (3) TGT# AJ7806 — ∡T — PE_R — TF	in EFF	Ammo Exp

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L2)	Df Fired	Chart Rg	HOB Corr	Si (-3)	El	QE	Exp	Type
HE DATA			#1			(27.2)	3168	L2	(3170)	11110		-3	247	(244)		
M825A1 DATA					-0.2	27.0		0	3170		+13			257		
			#2			(27.5)	3172	L2	(3174)	11180		-3	250	(247)		
					-0.2	27.3		0	3174		+13			260		
			#3			(27.7)	3176	L2	(3178)	11250		-3	253	(250)		
					-0.2	27.5		0	3178		+13			253		
			#4			(28.0)	3180	L2	(3178)	11330		-3	256	(253)		
					-0.2	27.8		0	3178		+13			266	(4)	
				L PLT EOM R PLT (2)												
			#1			(27.3)	3170	L2	(3172)	11140		-3	248	(245)		
					-0.2	27.1		0	3172		+13			258		
			#2			(27.9)	3178	L2	(3180)	11300		-3	255	(252)		
					-0.2	27.7		0	3180		+13			265	(8)	M825A1
			EOM	EOM												

GFT 1/A CHG 4H LOT A/H RG 14500 EL 416 TI 40.9 (M582)
TOT DF CORR L8 GFT DF CORR R7

Btry 1/A	DTG 051340ZJUN13	Tgt AJ7806	Replot Grid	Replot Alt

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SAMPLE

Legend:

AF – adjust fire
ALT – altitude
BRAMC – by round at my command
BTRY – battery
CAS – casualties
CHG – charge
CHT – chart
CONV – converged
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HOB – height of burst
I/E – in effect
IS – immediate suppression
L – left
L/R – left/right
LAT – lateral
MF – method of fire
MTL – maneuver-target line
MTO – message to observer
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
R – right
RD – round
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
SPEC – special
TF – time of flight
TGPCs – terrain gun position constants
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 13-5. Completed ROF for Shell M825A1, Using a 155-AM-3 GFT with Addendum T-2.

SECTION III: DUAL-PURPOSE IMPROVED CONVENTIONAL MUNITIONS

13-25. Dual-purpose improved conventional munitions are base-ejection, payload-carrying projectiles. These projectiles are filled with either 42 or 88 dual-purpose grenades, depending on the caliber of the weapons system. During flight, the base of the projectile is blown off and centrifugal force disperses the grenades radially from the projectile's line of flight.

OVERVIEW

13-26. The 105-mm DPICM projectile (M915) contains 42 dual-purpose grenades (M80). The 155-mm DPICM projectile (M483A1) contains two types of dual-purpose grenades (64 M42 and 24 M46). Both types are capable of penetrating more than 2.5 inches of rolled homogeneous armor. They are also capable of fragmentation for incapacitating personnel. The fuze is preset to function over the target area and initiate the expulsion charge. The expulsion charge pushes the grenades out of the container and onto the target area. The M483A1 projectile can be modified for the self-registration (SR) mode. The SR mode causes the round to point detonate so as to be visible to the observer and destroy the submunitions. It also may produce an airburst for high-burst registrations.

DETERMINING DPICM FIRING DATA

13-27. Methods for adjusting and determining DPICM firing data vary slightly depending on the caliber of the weapon system being used. The following guidelines apply:

- For 105-mm howitzers, graze burst data for M760 HE must be determined first due to the structure of the current firing tables and addendums. Once M760 graze data is determined, an initial HOB correction from addendum FT-105-ADD-G-1 is applied in order to determine M915 firing data. The 105-AS-4 charge 8 GFT can be used to assist with the determination of M760 graze data, but unlike some of the 155-mm GFTs it does not have supplementary DPICM scales that provide initial HOB corrections on it.
- For 155-mm howitzers, M483A1 firing data is determined from applying an initial HOB correction to M107, M795 or M483A1 graze burst data. For adjust fire missions, HE should be fired in the adjust phase whenever feasible in order to conserve M483A1 ammunition. For FFE missions, whether HE or M483A1 graze burst data is used to determine firing data should be based upon the availability of current GFT settings.

Note: The preferred method for determining M483A1 firing data is to apply a GFT setting to the 155-AR-2 GFT since both the base scale (M795) and M825A1 are in the same projectile family. An acceptable alternative is to use a 155-AM-3 GFT with GFT setting applied. When using the 155-AM-3 GFT there is a small reduction in accuracy since the total corrections are being applied across projectile families (M107 to M795). If a current GFT setting for only M107 is available, the convenience gained in computing firing data from the second method more than offsets the reduction in accuracy.

13-28. Regardless if a GFT or TFT is used in the determination of initial firing data, the appropriate firing table addendum must be used when computing subsequent height of burst corrections. Initial and subsequent height of burst corrections will result in an adjustment to both the quadrant elevation and the time fuze setting.

13-29. Table 13-5 on page 13-20 illustrates the different GFTs, TFTs and addendums that can be used in the determination of firing data. Paragraph 13-30 discuss how to determine DPICM firing data using a GFT with supplementary DPICM scales and using a TFT, respectively.

Table 13-5. Methods for Determining DPICM Firing Data.

Type of Propellant	*GFT*	*TFT*	*Corresponding Addendum*
M200	105-AS-4 (HE graze data only)	105-AS-4	105-ADD-G-1
M3A1, M4A2, M119A2	155-AN-2	155-AN-2	155-ADD-J-2
	155-AM-2 w/ M483A1 scales	155-AM-2	155-ADD-R-2
	155-AR-1 w/ M483A1 scales	N/A	N/A
M231, M232(A1), M119A2	N/A	155-AN-2 w/ C04	155-ADD-J-2
	155-AM-3 w/ M483A1 scales	155-AM-3	155-ADD-R-3
	155-AR-2 w/ M483A1 scales	N/A	N/A
Legend: GFT – graphical firing table HE – high explosive N/A – not apllicable TFT – tabular firing table w – with			

Note: While the 155-AR-1 and 155-AR-2 GFTs can be used in order to determine initial M483A1 firing data since they contain the appropriate supplementary scales, there currently is no corresponding addendum for the AR-1 or AR-2. Due to this you cannot compute M483A1 subsequent HOB corrections using M795 as the basis for the graze data. If subsequent HOB corrections are anticipated from the observer, this factor should be considered when determining which method to use for computing data.

13-30. Determining data from a GFT with DPICM scales and a GFT setting applied. The procedures are the same whether using a M107 or M795 projectile family GFT (if using the 155-AN-2 GFT, the base scale is used wherever HE is referenced):

13-31. To determine the DPICM fuze setting, place the MHL over the range and determine the M582 FS under the TI gauge line. Place the MHL over that M582 FS and read up to the M483A1 FS M577 scale under the MHL.

13-32. To determine the DPICM deflection to fire, you must first have the chart deflection from the HCO. There are two different ways to determine the deflection to fire on the basis of the type of mission being fired.

13-33. If DPICM is the only shell fired during the mission, to include the adjustment and fire for effect phases, or if a straight FFE mission was conducted, the drift is taken from the DPICM scale instead of the HE base scale. The MHL is placed over the HE QE on the base HE EL scale. Read up to determine the proper value for drift on the DPICM scale under the MHL. This drift will be used throughout the remainder of the mission.

13-34. If HE is used in the adjust-fire phase and DPICM is used to fire for effect, then as soon as the type of shell is changed (HE to DPICM) a new value for drift must be determined from the DPICM drift scale. This drift will be determined by placing the MHL over the HE QE on the base scale and then reading up to the DPICM drift scale. Compare this DPICM drift to the HE drift to determine the change in drift **(DPICM DRIFT – HE DRIFT= CHANGE IN DRIFT).** This change in drift is applied to the HE deflection fired (not to be confused with the chart deflection) to determine the DPICM deflection. Another method is to use:

DPICM DRIFT + GFT DF CORR + CHART DF = DPICM DF TO FIRE

13-35. To determine the DPICM QE, place the MHL over range and determine the HE EL under the elevation gauge line. Compute HE graze QE. Place the MHL over that HE QE and read up to the DPICM QE under the MHL.

13-36. To determine HOB corrections for DPICM, use the appropriate addendum to the TFT that the base data was computed from. Table A is used to determine the correction factor that will be applied to the QE.

Table B is used to determine the correction factor that will be applied to the fuze setting. Remember, the HE data are used to enter the tables, but the correction factors extracted are applied to the DPICM data.

13-37. Determining firing data using a TFT and corresponding addendum. FT-155-AM-3 and FT-155-ADD-R-3 are referenced for example purposes.

13-38. Using the proper charge and range, begin by determining HE data from the FT-155-AM-3, Table F. Elevation is extracted from Column 2, the fuze setting is extracted from Column 7 (M582), and the drift that will be added to the chart deflection is extracted from Column 8. Site is computed in the normal way and then algebraically added to the elevation.

13-39. Once the base HE data have been determined, the ballistic corrections to compensate for the DPICM projectile need to be extracted from the ADD-R-3. Table A of the appropriate charge will yield corrections for QE and deflection. Table A is entered with the HE QE expressed to the nearest listed value. Column 2 will yield the correction factor that must be added to the HE QE to determine the DPICM QE. Column 8 has the deflection correction that must be applied to the HE deflection (chart deflection plus drift) before firing. Table B contains the correction factor that will be applied to the HE fuze setting. Enter Table B with the HE fuze setting, and extract the fuze correction. Apply this correction to the HE fuze setting to determine the DPICM fuze setting.

13-40. The HOB of the DPICM projectile is dependent on the charge fired. If the observer transmits a request for an HOB correction, the ADD-R-3 will be used to determine the correction factors that must be applied to the DPICM fuze setting and QE. Table A, Column 3, of the appropriate charge will yield the correction factor for a 50-meter change in HOB. Multiply the correction factor by the number of 50-meter increments needed. Express the answer to the nearest mil. Apply the HOB correction to the DPICM QE. If it was an up correction, add the HOB correction to the DPICM QE; if it was a down correction, subtract the HOB correction from the DPICM QE. Table B, Column 3, of the appropriate charge will yield the FS correction for a 50-meter change in HOB. Multiply the correction factor by the number of 50-meter increments needed. Express the answer to the nearest FS increment. Apply the HOB correction to the DPICM fuze setting. If it was an up correction, add the HOB correction to the DPICM fuze setting; if it was a down correction, subtract the HOB correction from the DPICM fuze setting.

Note: 155-mm APICM (Projectile M449) data can be determined in a similar manner. The preferred method is to use the 155-AM-2 GFT with the APICM scales and a GFT setting. An alternative method is to use the 155-AM-2 GFT without a GFT setting or the FT 155-AM-2 and the addendum for APICM (ADD-I-2).

13-41. Figures 13-6 through 13-7 (pages 13-22 and 13-23) show completed ROFs using both a GFT and TFT when determining firing data for shell M483A1.

RECORD OF FIRE

CALL FOR FIRE

Observer C19 — AF (FFE) IS/S — Tgt
Grid: 3562 4993
Polar: Dir — Dis — U/D — VA
Shift: Dir: — L/R — +/- — U/D
MIG 30 PARKED ON RUNWAY, DPICM

TGT ALT 1044
-PLT ALT 1062
VI = -22

HE DRIFT L11
+GFT DF CORR R7
HE DF CORR L4

∆FS
100/R
/R
20/R

∡Si ÷ 10 — 10m Si — HOB Corr

FIRE ORDER AMC, APPLY CONV TGPCS (4) — Df Corr L4 — Si -2

INITIAL FIRE COMMANDS (FM) MF PLT (4) — Rg 12420 — Cht Df 3297 — El 306

Sp Instr APPLY CONV TGPCS, AMC — Sh DPICM — Lot D/H — Chg 4 — Fz TI — Ti (32.2) — DF (3301) — QE (304) (HE DATA)

MTO H (3) TGT# AJ7806 — ∡T — PE_R (<38) — TF — in EFF — Ammo Exp

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS												
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si (-2)	El	QE	Exp	Type
				(DPICM DATA)		30.9		L1	3298					312	(16)	
4450	R100	+100	RPT			(32.7)	3300	L4	(3304)	12560		-2	313	(311)		
						31.4		L1	3301					318	(32)	DPICM
			EOM	EOM												

GFT 1/A CHG 4 LOT A/H RG 14500 EL 416 TI 40.9 (M582)
TOT DF CORR L8 GFT DF CORR R7

MIG 30 DESTROYED

Btry 1/A	DTG 051340ZJUN13	Tgt AJ7806	Replot Grid	Replot Alt

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Legend:
AF – adjust fire
ALT – altitude
AMC – at my command
BTRY – battery
CHG – charge
CONV – converged
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DPICM – dual purpose improved conventional munitions
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
IS – immediate suppression
L – left
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
R – right
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGPCs – terrain gun position constants
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 13-6. Completed ROF for Shell M483A1 using a 155-AM-3 GFT with Supplementary M483A1 Scales and a GFT Setting Applied.

RECORD OF FIRE

CALL FOR FIRE			
Observer T03	(AF) FFE/IS/S	Tgt	TGT ALT 1152 -PLT ALT 1062 VI = +90
Grid: 3716 5237			HE DRIFT L11 +GFT DF CORR R7 HE DF CORR L4
Polar:Dir	Dis	U/D	VA
Shift: Dir:	L/R	+/-	U/D
BRDM PLT I/O, DPICM I/E		∡Si ÷ 10	10m Si

ΔFS	
100/R	
/R	
20/R	
HOB Corr	

FIRE ORDER APPLY CONV TGPCS I/E (4)		Df Corr L4	Si +7
INITIAL FIRE COMMANDS (FM) MF PLT ADJ #3 (1)	Rg 12830	Cht Df 3067	El 326
Sp Instr Sh Lot	Chg 4 Fz Ti	DF 3071	QE 333
MTO H (4) I/E, TGT# AJ7807 ∡T	PE_R (<38) TF	(4) DPICM in EFF	Ammo Exp (1) Q

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	SUBSEQUENT FIRE COMMANDS: MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L4)	Df Fired	Chart Rg	HOB Corr	Si (+7)	El	QE	Exp	Type
5010	R200	+100	FFE	PLT (4) APPLY												
				CONV TGPCS												
				SH DPICM												
				LOT D/H FZ TI												
				(HE DATA)		(34.6)	3060	L4	(3064)	13020		+7	335	(342)		
				(DPICM DATA)	-1.3	33.3		R3	3061		+6			348	(16)	
	-50	U50	RPT	(HE DATA)		(34.4)	3057	L4	(3061)	12970		+7	333	(340)		
				(DPICM DATA)	-1.3	(33.1)		R3	(3058)		+6			(346)		
				(HOB CORR)	0.0	33.1			3058		+4			350	(32)	DPICM
			EOM	EOM												

GFT 1/A CHG 4 LOT A/H RG 14500 EL 416 TI 40.9 (M582)
TOT DF CORR L8 GFT DF CORR R7

2 BRDM DESTROYED, EST 12 CAS

Btry 1/A	DTG 051340ZJUN13	Tgt AJ7807	Replot Grid	Replot Alt

DA FORM 4504, JAN 2016 PREVIOUS EDITIONS ARE OBSOLETE. FOR USE OF THIS FORM, SEE TC 3-09.81; THE PROPONENT AGENCY IS TRADOC APD LC v1.00

SAMPLE

Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
AMC – at my command
BTRY – battery
CAS – casualties
CHG – charge
CONV – converged
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DPICM – dual purpose improved conventional munitions
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST - estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L – left
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
PT – point
Q – quick
QE – quadrant elevation
R – right
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGPCs – terrain gun position constants
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure 13-7. Completed ROF for Shell M483A1 using a 155-AM-3 GFT with a GFT Setting Applied and Addendum R-3.

SECTION IV: FAMILY OF SCATTERABLE MINES

13-42. The family of scatterable mines (FASCAM) adds new dimension to mine warfare, providing the maneuver commander with a rapid, flexible means of delaying, harassing, paralyzing, canalizing, or wearing down the enemy forces in both offensive and defensive operations. Mines can force the enemy into kill zones, change their direction of attack, spend time in clearing operations, or take evasive actions. FASCAM presents an array of air and FA-delivered scatterable mines available to maneuver force commanders. The two types of FA-delivered scatterable mines are ADAM and RAAMS.

TYPES OF SCATTERABLE MINES

13-43. ADAM is an antipersonnel mine activated by deployed trip lines. There are 36 wedge-shaped mines contained in the 155-mm projectile. Minefield density can be selectively determined by altering the number of rounds applied. There are currently three densities: low, medium, and high. The mines are expelled from the projectile (approximately 600 meters) over the designated target. Shortly after ground impact, up to seven trip line sensors are released out to a maximum length of 20 feet. The detonators are armed to function in the event of any small disturbance. The ADAM mine has lethality out to 15 feet. Self-destruct times are 4 hours for short self-destruct (M731) and 48 hours for long self-destruct (M692). Figure 13-8 shows an ADAM projectile.

13-44. RAAMS is effective against armored vehicles. The mines are expelled from the rear of the projectile over the target. After ground impact and roll, the mine is armed and ready to detonate upon sensing a proper armored vehicle signature (electromagnetic). A percentage of the nine RAAMS mines are equipped with an anti disturbance device. RAAMS is highly effective when used in conjunction with the ADAM mine, which helps prevent neutralization by enemy ground troops. There are nine RAAMS mines per 155-mm projectile. Minefield densities and self-destruct times are the same as ADAM (M741 short-destruct, M718 long-destruct). Figure 13-9 on page 13-25 shows a RAAMS projectile.

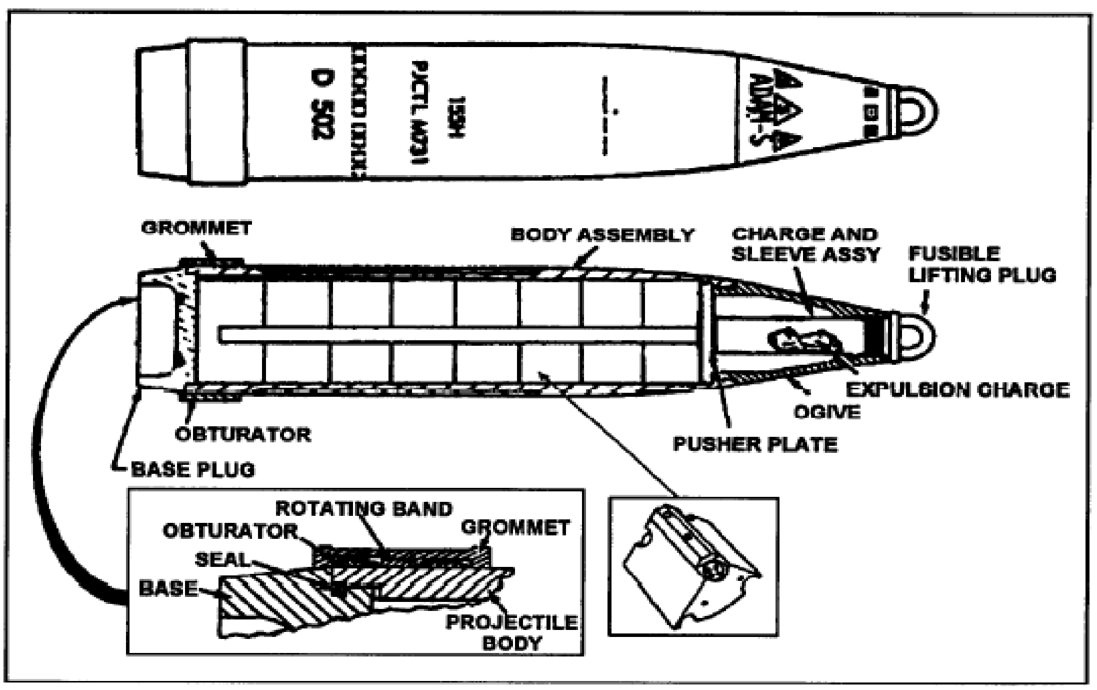


Figure 13-8. ADAM Projectile.

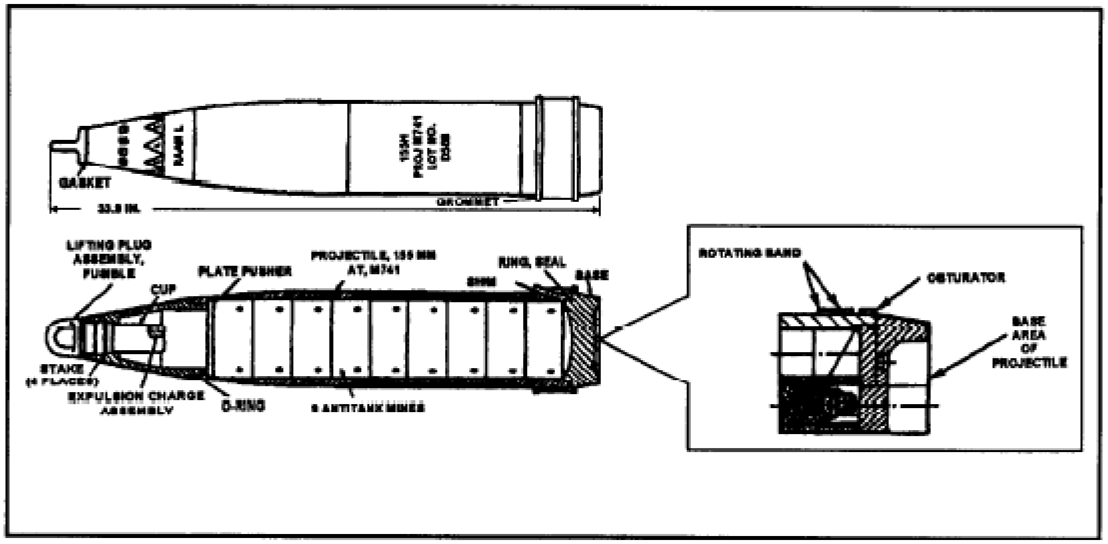


Figure 13-9. RAAMS Projectile.

FASCAM TACTICAL CONSIDERATIONS AND FIRE ORDER PROCESS

13-45. Two types of minefields can be developed with FASCAM–planned minefield and target of opportunity minefields.

13-46. Planned minefields begin with the development of the scheme of maneuver and then the barrier and/or obstacle plan by the assistant chief of staff, operations (G-3) and/or battalion or brigade operations staff officer (S-3) and engineer. Before deciding on the employment of ADAM and/or RAAMS, the Fire Support Coordinator (FSCOORD) is brought into the planning process to provide guidance on the availability of FA mines and delivery units. The process is then initiated with the DA Form 5032 (Field Artillery Delivered Minefield Planning Sheet).

13-47. Minefields employed against targets of opportunity (unplanned) must be emplaced immediately because of the tactical nature of the targets. They are requested through the fire support channels at any level. Once the maneuver brigade or division commander has approved the use of FA mines, they can be emplaced appropriately. Normally, targets of opportunity are used when the delivery of the mines can be observed. Aimpoints for target of opportunity minefields can be computed as in a planned minefield. However, this will be time-consuming and may not meet the demands of the tactical situation. Therefore, it is recommended that units establish an SOP for a "standard minefield" to fire when the tactical situation requires an immediate minefield. For example, the unit SOP may be for a 400 x 400 minefield, high angle, medium density, with two aimpoints. The SOP will allow FSOs to determine the number of target of opportunity minefields that are available for the maneuver commander. This determination is based on the unit's FASCAM unit basic load (UBL).

13-48. Upon receiving a request for a FASCAM minefield, the FDO must begin a detailed process to determine the fire order. The first thing that the FDO must understand is that FASCAM employment is based on a concept known as planning modules. The planning module for RAAMS low angle is 200 meters x 200 meters. The planning module for RAAMS high angle and for ADAM low or high angle is 400 meters x 400 meters. This does not mean that the minefield planner cannot request a minefield that is larger than the planning module. In any FASCAM minefield, the requesting agency defines the minefield size in terms of the length, width, and attitude. The length of the minefield is always the longest axis. The concept of the planning modules is based on the minefield width. In other words, the width of all minefields must be in multiples of the planning module defined above. The FDO will use the length, width, and planning module to determine the number of linear sheafs required to establish the required minefield. The linear sheafs will evenly divide each module and will be parallel to the long axis (length) of the minefield. Refer to paragraph (13) for an example that illustrates this concept.

13-49. Once the call for fire on a DA Form 5032 is received, the FDO will plot the target. In FASCAM missions, DPICM graze burst data, battery-minefield angle (BMA), angle of fire, number of aimpoints, and the desired minefield density must be determined before issuing the fire order.

> Note: For ADAM missions using M119A2 or MACS propellant models, graze burst data can be determined for either DPICM (M483A1) or M795. For RAAMS missions, graze burst data must be determined for M483A1 as there are currently no firing table addendums for M795 for that projectile.

13-50. Plot the minefield linear sheaf, determine the minefield center point of each linear sheaf, and determine the chart range and deflection to the minefield center point(s). Record the chart range and chart deflection on the ROF.

13-51. Determine DPICM graze burst data to the center point computed in (2) above. For RAAMS only, determine chart range. For ADAM, determine chart range and M483A1 QE.

13-52. Determine the battery minefield angle. The BMA is defined as the smaller angle formed by the intersection of the attitude of the minefield and the GT line with the vertex at the center point of the minefield. Using the target grid, set off the minefield attitude and with the vertex at the battery or platoon location, place the RDP against the center point. The smaller interior angle is the BMA. BMA is **always** less than 1,600 mils. Record this in the computation block of the ROF.

13-53. To determine the appropriate mine employment table to use, the FDO must ask three questions:

- What delivery technique am I using?
  - Met + VE (FFE).
  - Observer adjust (AF).
- What shell and trajectory will I fire?
  - M718/M741 (RAAMS) low angle.
  - M718/M741 (RAAMS) high angle.
  - M692/M731 (ADAM) low or high angle.
- What is the BMA?
  - Less than or **equal** to 800.
  - Greater than 800.

13-54. The matrix key is used to determine the mine employment table to use. The table number that is displayed for each of the three entry arguments is the table used for mine employment. See the matrix shown in table 13-6.

Table 13-6. Mine Employment Matrix.

	EMPLOYMENT TABLE							
ENTRY	1	2	3	4	5	6	7	8
Transfer or met + VE	X	X	X	X				
Observer adjust					X	X	X	X
M718/741 (RAAMS) low angle	X	X			X	X		
M718/741 (RAAMS) high angle			X	X			X	X
M692/731 (ADAM) low or high angle			X	X			X	X
BMA ≤ 800 mils	X		X		X		X	
BMA > 800 mils		X		X		X		X
Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error								

13-55. The trajectory makes a difference in the minefield module that can be achieved. RAAMS low-angle planning module is 200 x 200. RAAMS high-angle planning module is 400x 400. ADAM low- or high-angle planning module is 400 x 400. So, only with RAAMS low angle can you achieve a minefield width of 200 meters, or every 200 meters.

Note: If ADAM and RAAMS are employed together, then the process for determination of the appropriate mine employment table is performed for each shell.

13-56. The mine employment tables are used to determine the number of aimpoints required. Review the header information to verify the appropriate table is being used. The entry argument into the mine employment tables are the length (greatest axis) along the top and chart range for entering along the left side of the table (enter with the nearest listed value). If the chart range falls **exactly** halfway between two ranges, use the lower listed range. The mine employment tables are shown in tables 13-7 through 13-14 (pages 13-27 through 13-29).

Note: These tables are number of aimpoints per linear sheaf (planning module width).

Table 13-7. Mine Employment Table Number 1.

Delivery Technique: Transfer or met + VE Shell: M718/741 (RAAMS)					Trajectory: Low angle BMA: Equal to or less than 800 mils					
RANGE (METERS)	DESIRED MINEFIELD LENGTH (METERS)									
	100	200	300	400	500	600	700	800	900	1,000
4,000	2	3	3	4	4	5	5	6	6	7
6,000	2	3	3	4	4	5	5	6	6	7
8,000	2	3	3	4	4	5	5	6	6	7
10,000	3	3	4	4	5	5	6	6	7	7
12,000	3	4	4	5	5	6	6	7	7	8
14,000	4	4	5	5	6	6	7	7	8	8
16,000	4	4	5	5	6	6	7	7	8	8
17,500	4	5	5	6	6	7	7	8	8	9

Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error

Table 13-8. Mine Employment Table Number 2.

Delivery Technique: Transfer or met + VE Shell: M718/741 (RAAMS)					Trajectory: Low angle BMA: Greater than 800 mils					
RANGE (METERS)	DESIRED MINEFIELD LENGTH (METERS)									
	100	200	300	400	500	600	700	800	900	1,000
4,000	1	2	2	3	3	4	4	5	5	6
6,000	1	2	2	3	3	4	4	5	5	6
8,000	1	2	2	3	3	4	4	5	5	6
10,000	2	2	3	3	4	4	5	5	6	6
12,000	2	3	3	4	4	5	5	6	6	7
14,000	2	3	3	4	4	5	5	6	6	7
16,000	3	3	4	4	5	5	6	6	7	7
17,500	3	3	4	4	5	5	6	6	7	7

Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error

Table 13-9. Mine Employment Table Number 3.

Delivery Technique: Transfer or met + VE Shell: M692/731 (ADAM) M718/741 (RAAMS)						Trajectory: Low angle or high angle (ADAM) High angle (RAAMS) BMA: Equal to or less than 800 mils				
RANGE (METERS)	**DESIRED MINEFIELD LENGTH (METERS)**									
	100	200	300	400	500	600	700	800	900	1,000
4,000	1	2	2	2	2	3	3	3	3	4
6,000	1	2	2	2	2	3	3	3	3	4
8,000	1	2	2	2	2	3	3	3	3	4
10,000	2	2	2	2	3	3	3	3	4	4
12,000	2	2	2	3	3	3	3	4	4	4
14,000	2	2	3	3	3	3	4	4	4	4
16,000	2	2	3	3	3	3	4	4	4	4
17,500	2	3	3	3	3	4	4	4	4	5
Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error										

Table 13-10. Mine Employment Table Number 4.

Delivery Technique: Transfer or met + VE Shell: M692/731 (ADAM) M718/741 (RAAMS)						Trajectory: Low angle or high angle (ADAM) High angle (RAAMS) BMA: Greater than 800 mils				
RANGE (METERS)	**DESIRED MINEFIELD LENGTH (METERS)**									
	100	200	300	400	500	600	700	800	900	1,000
4,000	1	1	1	2	2	2	2	3	3	3
6,000	1	1	1	2	2	2	2	3	3	3
8,000	1	1	1	2	2	2	2	3	3	3
10,000	1	1	2	2	2	2	3	3	3	3
12,000	1	2	2	2	2	3	3	3	3	4
14,000	1	2	2	2	2	3	3	3	3	4
16,000	2	2	2	2	3	3	3	3	4	4
17,500	2	2	2	2	3	3	3	3	4	4
Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error										

Table 13-11. Mine Employment Table Number 5.

Delivery Technique: Observer Adjust Shell: M718/741 (RAAMS)							Trajectory: Low angle BMA: Equal to or less than 800 mils			
RANGE (METERS)	**DESIRED MINEFIELD LENGTH (METERS)**									
	100	200	300	400	500	600	700	800	900	1,000
4,000	2	2	3	3	4	4	5	5	6	6
6,000	2	2	3	3	4	4	5	5	6	6
8,000	2	3	3	4	4	5	5	6	6	7
10,000	2	3	3	4	4	5	5	6	6	7
12,000	2	3	3	4	4	5	5	6	6	7
14,000	2	3	3	4	4	5	5	6	6	7
16,000	3	3	4	4	5	5	6	6	7	7
17,500	3	3	4	4	5	5	6	6	7	7
Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error										

Table 13-12. Mine Employment Table Number 6.

Delivery Technique: Observer Adjust Shell: M718/741 (RAAMS)						Trajectory: Low angle BMA: Greater than 800 mils				
RANGE (METERS)	DESIRED MINEFIELD LENGTH (METERS)									
	100	200	300	400	500	600	700	800	900	1,000
4,000 through 17,500	1	2	2	3	3	4	4	5	5	6

Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error

Table 13-13. Mine Employment Table Number 7.

Delivery Technique: Observer Adjust Shell: M692/731 (ADAM) M718/741 (RAAMS)					Trajectory: Low angle or high angle (ADAM) High angle (RAAMS) BMA: Equal to or less than 800 mils					
RANGE (METERS)	DESIRED MINEFIELD LENGTH (METERS)									
	100	200	300	400	500	600	700	800	900	1,000
4000 through 17,500	1	1	1	2	2	2	2	3	3	3

Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error

Table 13-14. Mine Employment Table Number 8.

Delivery Technique: Observer Adjust Shell: M692/731 (ADAM) M718/741 (RAAMS)					Trajectory: Low angle or high angle (ADAM) High angle (RAAMS) BMA: Greater than 800 mils					
RANGE (METERS)	DESIRED MINEFIELD LENGTH (METERS)									
	100	200	300	400	500	600	700	800	900	1,000
4,000	1	1	2	2	2	2	3	3	3	3
6,000	1	1	2	2	2	2	3	3	3	3
8,000	1	2	2	2	2	3	3	3	3	4
10,000	1	2	2	2	2	3	3	3	3	4
12,000	1	2	2	2	2	3	3	3	3	4
14,000	1	2	2	2	2	3	3	3	3	4
16,000	2	2	2	2	3	3	3	3	4	4
17,500	2	2	2	2	3	3	3	3	4	4

Legend: ADAM – area denial artillery munition BMA – battery minefield angle RAAM – remote anti-armor mine VE – velocity error

13-57. On the basis of the module size and the number of aimpoints, the location of the aimpoints is determined.

- Module size 400- by 400-meters–even number of aimpoints. Place aimpoints 200 meters left and right of the center point along each centerline. Place the others at intervals of 400 meters. (See figure 13-10, page 13-30.)
- Module size 400- by 400-meters–odd number of aimpoints. Place the first aimpoint at the center point of the minefield. Place the others at intervals of 400 meters left and right of the center point along each centerline. (See figure 13-11, page 13-30.)
- Module size 200- by 200-meters–even number of aimpoints. Place the aimpoints 100 meters left and right of the center point along each centerline. Place the others at intervals of 200 meters. (See figure 13-12, page 13-30.)
- Module size 200- by 200-meters–odd number of aimpoints. Place the first aimpoint at the center point of the minefield. Place the others at intervals of 200 meters left and right of the center point along each centerline. (See figure 13-13, page 13-30.)

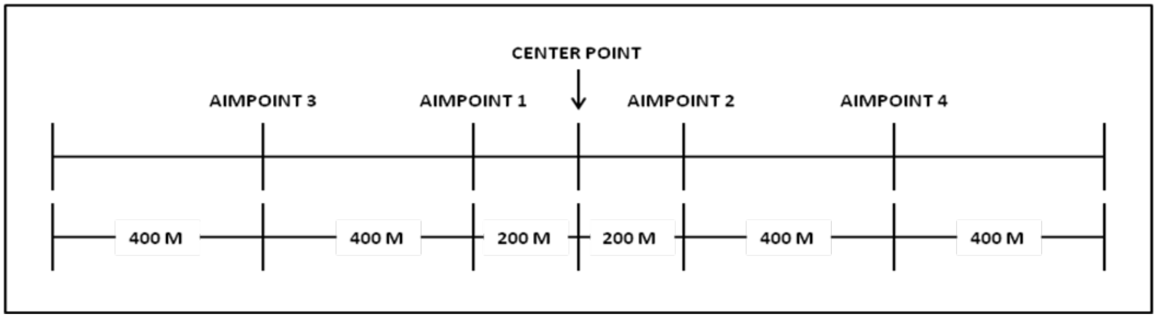


Figure 13-10. Module Size 400 x 400 – Even Number of Aimpoints.

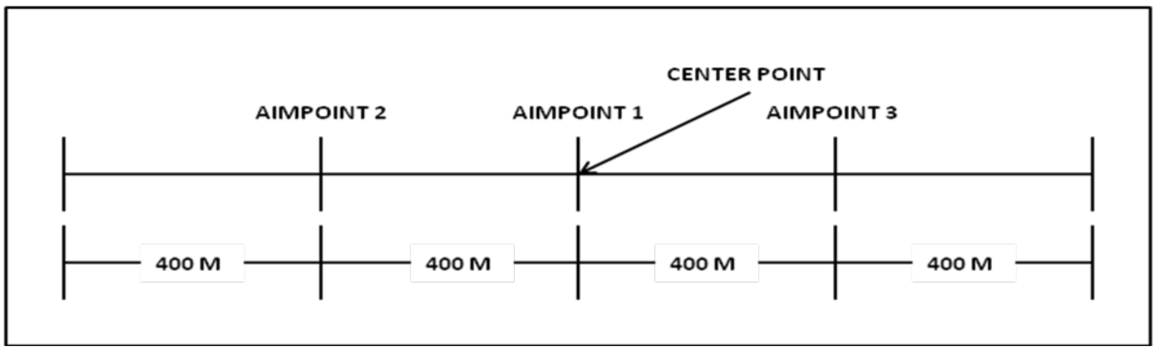


Figure 13-11. Module Size 400 x 400 – Odd Number of Aimpoints.

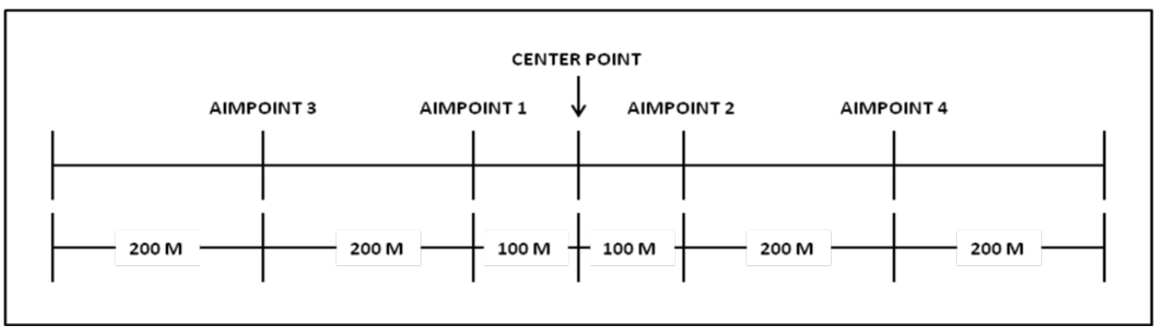


Figure 13-12. Module Size 200 x 200 – Even Number of Aimpoints.

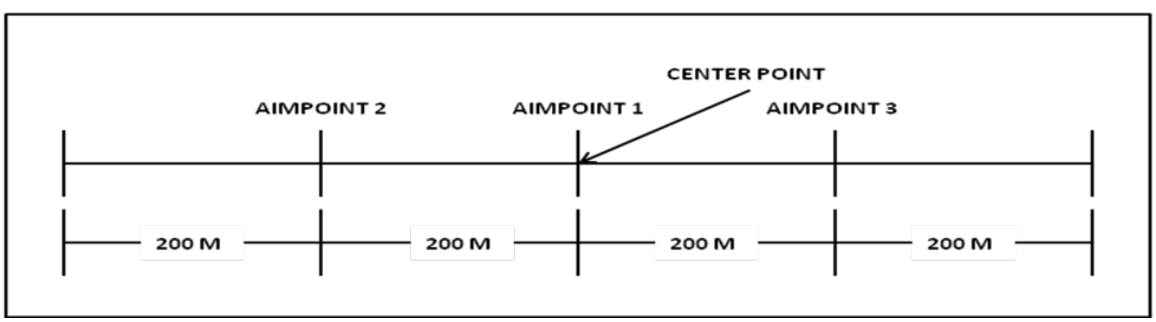


Figure 13-13. Module Size 200 x 200 – Odd Number of Aimpoints.

13-58. On the basis of the desired density, enter table 13-15 below to determine the number of rounds needed to achieve that density.

Table 13-15. Desired Density Rounds per Aimpoint.

HIGH-ANGLE RAAMS			
	LOW	**MEDIUM**	**HIGH**
Desired Density	0.001	0.002	0.004
Rounds per aimpoint	24	48	96
LOW-ANGLE RAAMS			
	LOW	**MEDIUM**	**HIGH**
Desired Density	0.0005	0.001	0.002
Rounds per aimpoint	6	12	24
HIGH- OR LOW-ANGLE ADAM			
	LOW	**MEDIUM**	**HIGH**
Desired Density	0.005	0.001	0.002
Rounds per aimpoint	3	6	12

Note: A density of .001 means that there will be approximately one mine every 1,000 square meters. In other words, there will be one mine in every 32- x 32-meter area. These density numbers are used for planning purposes only. Dispersion of the projectiles in the target area will dictate the actual pattern of mines. Tables 13-16 and 13-17 show recommended minefield densities.

Table 13-16. Recommended Minefield Density for Shell RAAMS.

Purpose of minefield	***Harassment***	***Minefield covered by heavy direct fire***	***Minefield covered by light direct fire***
Density designation for minefield planning sheet	LOW	MEDIUM	HIGH
Density mines	0.001	0.002	0.004

Table 13-17. Recommended Minefield Density for Shell ADAM.

Purpose of minefield	***Used with RAAMS or other at obstacles or harassment***	***Minefield covered by heavy direct fire***	***Minefield covered by light direct fire***
Density designation for minefield planning sheet	LOW	MEDIUM	HIGH
Density mines	0.001	0.002	0.004
Legend: RAAMS – remote anti-armor minefield system			

13-59. Now, using all available information, the FDO issues the fire order and the computer records it on the ROF.

13-60. There are some additional tactical considerations to consider when determining which firing unit(s) will deliver the mines on target. The FDO must consider the total emplacement time, the BMA angles of the firing units, the units available, distribution of FASCAM ammunition, and distribution of aimpoints. When firing a minefield containing both ADAM and RAAMS mines, RAAMS should be fired first to prevent premature detonation of ADAM mines.

Example	
FIRING UNIT A M109A6 platoon (4 Guns)	FIRING UNIT B Two batteries of M109A6 (16 Guns)
Known data	
a. Rg 10,000m b. Technique: Met + VE c. BMA > 800 d. Low Angle e. RAAMS Table 2 f. ADAM Table 4 g. 400 x 400 high-density minefield h. Shell ADAM and RAAMS i. Two ADAM aimpoints, 12 rounds each j. Six RAAMS aimpoints, 24 rounds each (TOTAL ROUNDS = 168) k. Max rate: 4 rounds per minute for 3 minutes l. Sustained rate: 1 round per minute	
FIRING UNIT A	FIRING UNIT B
M109A6 platoon (4 Guns) @ MAX RATE 48 RDS/3MIN @ SUST RATE 120 RDS/30 MIN TOTAL EMPLACE TIME: 33 MIN	Two batteries of M109A6 (16 Guns) @ MAX RATE 168 RDS/<3 MIN TOTAL EMPLACE TIME: <3 MIN

Note: The above example is for illustrative purposes only and does not include the time required to shift between aimpoints.

13-61. The FDO must also consider how to segment a target that is larger than the established planning modules. Segmenting a large target may require the FDO to establish two or more linear sheafs in the target area. The tactical considerations discussed in paragraph (12) are considered for each linear sheaf as if it were a separate fire mission. This decision to segment a large target is normally the responsibility of the battalion FDO.

13-62. To illustrate this concept, consider the following situation:

- Weapon: M109A6
- Minefield size: 1,000 x 800
- Attitude: 0400
- Munitions: RAAMS
- Angle of fire: High angle
- Module size: 400 x 400

13-63. Since the width of the minefield is a multiple of the planning module (800/400 = 2), the FDO can continue with the fire order process. If the establishing agency requests a minefield width that is **not** a multiple of the planning module, this must be resolved before the FDO can properly segment the target to achieve the desired density. In this example, the FDO will segment the minefield into two targets of 1,000 x 400 each. On the firing chart, the FDO will establish a centerline along each separate minefield. The easiest way to do this is to place the target grid over the center of the grid to the minefield and orient along the attitude. Next, place plotting pins left and right of the attitude (200 meters) to establish the offset centerpoints.

13-64. The FDO will use the offset center points to determine chart range and the BMA. In some cases, this may cause the number of aimpoints to be different for each centerline, In this example, the chart operator determined the following data:

Centerline 1: 1/A RG 10,930, BMA 1150

Centerline 2: 1/A RG 11,350, BMA 1170

13-65. The FDO will enter the appropriate minefield employment table and determine the number of aimpoints for each centerline. Finally, he will determine the aimpoint spacing along each centerline. In this example, the FDO determined the following data:

Centerline 1	Centerline 2
Mine Table: 4	Mine Table: 4
Entry Range: 10,000	Entry Range: 12,000
No Aimpoints: 3	No Aimpoints: 4
Spacing: Center, 400 L/R	Spacing: 200 L/R, 400

13-66. The remainder of the tactical considerations are performed as described in the steps from paragraph 13-27b (l3). Figure 13-14 on page 13-34 depicts the results achieved from the above situation.

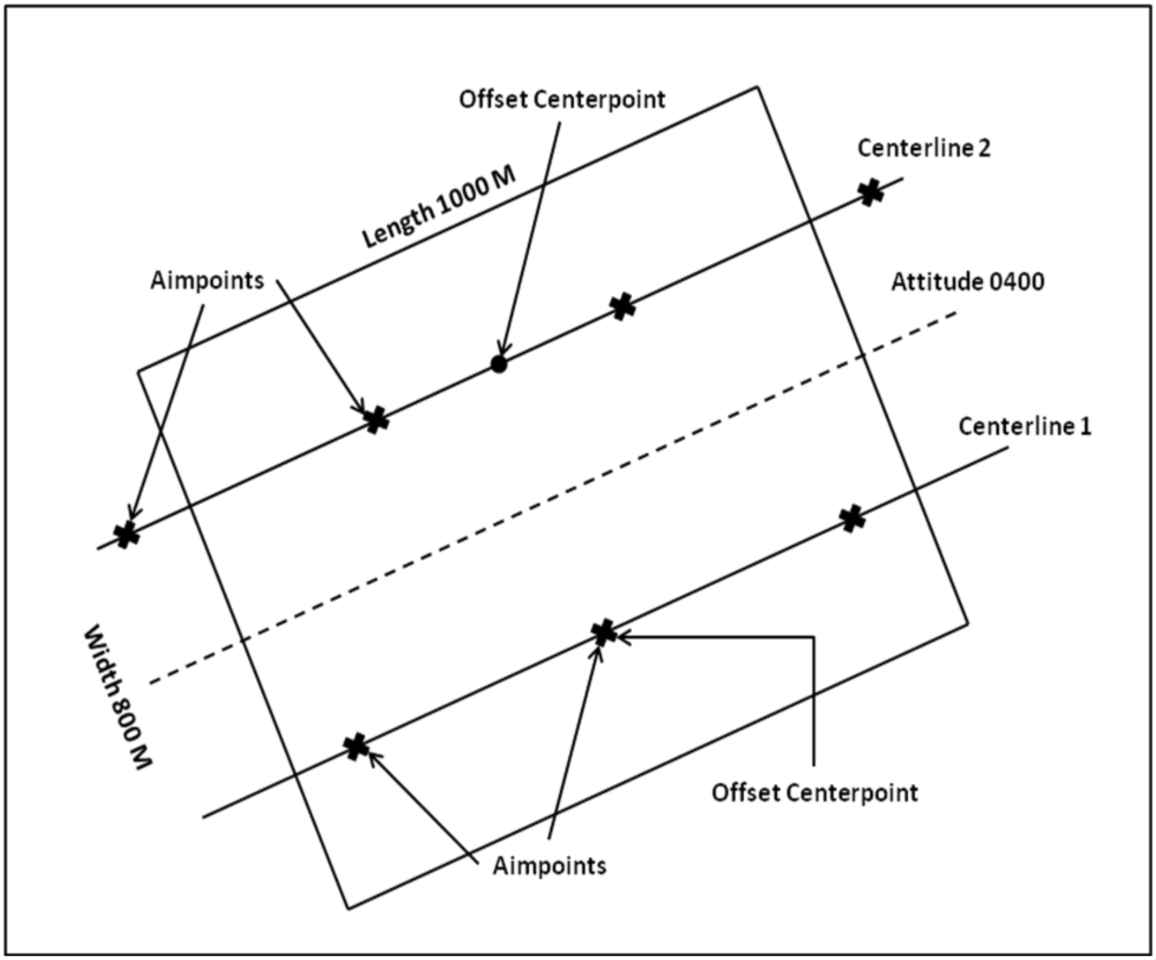


Figure 13-14. Segmenting a Large FASCAM Target.

TECHNICAL FIRE DIRECTION PROCEDURES

13-67. Now that the fire order is issued, technical fire direction must be determined by using DPICM graze burst data and then converting these DPICM data to either RAAMS or ADAM data. The preferred method is to us the 155-AN-2 GFT with a GFT setting applied. This will allow you to quickly determine both DPICM graze burst data as well as RAAMS and ADAM firing data. The GFT setting can be determined either through a DPICM registration or through the met + VE technique. An alternate method of determining DPICM graze burst data is to use the 155-AN-2 TFT, and then use the appropriate firing table addendum (155-ADD-L-2 for ADAM and 155-ADD-N-2 for RAAMS) in order to determine firing data. Regardless if a GFT or TFT is used in the determination of initial firing data, the appropriate firing table addendum must be used when computing subsequent height of burst corrections. The computer records the initial fire commands through the Fz block and the MTO block on the ROF.

13-68. Now plot the aimpoints on the (target grid) firing chart (placing plotting pins left and right along the centerline arrow, representing the attitude) and determine chart data to the aimpoints. These are aimpoints where you want the rounds to impact. For ADAM, these chart data are not recorded on the ROF but are used to determine VI and site (we determine site to the actual impact of the rounds, not to an offset aimpoint location). For future use, record the chart range, VI, and site in the computational space of the ROF. For RAAMS, record the chart data, VI, and site for each aimpoint.

13-69. Since low-level winds will cause ADAM mines to be blown away from the intended aimpoint, a modification in meters must be made to the location of the aimpoints. This will allow the mines to impact at the intended location. Low-level wind corrections are not computed for RAAMS. For RAAMS, go to paragraph f(3).

13-70. The computer must enter FT 155-ADD-L-2, Table A, Column 1, with the DPICM graze burst quadrant determined to the center point grid (paragraph 13-27b(3)) and extract the correction for low-level winds from Column 5. This offset correction allows the delivered ADAM mines to be on target for a wind speed of 1 knot. The Low-level wind correction is recorded in the subsequent fire commands portion of the ROF.

- Since ADAM has a 600-meter HOB, line 02 from a current computer met message is used to determine the wind speed and direction. Line 02 is used because 00 = 0 to 250 meters, 01 = 250 to 500 meters, and line 02= 500 to 1,000 meters. As discussed in Chapter 11, the wind speed and direction extracted from the computer met message can be assumed to be equivalent to that of a ballistic met message so that the respective TFT can be entered appropriately.
- The computer multiplies the correction factor in paragraph d by the wind speed in paragraph d(1) to determine the total distance, in meters, needed to offset each aimpoint to compensate for low-level winds. Express this value to the nearest 10 meters, and record it on the ROF. This distance in meters, in conjunction with the direction of the wind, will be used to offset the aimpoints.

13-71. The HCO places the target grid over the center point and sets off the direction of wind. Remember, this is the direction from which the wind is blowing. The HCO then offsets the center point into the wind by the distance determined in step d(2). (See figure 13-15.)

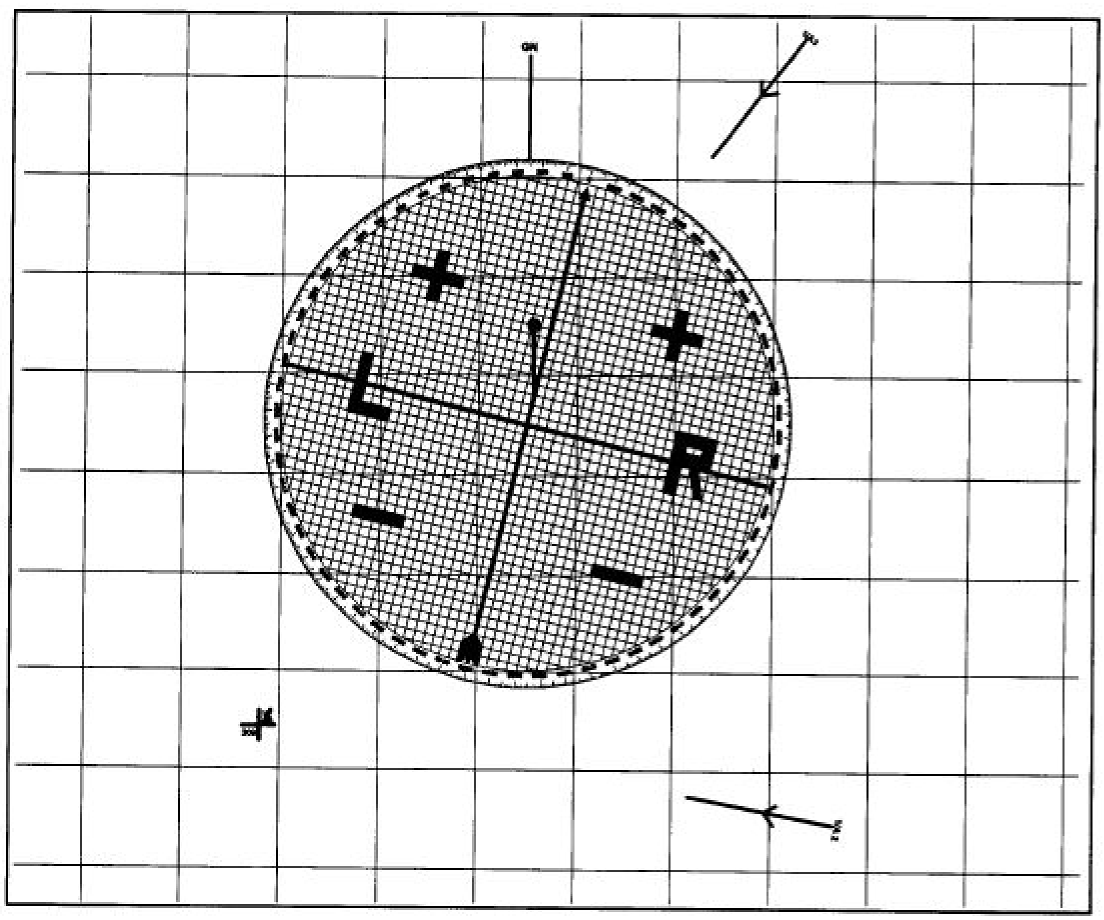


Figure 13-15. Target Grid Oriented on the Direction of Wind.

13-72. The HCO reorients the target grid over this point, resets the minefield attitude off, and places plotting pins left and right of the center point as determined in step (9) above, **using the target grid centerline (arrow).** Note that the "head and tail" of the target grid represents the attitude. (See figure 13-16.)

13-73. The computer determines FASCAM firing data to each offset aimpoint.

- The HCO determines and announces chart range and deflection to the two aimpoints.
- The VCO determines site. Using the location and range to the original aimpoints which are recorded in the computational space of the ROF, the VCO determines VI and site.
- The computer determines DPICM graze burst time, deflection, elevation, and quadrant elevation to each aimpoint. Since these are not the data to be fired, place the time, deflection, and quadrant in parentheses.

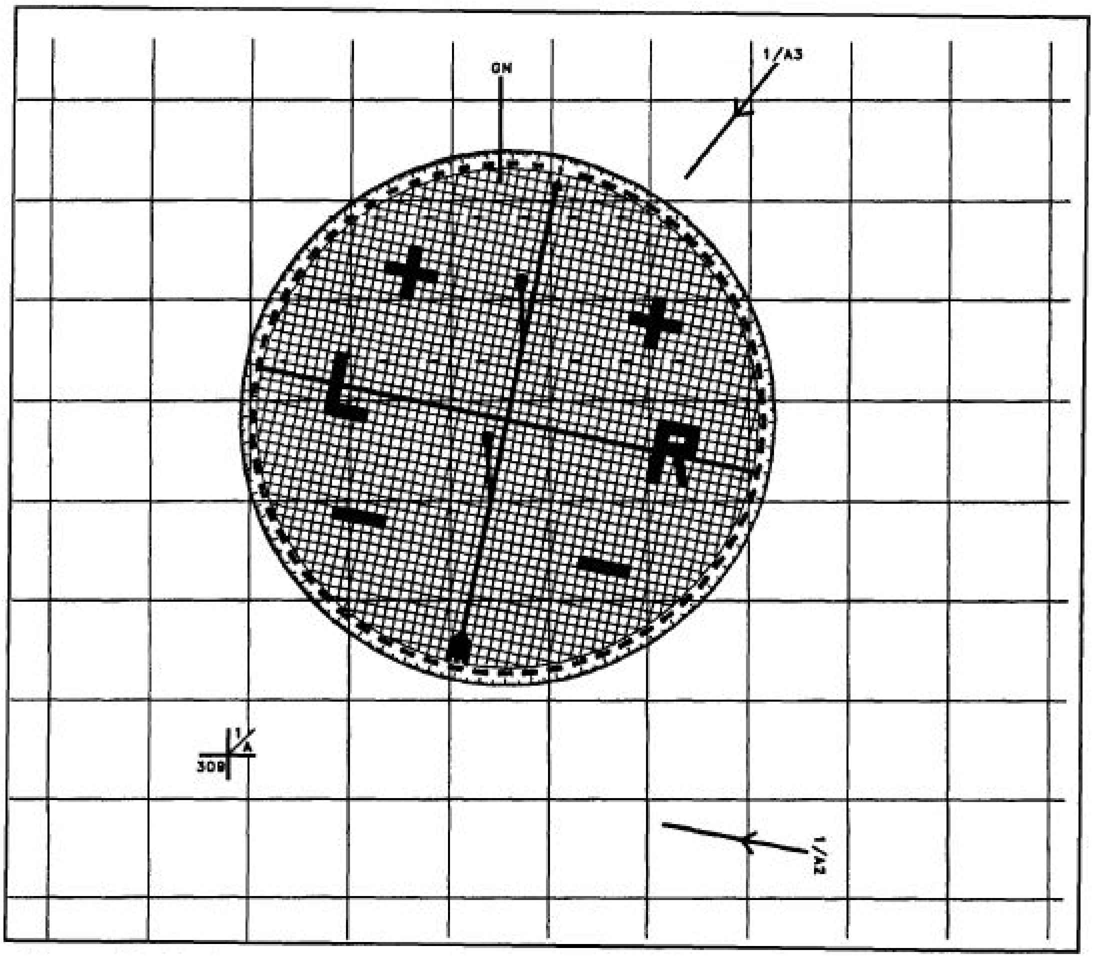


Figure 13-16. Target Grid Reoriented Over Offset Point Aligned on the Attitude.

13-74. The computer determines and records FASCAM firing data by either placing the MHL over the DPICM graze burst time and quadrant or extracting quadrant and fuze setting corrections from the appropriate addendum. The deflection to fire is the chart deflection to the aimpoint plus the total deflection correction **(GFT DF CORR + DPICM DRIFT).**

ADAM

13-75. Firing Table Addendum L-2 is used in conjunction with the AN-2 base TFT to determine firing data for shell ADAM.

13-76. Table A, Column 1, is entered with the graze burst QE that was determined by using the AN-2 TFT. The correction to quadrant is found in Column 2 and is added to the graze burst data.

13-77. Table B, Column 1, is entered with the graze burst fuze setting that was determined by using the AN-2 TFT. The correction to fuze setting is found in Column 2 and is added to the graze burst data.

13-78. Subsequent corrections for quadrant are determined from Table A, Columns 3 and 4; for fuze setting, Table B, Columns 3 and 4.

RAAMS

13-79. Firing Table Addendum N-2 is used in conjunction with the AN-2 base TFT to determine firing data for shell RAAMS.

13-80. Table A, Column 1, is entered with the graze burst QE that was determined by using the AN-2 TFT. The correction to quadrant is found in Column 2 and is added to the graze burst data.

13-81. Table B, Column 1, is entered with the graze burst fuze setting that was determined by using the AN-2 TFT. The correction to fuze setting is found in Column 2 and is added to the graze burst data.

13-82. Subsequent corrections for quadrant are determined from Table A, Columns 3 and 4; for fuze setting, Table B, Columns 3 and 4.

DA FORM 5032

13-83. DA Form 5032 (figures 13-17 and 13-18, pages 13-38 and 13-39) is used for planned FA-delivered barrier or obstacle minefields, target of opportunity minefields, and minefields established in conjunction with other munitions.

13-84. The sections shown on this sheet are completed at different levels during the planning and execution sequence. The purpose of the planning sheet is as follows:

- Provide a standard procedure for placing planned minefield data into fire support channels.
- Provide data for computation and dissemination of a safety zone after minefield emplacement.

FIELD ARTILLERY DELIVERED MINEFIELD PLANNING SHEET
For use of this form, see ATP 3-09.42. The proponent agency is TRADOC.

SAMPLE

SECTION A-MINEFIELD DATA

1 TARGET NUMBER	2 PRIORITY	3 REQUESTER
AC7021	High	CDR, 1BCT

4 MINEFIELD END POINTS (COORDINATES)
FROM 243 307 TO: 247307

5 MINEFIELD DEPTH	6 MINEFIELD WIDTH
400 meters	400 meters
7 ADAM (APERS) DENSITY	**8 RAAMS (AT) DENSITY**
Low	Low

9 SELF-DESTRUCT TIME SHORT ☒ LONG ☐
10 SCHEDULED MINEFIELD N/A HRS ± MIN ON-CALL ☒

11 CAUTION NLT EMPLACEMENT TIME	12 APPROVAL AUTHORITY	13 DATE-TIME GROUP (DTG)
N/A	CDR, 2AD	221320JAN15

14 REMARKS

SECTION B-G-3/S-3/ENGR

15 DTG RECEIVED	16 DTG SAFETY ZONE DISSEMINATED
230638JAN15	2306[illegible]JAN15

17 REMARKS

SECTION C-FC/FSO

18 DTG TO UNIT	19 DTG FROM UNIT	20 DTG TO G3/S3/ENGR
221345JAN15	[illegible]634JAN[illegible]	230643JAN15

21 REMARKS
G-3 - CPT Edwards notified 23064[illegible]
S-3 - SSG Jones notified 230641
ENGR - CPT Roberts notified 23[illegible]42

SECTION D-FDC DATA

22 TARGET NUMBER	23 FIRING UNIT	24 RANGE TO MINEFIELD CENTER
AC7821	A/6-14FA	5830 meters

25 TRAJECTORY
ADAM ☒ HIGH ☐ LOW RAAMS ☒ HIGH ☐ LOW

26 DELIVERY TECHNIQUE
MET+ VE/TRANSFER ☒ OBSERVER ADJUST ☐

27 AIMPOINT COORDINATE(S) (LEFT AND RIGHT OR SINGLE)
ADAM FROM 243 307 TO 247 307 RAAMS FROM 243 307 TO 247 307

28 DTG MISSION COMPLETED
230632JAN15

29 REMARKS

DA FORM 5032, DEC 2015 APD LC v1.00

AD – armored division
ADAM – area denial artillery munition
BCT – brigade combat team
CDR – commander
CPT – Captain
DTG – date-time group
ENGR – engineer
FA – field artillery
FC – fires cell
FSO – fire support officer
G-3 – assistant chief of staff, operations
MET – meteorological
N/A – not applicable
RAAMS – remote antiarmor mine system
S-3 – brigade or battalion operations officer
SSG – Staff Sergeant
VE – velocity error

Figure 13-17. Field Artillery Delivered Minefield Planning Sheet.

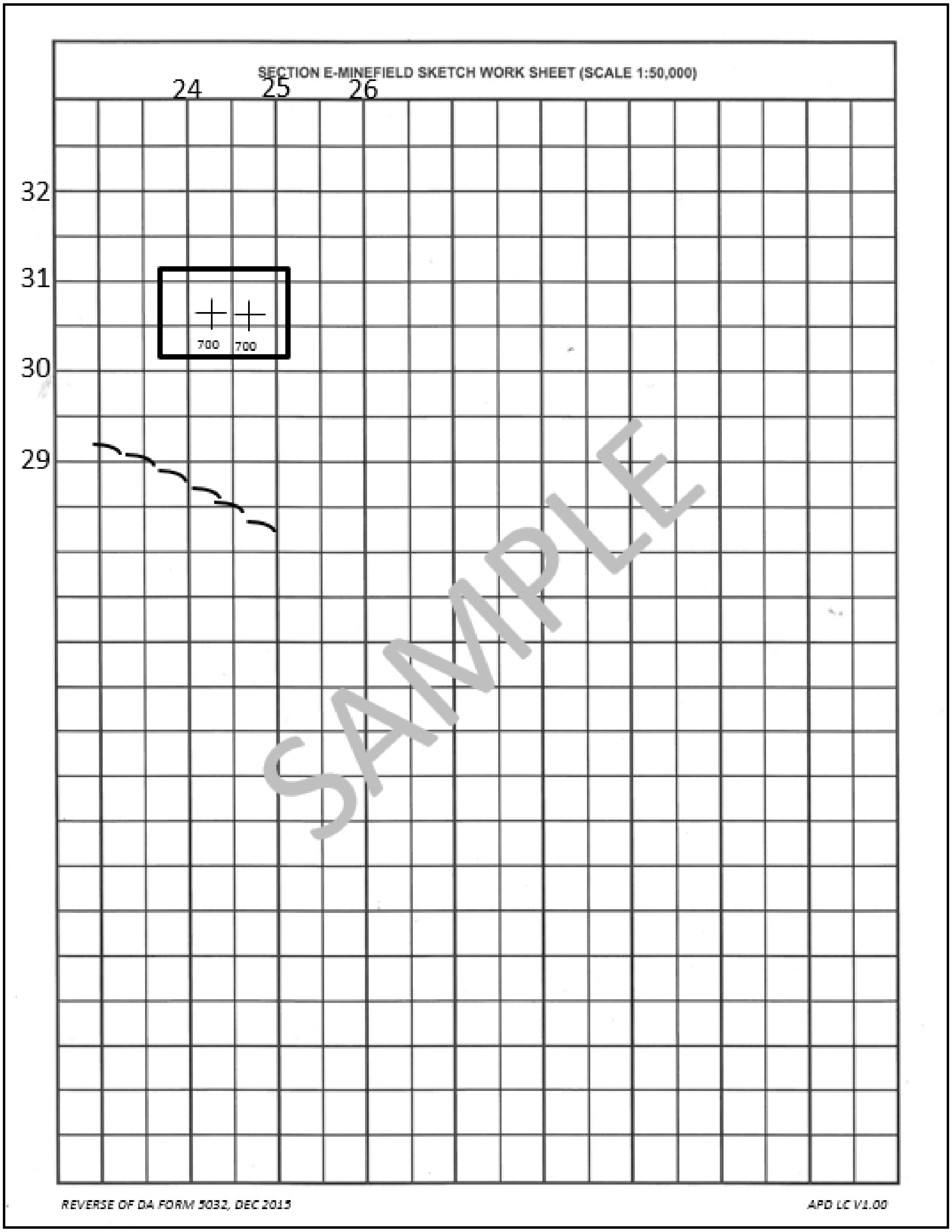


Figure 13-18. Reverse Field Artillery Delivered Minefield Planning Sheet.

PLANNED MINEFIELDS

13-85. The planning sequence starts with the G-3, S-3, and engineer with guidance from the FSCOORD:

- Section A is completed by the G-3, S-3, and/or engineer when requesting an FA-delivered scatterable minefield to support a barrier or obstacle plan.
- Section B is completed by the G-3, S-3, and/or engineer to record dissemination of safety zones.
- Section C is completed by the FSE.
- Section D is completed by the firing unit FDO.

TARGET OF OPPORTUNITY MINEFIELDS AND MINEFIELDS ESTABLISHED IN CONJUNCTION WITH OTHER MUNITIONS

13-86. These minefields are initiated over fire support channels directly to the firing units. Therefore, the use of the planning sheet starts in reverse sequence.

- Section D is completed by the firing unit FDO.
- Section C is completed by the FSE.
- Section B is completed by the G-3, S-3, and/or engineer to record dissemination of safety zones.
- Section A is not applicable.

Note: A blank DA Form 5032 is shown in Figures 13-17 and 13-18, and a description of each block is shown in table 13-18.

Table 13-18. Block-by-Block Explanation of DA Form 5032.

STEP	*BLOCK*	*ACTION*
	SECTION A – MINEFIELD DATA	
1	Target Number	The number used to identify the minefield is provided by the FSCOORD at the maneuver level directing the emplacements.
2	Priority	This block is used if the employing unit uses an obstacle priority system.
3	Requester	The commander of the maneuver element requesting the minefield.
4	Minefield End Points from/to (Coordinates)	The two sets of coordinates that represent the endpoints of the minefield.
5	Minefield Depth	This block indicates the depth of the minefield. When planning the depth, there is only a 400- by 400-meter module size except for RAAMS fired at low angle, which is 200 by 200 meters.
6	Minefield Width	This block shows the width of the minefield and should agree with the distance between end point coordinates in Block 4.
7	ADAM (APERS) Density	The density is expressed as HIGH, MEDIUM, or LOW, according to the density per square meter required. The recommended densities are shown in Table 13-16 (page 13-31).
8	RAAMS (AT) Density	The density is expressed as HIGH, MEDIUM, or LOW, according to the density per square meter required. The recommended densities are shown in Table 13-17 (page 13-31).
9	Self-Destruct Time Short ☐ Long ☐	An X is placed in the block designating the self-destruct time desired. Only one self-destruct time should be used when both RAAMS and ADAM are used together. If an exception is made, it should be entered in the REMARKS block.
10	Scheduled Minefield ___Hrs + ___Min	If the requester wants the minefield emplaced at a certain time, he enters the time in the hour portion of the block. The second portion of the block is variable time, in minutes, the minefield may be emplaced before or after the desired time.

Table 13-18. Block-by-Block Explanation of DA Form 5032 (continued).

STEP	*BLOCK*	*ACTION*
	On Call ☐	If the requester wants the minefield delivered at his command, he places an X in the ON-CALL MINEFIELD block. If this block is used, NA is places in the SCHEDULED MINEFIELD block.
11	Caution NLT Emplacement Time	The requester can provide a not later than (NLT) time (13 April 2016-time) for the minefield to be emplaced. This is a safety factor that may or may not be used. If not used, NA is placed in the block.
12	Approval Authority	This block is used to record the approval authority for the emplacement of the minefield.
13	13 April 2016-Time Group	This block gives the date-time group (DTG) of the initiation of the request. The DTG is entered after Section A is completed and approved.
14	Remarks	Enter distance from closest friendly unit to nearest point on minefield centerline.
SECTION B – G-3/S-3 ENGR		
15	DTG Received	The date-time group is entered when the G-3, S-3, and/or engineer receives the minefield emplacement data in Section D.
16	DTG Safety Zone Disseminated	The date-time group that safety zone information is disseminated to higher, lower, or adjacent units, as required, is entered in this block.
17	Remarks	As appropriate.
Section C – FC/FSO		
18	DTG to Unit	The date-time group that Section D data are received from the firing unit.
19	DTG from Unit	This is the date-time group that Section D data are received from the firing unit.
20	DTG to G-3/S-3/Engr	This is the date-time group that Section D data are passed to the G-3, S-3 and/or engineer for computation and dissemination of safety zones.
21	Remarks	As appropriate
Section D – FDC Data		
22	Target number	For planned minefields, the target number is the same as in Section A, Block 1. Unplanned minefields are given a target number by the FA firing unit.
23	Firing Unit	The unit firing in the minefield is entered in this block.
24	Range to Minefield Center	The range from the firing unit to the minefield center is entered in this block. Range is necessary to compute the safety zone.
25	Trajectory ADAM☐ High ☐ Low ☐ RAAMS ☐ High ☐ Low ☐	The use of high-or-low angle fire to emplace the minefield is indicated by an X in the appropriate block corresponding to mines emplaced (ADAM/RAAMS). The angle of fire is needed to compute the safety zone.
26	Delivery Technique MET + VE ☐ Observer adjust ☐	An X indicates the delivery technique used. Delivery technique is necessary for computation of the safety zone.

Table 13-18. Block-by-Block Explanation of DA Form 5032 (continued).

STEP	***BLOCK***	***ACTION***
27	Aimpoint Coordinate(s) Left and Right or Single ADAM From__ To__ RAAMS From __ To__	The aimpoint coordinates for the leftmost aimpoint are placed in the FROM block and for the rightmost aimpoint in the To block. If there is just one aimpoint, the coordinates are entered in the FROM block and NA is placed in other blocks. In all cases, coordinates are placed in the block corresponding to the mines fired (ADAM/RAAMS). The aimpoint coordinate(s) and the mines fired (ADAM/RAAMS) are needed to compute the safety zone.
28	DTG Mission Completed	This is the date-time group the emplacement of the minefield is completed (that is, the last mines fired impact).
29	Remarks	As appropriate.
Section E – minefield sketch work sheet		
30	Reverse side of form	The minefield planners sketch the minefield location and safety zones on the worksheet in Section E (back). (See figure 13-25, page 13-55.)
Legend: ADAMS – area denial artillery minefield system APERS – anti-personnel AT – anti-tank DTG – date time group ENGR – engineer FC – fires cell FDC – fire direction center FSCOORD – fire support coordinator FSO – fire support officer NLT – no later than RAAMS – remote anti-armor artillery minefield system VE – velocity error		

SAFETY ZONE DETERMINATION

13-87. The G-3, S-3, and/or engineers are normally responsible for determining the safety zones for FASCAM and disseminating them to the appropriate higher, lower, and adjacent units. The FSCOORD at any level can also determine safety zones for minefields that are fired into the maneuver area for which he is providing support. This would only be done for expediency to support maneuver operations.

13-88. As a safety check, the FDO should also determine the safety zone before firing FASCAM. The determined safety zone should be compared to the situation map to ensure there are no units within the safety zones for FA-delivered scatterable minefields. The two techniques used to determine the safety zone are as follows:

- Safety zone tables.
- Safety zone templates.

Note: About 99 percent of all mine delivery missions will result in the entire minefield (minefield modules) being inside the safety squares.

13-89. For both techniques, the following information is required:

- Type of projectile (ADAM or RAAMS).
- Trajectory (high angle or low angle).
- Range to center of the minefield.
- Aimpoint coordinates.
- Delivery technique (met+ VE, or observer adjust).

SAFETY ZONE TABLES

13-90. The steps for using the safety zone tables are shown in table 13-19 on page 13-43.

Table 13-19. Use of Safety Zone Tables.

STEP	*ACTION*
1	Select the appropriate table on the basis of the projectile type and trajectory. (See tables 13-20 through 13-22.)
2	Enter the table with the nearest listed range and delivery technique, and extract the safety zone size.
3	Draw the aimpoints on the situation map.
4	Draw the determined safety zone so that it is centered over each of the aimpoints. This will establish the minefield safety zone.
5	Compare the minefield safety zone to friendly locations on the situation map. Notify the battalion fire direction center or supported fire support officer if any friendly units plot inside the minefield safety zone.

Table 13-20. RAAMS – Low Angle.

Range (kilometers)	*Met + Velocity Error*	*Observer Adjust*
4	500 x 500	500 x 500
7	550 x 550	500 x 500
10	700 x 700	550 x 550
12	850 x 850	550 x 550
14	1000 x 1000	650 x 650
16	1050 x 1050	650 x 650
17.5	1200 x 1200	650 x 650

Table 13-21. ADAM – Low Angle.

Range (kilometers)	*Met + Velocity Error*	*Observer Adjust*
4	700 x 700	700 x 700
7	750 x 750	700 x 700
10	900 x 900	750 x 750
12	1050 x 1050	750 x 750
14	1200 x 1200	850 x 850
16	1250 x 1250	850 x 850
17.5	1400 x 1400	850 x 850

Table 13-22. RAAMS and ADAM – High Angle.

Range (kilometers)	*Met + Velocity Error*	*Observer Adjust*
4	750 x 750	700 x 700
7	900 x 900	700 x 700
10	1050 x 1050	750 x 750
12	1200 x 1200	750 x 750
14	1400 x 1400	750 x 750
16	1500 x 1500	850 x 850
17.5	1400 x 1400	850 x 850

SAFETY ZONE TEMPLATES

13-91. If safety zone templates are available, the steps are basically the same as the safety zone tables. The selected template is centered over the aimpoint locations and the safety zone is traced onto the situation map. The field artillery mine safety template is shown in figure 13-19.

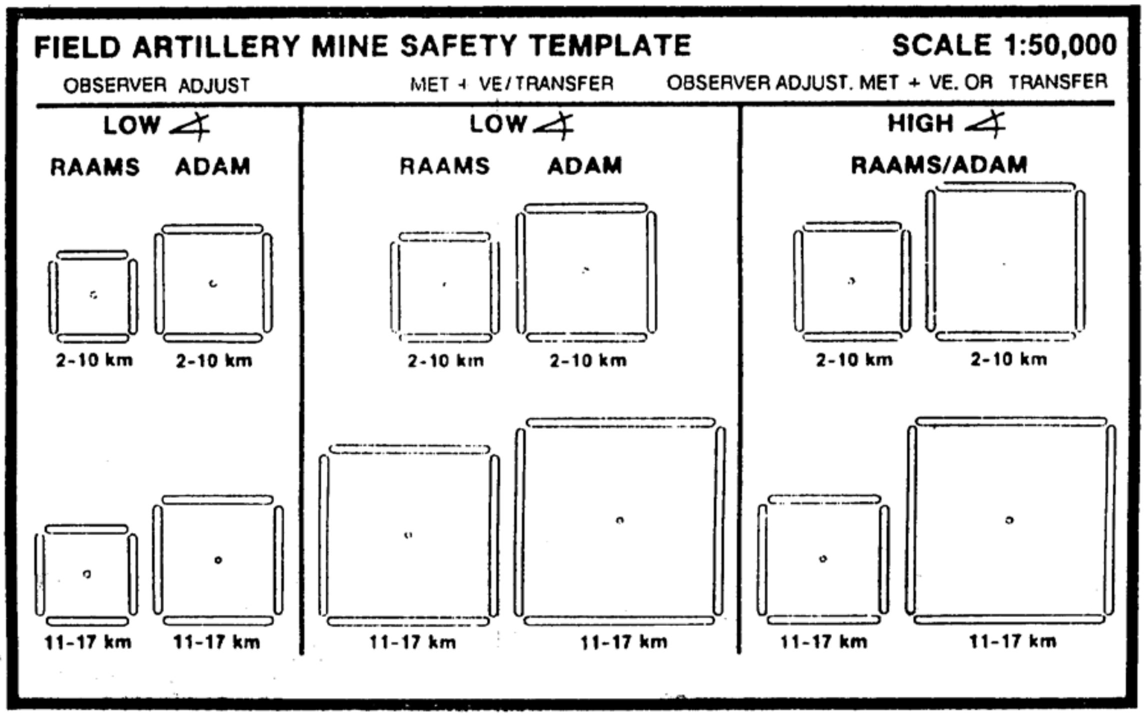


Figure 13-19. Field Artillery Mine Safety Template.

FASCAM EMPLOYMENT STEPS

13-92. Table 13-23 shows the employment procedures for shell ADAM.

Table 13-23. Shell ADAM Employment Procedures.

STEP	*ACTION*
1	The Computer/RTO records the target information on the ROF (from DA Form 5032 or observer call for fire).
2	The HCO plots the minefield center and determines the chart range.
3	Using the target grid, the HCO sets off the minefield attitude and with the vertex at the unit location, places the RDP arm against the center point. Now determine the battery minefield angle.
4	The FDO enters the mine employment matrix to determine which employment table to use.
5	The FDO enters the appropriate mine employment table and extracts the appropriate number of aimpoints.
6	The FDO determines aimpoint spacing.
7	The FDO enters the appropriate table to determine the required number of rounds per aimpoint on the basis of the desired density.
8	The FDO issues the fire order.

Table 13-23. Shell ADAM Employment Procedures (continued).

STEP	***ACTION***
9	The computer determines DPICM graze burst quadrant to center point.
10	Using the target grid along the attitude requested, the HCO plots the aimpoints.
11	The HCO determines chart range to the aimpoints.
12	The VCO determines the VI to each aimpoint and computes site.
13	The computer determines the low-level wind corrections.
13a	Enter FT 155-ADD-L-2, Table A, with DPICM graze burst quadrant. Extract the correction factor for a 1-knot wind.
13b	Extract the wind speed from line 02 of a current, valid ballistic met message.
13c	Multiply the value from step 13a by the value from step 13b to determine the total distance, in meters, needed to offset each aimpoint(s) into the wind. Express this value to the nearest 10 meters.
14	The HCO places the target grid over the center point and sets off the direction of the wind for line 02 of a current, valid ballistic met message.
15	The HCO offsets the center aimpoint into the wind by the distance determined in step 13c above.
16	The HCO reorients the target grid over this point, sets the minefield attitude and places plotting pins left and right of the center point along the attitude as determined in step 6.
17	The HCO determines and announces the chart range and chart deflection to each offset aimpoint.
18	The computer determines DPICM graze burst data to each offset aimpoint.
19	The computer determines the ADAM fuze setting and quadrant from the AN-2 GFT by using the DPICM graze burst fuze setting and quadrant **OR** the computer can determine the ADAM fuze setting and quadrant by using the DPICM graze burst fuze setting and quadrant as entry arguments for Tables A and B of FT 155-ADD-L-2. The determined corrections are then applied to the graze burst data.
20	The ADAM deflection to fires is the offset aimpoint chart deflection plus the total deflection correction (GFT deflection correction and DPICM drift).
21	Subsequent height of burst corrections are determined by using the FT 155-ADD-L-2.
	Note: The above steps are used only after the center grid and altitude to the minefield are determined. The following steps are considered for determining the center grid and altitude.
22	For met + VE, the center grid and altitude are given by the establishing agency to an accuracy of 10 meters.
23	For observer adjust technique, the observer would first adjust DPICM-SR graze burst data to the desired location. The FDC would then replot the target to determine an accurate grid and altitude to the center of the minefield.
Legend: ADAMS – area denial artillery minefield system DPICM – dual-purpose improved conventional munition FDO – fire direction officer GFT – graphical firing table HCO – horizontal control operator RDP – range deflection protractor RTO – radio telephone operator VE – velocity error	

13-93. Table 13-24 on page 13-46 shows the employment procedures for shell RAAMS.

Table 13-24. Shell RAAMS Employment Procedures.

STEP	***ACTION***
1	The Computer/RTO records the target information on the ROF (from DA Form 5032 or observer call for fire).
2	The HCO plots the minefield center and determines the chart range.
3	Using the target grid, the HCO sets off the minefield attitude and with the vertex at the battery location, places the RDP arm against the center point. Now determine the battery minefield angle.
4	The FDO enters the mine employment matrix to determine which employment table to use.
5	The FDO enters the appropriate mine employment table and extracts the appropriate number of aimpoints.
6	The FDO determines aimpoint spacing.
7	The FDO enters the appropriate table to determine the required number of rounds per aimpoint on the basis of the desired density.
8	The FDO issues the fire order.
9	Using the target grid along the attitude requested, the HCO plots the aimpoints.
10	The HCO determines chart range to the aimpoints.
11	The VCO determines the VI to each aimpoint and computes site.
12	The computer determines DPICM graze burst data to each aimpoint.
13	Using the DPICM graze burst fuze setting and quadrant, the computer determines the RAAMS fuze setting and quadrant from the AN-2 GFT **OR** the computer can determine the RAAMS fuze setting and quadrant by using the DPICM graze burst fuze setting and quadrant as entry arguments for Tables A and B of FT 155-ADD-N-2. The determined corrections are then applied to the graze burst data.
14	The computer determines firing data for shell RAAMS. The RAAMS deflection to fire is the aimpoint chart deflection plus the total deflection correction (GFT deflection correction and DPICM drift).
15	Subsequent height of burst corrections are determined by using the FT 155-ADD-N-2.
	Note: The above steps are used only after the center grid and altitude to the minefield are determined. The following steps are considered for determining the center grid and altitude.
22	For met + VE, the center grid and altitude are given by the establishing agency to an accuracy of 10 meters.
23	For observer adjust technique, the observer would first adjust DPICM-SR graze burst data to the desired location. The FDC would then replot the target to determine an accurate grid and altitude to the center of the minefield.
Legend: DPICM – dual-purpose improved conventional munition FDC – fire direction center FDO – fire direction officer GFT – graphical firing table HCO – horizontal control operator RAAMS – remote anti-armor artillery minefield system RDP – range deflection protractor ROF – record of fire RTO – radio telephone operator VCO – vertical control operator VE – velocity error	

SECTION V: BASE BURN DPICM

13-94. The base burn DPICM projectile (M864) brings a DPICM capability to the battlefield at ranges that are further that the conventional M483A1 DPICM projectile can achieve.

BASE BURN DPICM (M864)

13-95. The M864 projectile is a dual-purpose ICM projectile that incorporates base burn technology to increase its range. Base burn technology was developed to reduce the amount of base drag on a projectile, thereby increasing the achieved range. The drag is reduced by a (base) burner unit located on the base of the projectile. Once ignited, the base burner unit bleeds hot gas which causes the flow of air at the base to be less turbulent. The decrease in turbulence causes less base drag. (Base drag accounts for about 50 percent of total drag.) The amount of thrust produced by the base burner unit is negligible and does not serve the same function as the rocket motor on RAP. (See figure 13-20.)

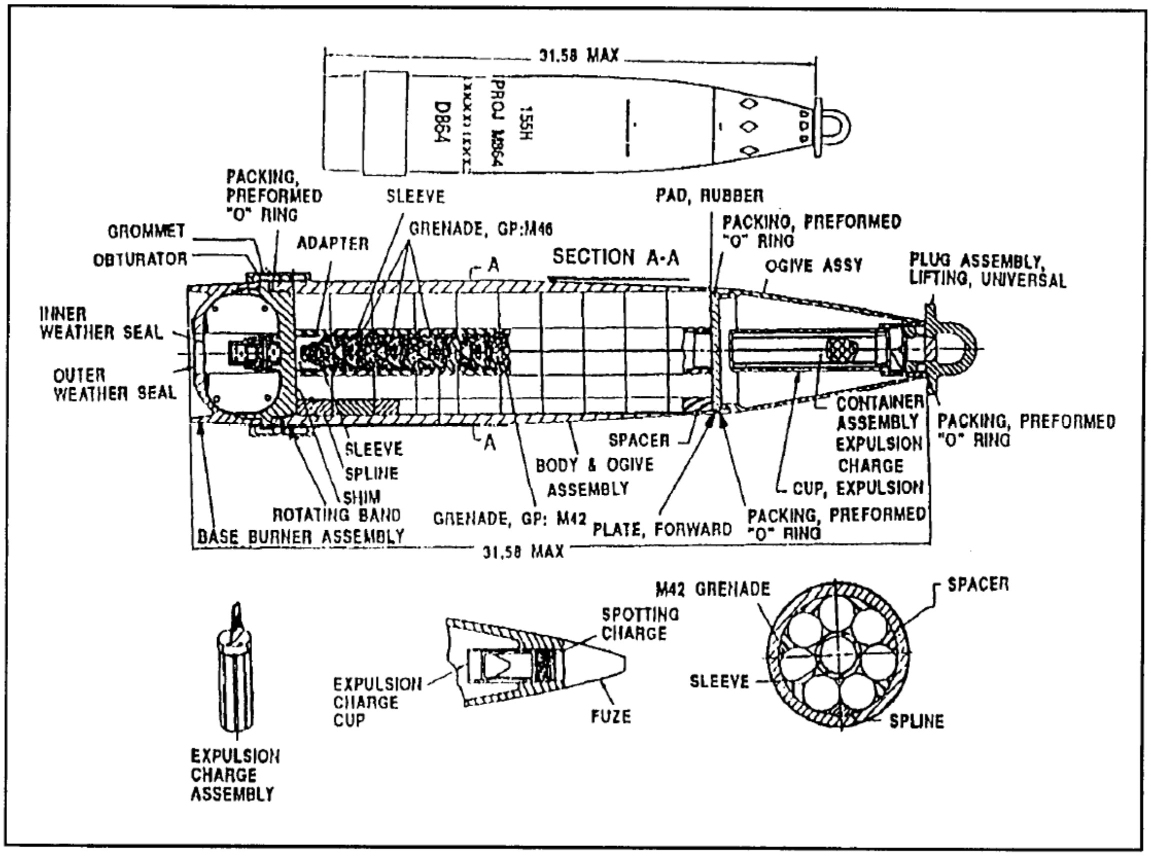


Figure 13-20. Base Burner DPICM (M864).

M864 FIRING DATA COMPUTATIONS

13-96. The current sources of firing data for M864 are the FT 155-AU-PAD and FT 155-ADD-U-PAD. It is used much in the same manner as the FT 155-ADD-R-3 is used to determine M483A1 firing data from M107 firing data.

13-97. The M864 projectile is not ballistically matched to any projectile currently in the inventory.

MET TO A TARGET

13-98. Because of the amount of time needed to work a met to a target, this technique would be best employed for planned targets. The FT 155-AU-PAD is designed in the same basic format as the FT 155-AN-2 TFT for M483A1 and provides graze burst data. Once the graze burst data are determined, corrections from the FT 155-ADD-U-PAD are applied to the fuze setting, deflection and quadrant to determine data to yield the appropriate HOB. If MV information has been determined with the MVS, the MVV is used as the velocity error.

Note: An MVV for M864 determined by calibration may not be available. The loss in muzzle velocity because of tube erosion (as determined from a recent pullover gauge reading and/or from EFC rounds) can be used as the position VE.

M864 Registrations

13-99. M864 projectiles can be fired in the SR mode by using the same procedures as for the M483A1. Because of the increased range, registrations may be difficult. Observers may have difficulty determining spotting and corrections, and radar, in the friendly fire mode, has an effective range of 14.7 kilometers.

Note: If a registration is conducted with the extended range dual-purpose improved conventional munitions (ERDPICM) projectile, the values for range K and fuze K would be computed in the same manner as conventional techniques.

Chapter 14

Emergency FDC Procedures

Field artillery units must be capable of delivering fire at all times. Requests for immediate fires may be received when the unit is moving or when the FDC is not yet set up. The loss of personnel or equipment may cause the battery to rely on some type of emergency backup procedures. The firing battery executing an emergency fire mission has two priorities technical fire direction tasks:

- Determine initial firing data to the target.
- Prepare for determination of subsequent data on the basis of the observer's corrections.

METHODS OF DETERMINING INITIAL DATA

14-1. The first priority is to compute initial data, announce it to the howitzer, and fire a round. Depending on the call for fire, the XO or FDC may accomplish this by using one of several methods:

14-2. **Adjust Fire**. The platoon leader determines direction and range to the target grid location from the map-spotted platoon location. This is done most rapidly by using a map and a range-azimuth fan of the correct scale (figure 14-1). The platoon leader directs that the platoon be laid on the azimuth to the target, or he may orient the base piece himself by using the howitzer backlay method or a distant aiming point. If he has time, the platoon leader should lay the base piece with an aiming circle. The platoon leader selects a charge, or uses the standard charge, and converts the range to an elevation. The initial firing data are announced to the howitzer(s).

- Deflection equals the common deflection for the weapon system in use.
- QE equals elevation corresponding to range to target (GFT, TFT, and so on). Site is ignored unless it is excessively large. The FDO or platoon leader is responsible for analyzing the terrain in the target area and checking intervening crests to determine if he should include site.

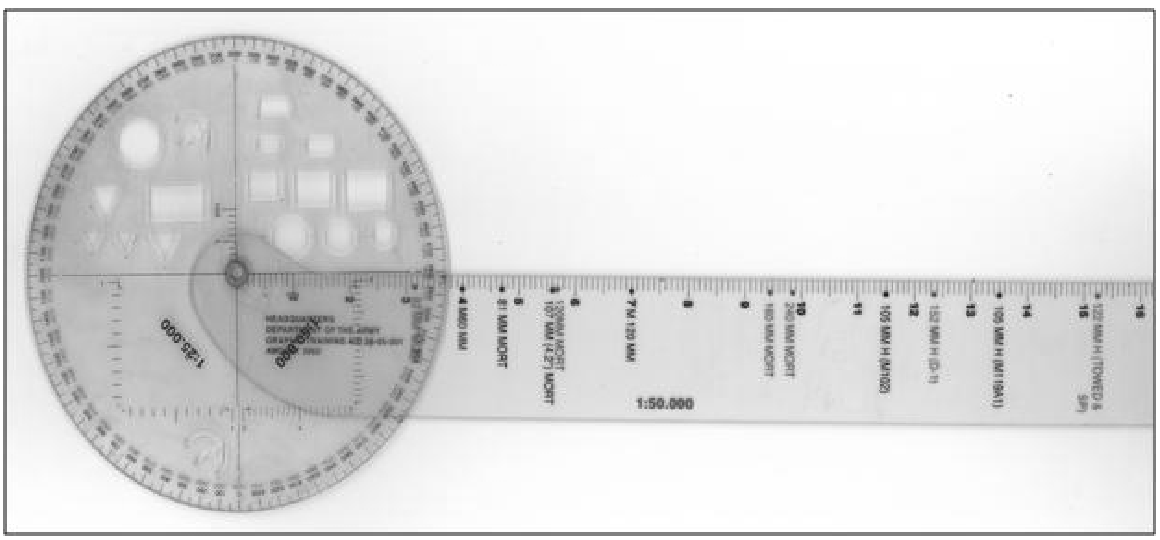


Figure 14-1. Range-Azimuth Fan.

14-3. **Mark Center of Sector**. This is requested when the observer is not oriented to the terrain. The platoon leader determines direction and range to the center of the supported unit's zone of action from the map-spotted battery location. If the platoon leader is not sure of the situation or the location of the sector center or if he feels a center of sector round may be unsafe, white phosphorus with fuze time for an airburst should be fired. The platoon leader directs that the platoon be laid on the azimuth he determines to the sector center. The platoon leader determines the elevation corresponding to the range and charge. The initial firing data are announced to the piece.

- For a WP or an HE high airburst, the trajectory is raised to a 200-meter HOB by using the100/R factor. The FS corresponding to the initial elevation is used. The error introduced by a vertical interval greater than 100 meters is ignored.
- If shell HC smoke or WP is requested, HE data are fired without making corrections for projectile weight. For shell HC smoke, the time fuze setting to fire is determined by subtracting 2 seconds from the FS corresponding to the HE elevation.

Note: A grid location is preferred over mark center of sector because the first round fired engages the target directly.

METHODS OF DETERMINING SUBSEQUENT DATA

14-4. After the initial fire commands are announced, emergency equipment must be prepared to convert the observer's corrections into subsequent fire commands. There are several expedient means of obtaining subsequent data that are available to the XO. He or the FDO must be able to quickly convert observer corrections into firing data.

- **Emergency Firing Chart**. Use of the emergency firing chart to adjust fire is discussed below.
- **M19 or M17 Plotting Board**. Use of the M19 or M17 plotting board to adjust fire is discussed in table 14-2 on page 14-9.

EMERGENCY FIRING CHART

14-5. The emergency firing chart employs the same basic techniques as observed firing charts. Establish location and direction by using the relationship between the firing unit and its targets. The relationship is determined by firing and will contain errors. The emergency chart is only a temporary expedient to be used until a surveyed chart can be constructed.

14-6. The emergency chart may be constructed on any surface suitable for plotting (can accommodate an RDP and plotting pins).

14-7. Use table 14-1 to construct an emergency firing chart.

Table 14-1. Emergency Firing Chart Procedures.

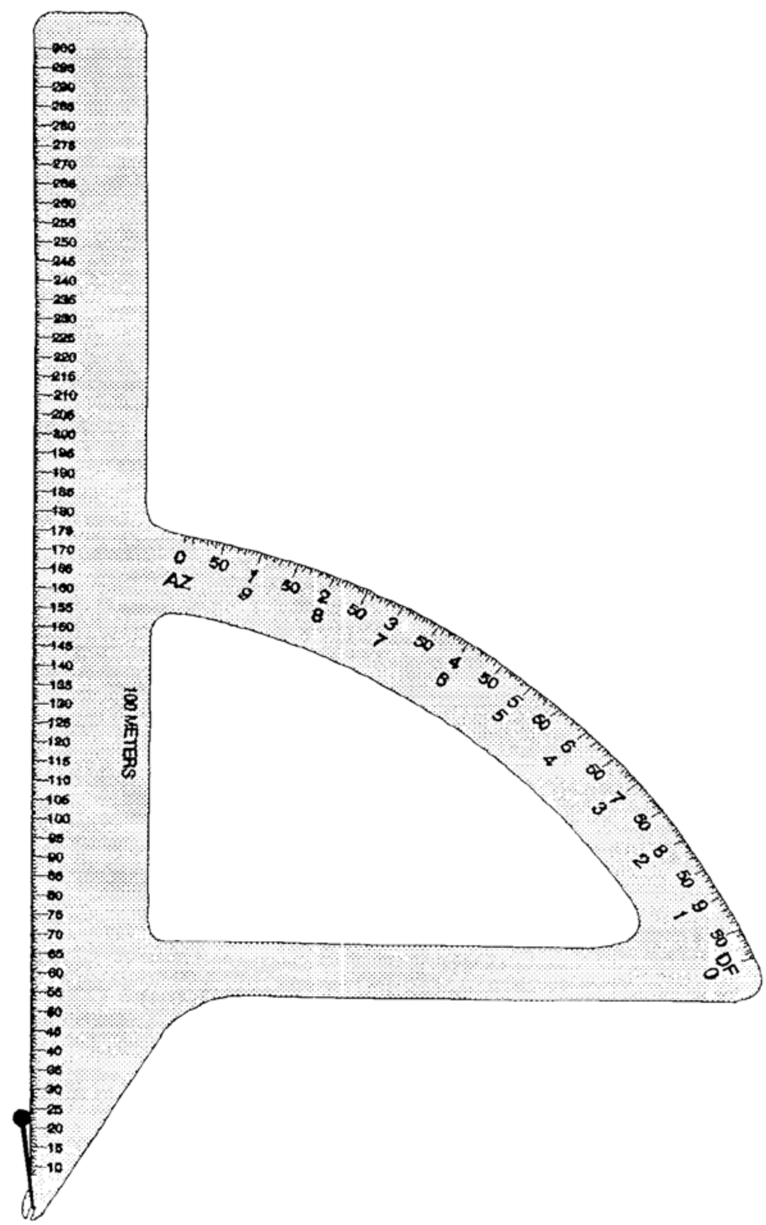
STEP	*ACTION*
1	Determine the azimuth and range to the target or center of sector
2	Announce deflection 3200, the common deflection, to fire. If time permits or situation dictates, determine and add drift to the announced deflection. This will be the Announce deflection to fire.
3	From the range determine in step 1, determine the elevation corresponding to the charge and range. This will be the QE to fire. If time permits or situation dictates, determine and add site to the elevation determine above. This will be the QE to fire.
4	Place the RDP in the middle of the plotting surface.
5	Orient the RDP in the general azimuth of fire, as announce by the FDO, XO, or platoon commander.
6	Place a pin in the vertex of the RDP. This pin represents the location of the platoon (see figure 14-2, page 14-5).

Table 14-1. Emergency Firing Chart Procedures (continued).

STEP	***ACTION***
7	Without moving the RDP, establish the primary deflection index by placing a pin opposite the graduation on the arc of the RDP that represents the common deflection (see figure 14-3, page 14-6).
8	Insert a pin through the center of the target grid.
9	Without moving the RDP, place the pin from step 8 opposite the range to the center of the center sector or the range to the target.
10	Move the RDP and allow the target grid to rest on the plotting surface. Keep the vertex of the RDP at the platoon location.
11	Move the RDP until the arm is against the pin marking the center sector or target location. The arm of the RDP should be on top of the target grid.
12	Align the arrow (0-3200 line) on the target grid so that it is parallel to the arm of the RDP. The head of the arrow on the target grid should point away from the vertex of the RDP along the GT line. (See figure 14-4, page 14-7.)
13	Place a pin opposite the target grid graduation corresponding to the azimuth of fire (from step1 above). This pin represents a north index for the target grid and graphically shows the relationship between grid north and the azimuth of fire. (see figure 14-4, page 14-7)
14	Move the RDP away from the target grid.
15	Rotate the target grid until the announced observer's target direction is opposite the north index pin. The target grid is now properly oriented for the plotting of the observer's subsequent corrections. After the target grid is oriented, at least two pins should be inserted in the target grid at all times. Angle T is measured in the normal fashion. (See Figure 14-5 on page 14-8, which shows a target oriented on observer direction 0250)
16	Plot the left or right correction given by the observer by measuring the appropriate number of squares left or right of the pin in the center of the sector or target location. Each square on the target grid represents 100 meters and can be visually interpolated to the nearest 10 meters.
17	Plot add or drop correction given by the observer by measuring the appropriate number of grid squares **UP** or **DOWN** along the observer's direction from the point plotted in step 16 above. Place a pin in this location.
18	Move the RDP so that the arm is against the pin from step 17
19	Determine and announce the range opposite the pin to the nearest 10 meters. The platoon designation is announced first followed by the range. For example 1/A range3400 would be announced as **ONE ALPHA RANGE THRE FOUR HUNDRED.**
20	Determine and announce the chart deflection from the arc opposite the pin marking the primary deflection index to the nearest mil. For example, **deflection 3280** would be announced as **DEFLECTION THREE TWO EIGHT ZERO.**
21	The deflection announced to the firing howitzer(s) is the chart deflection plus drift (if previously included in the mission).
22	The QE announced to the firing howitzer(s) is the elevation corresponding to the announce range plus site (if previously included in the mission).
23	Repeat steps 16 through 22 for all subsequent corrections, to include the observer's final refinements.
24	After plotting the observer's final refinement, determine the final chart range can deflection.
25	Remove the plotting pin marking the final adjusted location, and construct and label a tick mark to mark this location. The tick mark should be constructed with a red pencil since the target was located by firing.

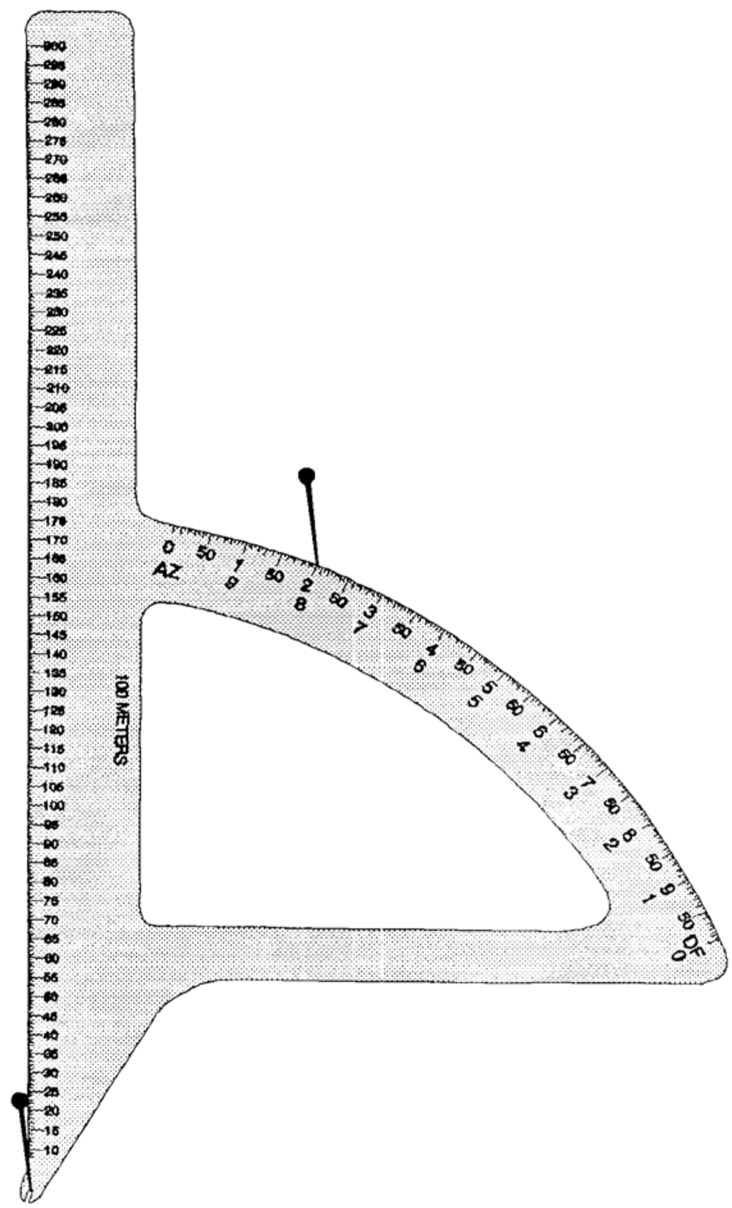
Table 14-1. Emergency Firing Chart Procedures (continued).

STEP	***ACTION***
26	Remove the pin at the platoon location, and construct a label a tick mark to mark this location.
	Note: A permanent north index will be constructed.
27	Orient the target grid, with the pin in the middle, and RDP over the final adjusted location as in steps 5 through 9.
28	Determine the azimuth to the final pin location comparing the initial deflection to the final deflection. Apply the difference to the azimuth of fire from step 2. If the change in deflection is left subtract its value from the direction of fire. If the change in deflection is right, add its value to the azimuth of fire. **FINAL DEFLECTION 3257** **INITIAL DEFLECTION 3200** **CHANGE IN DF L57(INITIAL TO FINAL)** **AZIMUTH OF FIRE 0820** **+CHANGE IN DF (RALS) L57** **AZIMUTH TO TARGET 0763**
29	Remove the old north index pin, and place it opposite the graduation on the target grid corresponding to the value demined in 28. This pin represents the new grid north index.
30	Align the arm of the RDP with the pin in the target location and the north index pin, and construct a permanent north index. Remove the north index pin. Use a 6H pencil to construct a line along the left-hand edge of the arm beginning at the north index. Pinhole and extending out 1 inch. Using a 4h pencil, label, the line “N”. The labeling should be done immediately above the end of the line.
31	Replace the pin representing the temporary 3000 deflection index with a permanent deflection index.
	Note: if it appears the firing unit will remain in this position for a sustained period of time, a surveyed firing chart should be constructed.
Legend: DF – deflection FDO – fire direction officer GT – gun-target QE – quadrant elevation RDP – range deflection protractor XO – executive officer	



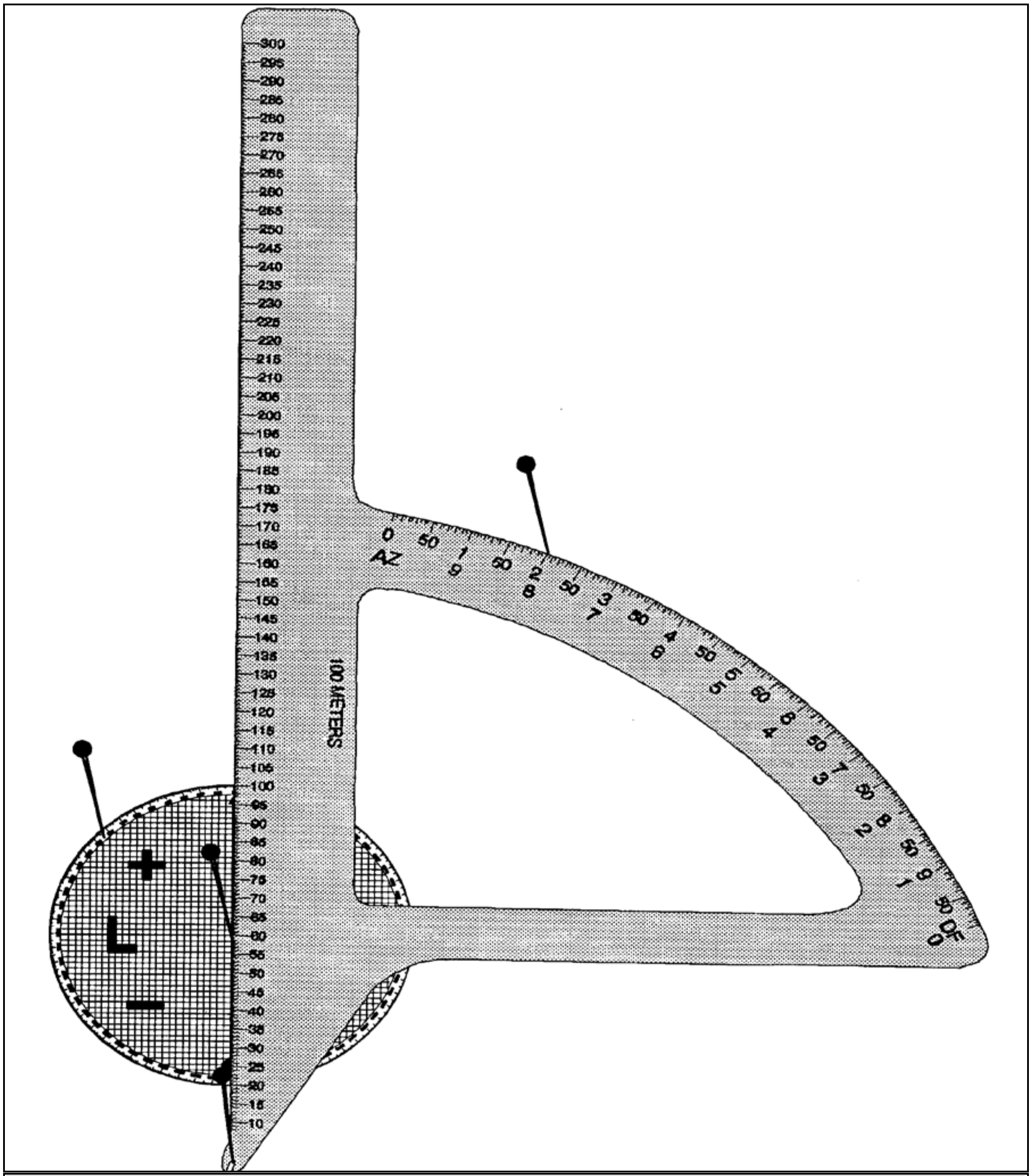
Legend: AZ – azimuth   DF – deflection

Figure 14-2. Platoon Location.



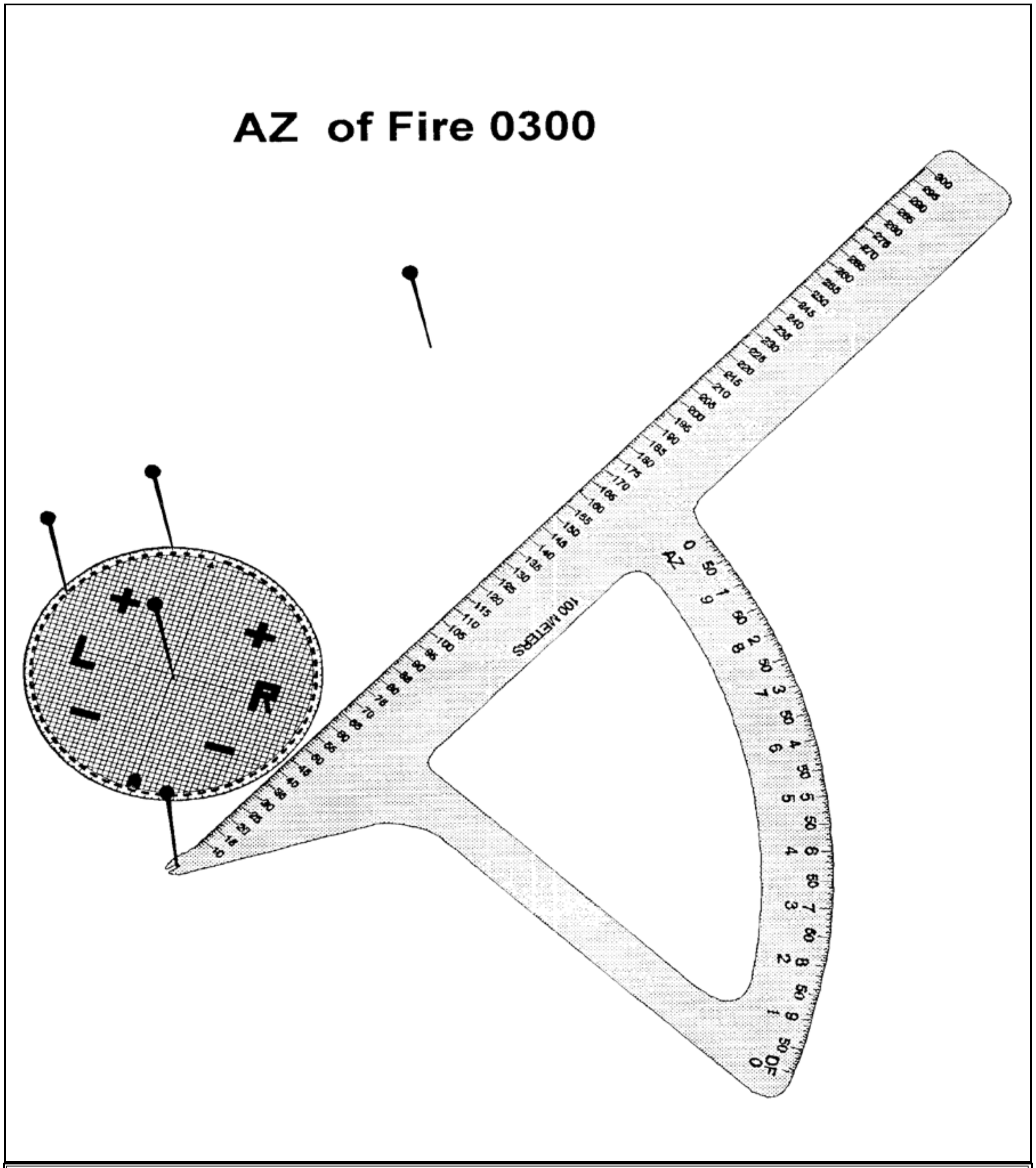
Legend: AZ – azimuth DF – deflection

Figure 14-3. Common Deflection 3200.



Legend: AZ – azimuth DF – deflection

Figure 14-4. RDP With the Target Grid Oriented.



Legend: AZ – azimuth DF – deflection

Figure 14-5. Target Grid Oriented on Observer Direction.

M19 OR M17 PLOTTING BOARD

14-8. The M19 or M17 plotting board may be used for determining data for subsequent corrections in place of an emergency firing chart. Once prepared, observer corrections along the OTL can be converted to corrections along the GTL. For this procedure, the rivet (center) of the plotting board represents the location of the last burst.

14-9. Use table 14-2 (on page 14-9) to determine data for subsequent corrections in place of an emergency firing chart.

Table 14-2. M19 or M17 Plotting Board Procedures.

STEP	*ACTION*
1	Place a mark on the clear plastic disk opposite the number on the outer scale that corresponds to the OT direction. Label it "O".
2	Place a mark on the clear plastic disk opposite the number on the outer scale that corresponds to the GT direction. Label it "GT"
3	Determine angle T by comparing the OT direction to the GT direction. Angle T is represented by the angle form by the OT direction and the GT direction.
	Note: Following normal adjust-fire procedures, the observer will determine and announce his subsequent corrections.
4	Rotate the clear plastic disk until the mark representing the OT direction is over the red arrow on the base. The plotting board is now oriented in the OT direction.
5	Plot the observer's deviation correction on the clear plastic disk.
6	Plot the observer's range correction on the clear plastic disk, and mark this location.
	Note: The observer's correction should be plotted in reference to the rivet (center). If possible, the scale used should be 10 meter. This will allow for rapid conversion of OT corrections to GT corrections.
7	Rotate the disk until the GT mark is over the red arrow. The plotting board is now oriented on the GT line.
8	Determine the GT deviation correction by measuring the number of meters the location marked in step 6 is left or right of the rivet (center)
9	Determine the GT range correction by measuring the number of meters the location marked in step 6 is above or below the rivet (center).
10	Determine the 100/R by dividing the 100 by the initial range to the target (in thousands), and express the result to the nearest mil. $\frac{\mathbf{100}}{\boldsymbol{R}} = \frac{\mathbf{1}}{\boldsymbol{RANGE\ (in\ thousand)}}$
11	Determine the correction to deflection by multiplying the GT deviation correction (step 8) by 100/R (step 10) and dividing the product by 100. Express the result to the nearest 1₥.
12	Determine and announce the deflection to fire by applying the correction to deflection (step11) to the deflection fired.
13	Determine the range to fire by applying the GT range correction to the last range fired.
14	Using standard procedures, determine the elevation to fire from the GFT (with or without a GFT setting).
15	Determine and announce QE by applying site (if previously included) to the elevation to fire (step 14).
	Note: There are two methods for determining new elevation. The first option is to use the new range determined in step 13 as the entry argument to determine elevation. The second option is to divide the value of the GT range correction determined in step 9 by the change in range per 1-mil change in elevation corresponding to the last range fired (TFT, Table F, Colum 5). Add this value to the last elevation fired to determine the new elevation.
	EXAMPLE FIRED RANGE 15000 CHG 4H M232A1 429 RG CORR +100 ENTRY ARGUMENT RG 15100= EL 434.8≈ 435 OR ENTRY ARGUMENT RG 15000 428.8 DR PER 1 MIL Δ EL 17 RG CORR +100/DR R/1MIL Δ EL= 5.9 +428.8= 434.7≈ EL435
Legend: CHG – charge CORR – correction EL – elevation GFT – graphical firing table GT – gun-target ₥ - mil OT – observer-target QE – quadrant elevation RG – range TFT – tabular firing table	

EMERGENCY FIRING CHART EXAMPLE

14-10. You receive a call for fire while traveling to your next position. From a map spot, you determine the range to the target to be 14200 and the direction to be 4950. Use table 14-3 to process the mission.

Table 14-3. Emergency Fire Mission.

STEP	***ACTION***
1	Determine the azimuth and range to the target or center of sector. On the basis of the range, determine the charge to fire (range 14200, direction 4950, charge 4H M232A1).
2	Announce deflection 3200, the common deflection, to fire. If time permits; determine DRIFT and add drift to the common deflection. The result will be the deflection to fire.
3	From the range determined in step 1, determine the elevation corresponding to the charge and range; This will be the QE to fire. If time permits; determine site and add site to the elevation determined. The result will be the QE to fire **(QE= EL of 246). Announce QE 246 to the howitzer(s).**
4	Place the RDP in the middle of the plotting surface.
5	Orient the RDP in the general azimuth of fire as announced by the FDO, XO, or platoon commander **(direction 4950).**
6	Place a pin in the vertex of the RDP. This pin represents the location of the firing unit.
7	Without moving the RDP, establish the primary deflection index by placing a pin opposite the graduation on the arc of the RDP that represents the common deflection **(deflection 3200).**
8	Insert a pin through the center of the target grid.
9	Without moving the RDP, place the pin from step 5 opposite the range to the center of sector or the range to the target **(range 14200).**
10	Move the RDP, and allow the target grid to rest on the plotting surface. Keep the vertex of the RDP at the firing unit location.
11	Move the RDP until the arm is against the pin marking the center of sector or target location. The arm of the RDP should be on top of the target grid.
12	Align the arrow (0-3200 line) on the target grid so that it is parallel to the arm of the RDP. The head of the arrow on the target grid should point away from the vertex of the RDP along the GT line.
13	Place a pin opposite the target grid graduation corresponding to the azimuth of fire (from step 2 above). This pin represents a north index for the target grid and graphically shows the relationship between grid north and the azimuth of fire. Place the pin at 4950.
14	Move the RDP away from the target grid.
15	Rotate the target grid until the announced observer target direction is opposite the north index pin. **Observer announces DIRECTION 0250.** The target grid is now properly oriented for the plotting of the observer’s subsequent corrections. After the target grid is oriented, at least two pins should be inserted in the target grid at all times. Angle T is measured in the normal fashion.
16	Plot the left or right correction given by the observer by measuring the appropriate number of squares left or right of the pin in the center of sector or target location. Each square on the target grid represents 100 meters and can be visually interpolated to the nearest 10 meters **(right 200, drop 500).**
17	Plot the add or drop correction given by the observer by measuring the appropriate number of grid squares up or down from the point plotted in step 13 above. Place a pin in this location.
18	Move the RDP so that the arm is against the pin from step 14.

Table 14-3. Emergency Fire Mission (continued).

STEP	ACTION
19	Determine and announce the range to the nearest 10 meters. The unit designation is announced first followed by the range (**1/A range 14200) (ONE ALPHA RANGE 14200).**
20	Determine and announce the chart deflection from the arc opposite the pin marking the primary deflection index **(DEFLECTION 3328).**
21	The QE announced to the howitzer(s) is the elevation corresponding to the announced range plus site (if previously included in the mission) **(QE= EL OF 383). Announce QE 383 to the howitzer(s).**
22	Repeat steps 13 through 20 for all subsequent corrections, to include the observer's final refinement. OBS Subsequent Corr: **Right 50, add 100** Firing Data: **1/A range 14300, DF 3307, QE 388** OBS Subsequent Corr: **Add 50, fire for effect** Firing Data: **1/A range 14350, DF 3284, QE 391** OBS Final Refinement: **Left 20, drop 20, record as target**
23	After plotting the observer's final refinement, determine the final chart range and deflection. Chart data are **1/A range 14320, deflection 3289**.
24	Remove the plotting pin marking the final adjusted location, and construct and label a tick mark to mark this location. The tick mark should be constructed with a red pencil, since the target was located by firing.
25	Remove pin at the firing unit location, construct and label a tick mark to identify the location.
	Note: A permanent north index will be constructed.
26	Orient the target grid, with the pin in the middle and RDP over the final adjusted location, as in steps 5 through 9.
27	Determine the azimuth to the final pin location by comparing the initial deflection to the final deflection. Apply the difference to the azimuth of fire from step 2. If the change in deflection is left, subtract its value from the direction of fire. If the change in deflection is right, add its value to the azimuth of fire.
	EXAMPLE **FINAL DEFLECTION 3299** **INITIAL DEFLECTION 3200** **CHANGE IN DF L99 (INITIAL TO FINAL)** **AZIMUTH OF FIRE 4950** **+CHANGE IN DF L99 (RALS)** **AZIMUTH TO TARGET 4851**
28	Place a pin opposite the graduation on the target grid corresponding to the value determined in step 27. This pin represents the new grid north index.
29	Remove the old north index pin.
30	Align the arm of the RDP with the pin in the target location and the north index pin.
31	Remove the north index pin.
32	Beginning at the north index pinhole, draw a line along the left-hand edge of the arm and extend the line out 1 inch. Using a 4H pencil, label the line "N." The labeling should be done immediately above the end of the line.
33	Replace pin representing temporary 3000 deflection index with a permanent deflection index.
	Note: If it appears the unit will remain in this position for a sustained period of time, a surveyed firing chart should be constructed.
Legend: DF – deflection EL – elevation FDO – fire direction officer GT – gun-target RALS – right add left subtract RDP – range deflection protractor QE – quadrant elevation XO – executive officer	

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Chapter 15

Safety

DA Pamphlet (PAM) 385-63, Chapter 10 implements the chain-of command safety concept. Under this concept, the firing battery chain of command is responsible for safety during firing, training, and combat. This chapter reinforces DA PAM 385-63. However, if local range regulations are more restrictive than the material in this chapter, the local range regulations must be followed.

SECTION I: RESPONSIBILITIES AND DUTIES

15-1. This section describes safety responsibilities, the duties of safety personnel, and the safety aids used by those personnel.

RESPONSIBILITIES

15-2. **Commanders of Field Artillery Brigades/Regiments**. Commanders establish and maintain a Safety Training and certification program for their personnel. The purpose of this program is to train and qualify personnel within their command in the safety procedures for their specific areas of responsibility. When the commander is satisfied that the personnel are qualified to conduct safety certification programs, he certifies them.

15-3. **Battalion Commander**. The FA battalion commander is responsible for safety during all phases of a firing exercise under his control. He selects, trains, and certifies the personnel needed to help him discharge this responsibility. These personnel include, but are not limited to, the following:

- Battery commander.
- Executive officer or Platoon leader.
- Fire direction officer.
- Chief of firing battery.
- Battery gunnery sergeant.
- FDC chief computer.
- Howitzer section chief.

Note: If any position is not filled by a command safety-certified individual, another individual who is certified and qualified to fill that position performs the safety checks.

15-4. **Officer in Charge**. The officer in charge (OIC) is the battery commander or his command safety-certified representative. The OIC is responsible for all aspects of safety in the firing unit and on the assigned firing range. Before the firing exercise, the range officer provides the OIC with the required safety data and any firing limitations. The OIC verifies that the unit is in the proper firing position. He supervises the conversion of the safety data into a safety diagram and ensures that this diagram is verified by another command safety-certified individual. The safety data determined from the safety diagram provide right and left deflection limits, minimum and maximum quadrant elevations for authorized charges, and minimum safe fuze times. The Safety T, modified as needed by the XO's minimum QE, is given to the appropriate members of the firing battery.

15-5. **Executive Officer or Platoon Leader**. The XO or platoon leader is responsible for the safety practices of the firing element. He ensures that the section chiefs have safety data represented in the form of a Safety T. He is responsible for determining the lowest QE that can be fired safely from the firing position and will ensure that projectiles **clear all immediate crests** (XO's minimum QE). He is assisted by the FDO, the platoon sergeant, and/or the gunnery sergeant.

15-6. **Fire Direction Officer**. The FDO has primary responsibility for computing safety data and for ensuring that all safety data are updated after registrations and receipt of current met data, if required. He is responsible for plotting the impact area on a map or chart in the FDC. He is assisted in his duties by the chief computer/operations chief. He ensures that all firing data are within prescribed safety limits before they are sent to the firing sections. He is responsible for adjusting minimum **QE for intervening crests**.

15-7. **Chief of Fire Direction Computer/Operations Chief.** The chief of fire direction/operations chief (chief computer/ops chief) has the primary responsibility of being the technical expert within the FDC. His additional responsibilities include being the primary secondary safety check within the FDC as far as processing missions as well as computing and updating safety, as required. He assists the FDO and in the absence of the FDO, during 24 hour operations, can process missions with the aid of an additional safety certified individual.

15-8. **Battery Gunnery Sergeant/Platoon Sergeant.** The battery gunnery sergeant/platoon sergeant helps the XO or platoon leader in his duties and must be prepared to perform many of the duties in his absence. His main responsibilities are laying the battery, performing the duties of the XO or platoon leader, and working in shifts with the XO or platoon leader.

15-9. **Howitzer Section Chief**. The section chief is responsible for supervising all practices that take place at or near his weapon. These include verifying that the announced safety data are applied to his weapon and that the proper charge, fuze, and projectiles are fired in accordance to his applicable Safety T. He has the final responsibility for the safe firing of his weapon.

15-10. **Range Control Officer**. The range control officer may provide the OIC of the firing unit the following safety data:

- Grid coordinates of the firing position.
- Lateral safety limits.
- Minimum and maximum ranges.
- Authorized ammunition to be fired (fuze, projectile, and charge).
- Maximum ordinate (high angle or low angle).
- Hours during which firing is conducted.

Note: This billet may also be performed by a Battalion/Battery FDO if there is no local Range Control Officer.

DUTIES OF SAFETY PERSONNEL

15-11. In accordance with Army Regulation (AR) 385-63, a separate battery safety officer is not required during the firing of field artillery. Normally, the XO or platoon leader performs this function. The XO or platoon leader is not required to verify all data placed on the on-carriage fire control equipment. He may rely on safety stakes, Safety Tape, or physical constraints on the weapon to ensure that the safety limits are not exceeded. All key personnel must be thoroughly familiar with six references:

- AR 385-63. Range Safety.
- DA PAM 385-63– Range Safety.
- TC 3-09.81. Tactics, Techniques and Procedures for Field Artillery Manual Cannon Gunnery.
- ATP 3-09.50. The Field Artillery Cannon Battery.
- TM 43-0001-28. Army Ammunition Data Sheets.
- Appropriate TM for the weapon. Commonly referred to as a Weapon-10.
- Local range regulations.

Note: In case of conflict, the most restrictive, usually local range regulations, takes precedence.

Note: The following are guidelines that can help units develop SOPs.

15-12. Specific duties of safety personnel **before** firing are, but are not limited to, the following:

- Verify that the data the range control officer gives the OIC applies to the unit firing, that the unit is in the correct location, and that the data are correct. (OIC and safety officer)
- Compute and verify the basic safety diagram is performed by at least two safety-certified personnel. (normally FDO and chief computer/ops chief)
- Check DA Form 581 (Request for Issue and Turn-in of Ammunition) and the range safety card to ensure that only authorized ammunition is fired. (XO, platoon leader or platoon sergeant)
- Ensure that no safety violations occur at or near the weapon(s). (All members of the firing unit)
- Check the weapons for correct boresighting. (Section chief)
- Verify the lay of the battery. (XO, platoon leader, battery gunnery sergeant or platoon sergeant)
- Compute and verify minimum QE. (XO, platoon leader or FDO)
- Compare minimum QE with the QE for minimum range shown on the safety diagram. Use the larger of the two as the minimum QE. (XO, platoon leader or FDO)
- Verify that the section chief has safety data (Safety T). (XO, platoon leader, or platoon sergeant)
- Supervise and check the emplacement of safety aids, if required by local range regulations or unit SOP (stakes, tape, and other devices). (XO, platoon leader, platoon sergeant, or gunnery sergeant)
- Verify that range clearance has been obtained. (XO, platoon leader, or FDO)

15-13. Specific duties of safety personnel **during** firing are, but are not limited to, the following:

- Verify the serviceability of ammunition. (Section chief)
- Supervise key safety personnel in the performance of their duties. (OIC or safety officer)
- Verify that the charges, projectiles, and fuzes being fired are only those prescribed on the safety card issued by the range control officer. (XO, platoon leader, battery gunnery sergeant or platoon sergeant)
- Verify that rounds are not fired below the minimum QE or above the maximum QE. (XO, platoon leader, battery gunnery sergeant, platoon sergeant or section chief)
- Verify that rounds are not fired outside the lateral (deflection) safety limits specified on the safety card. (XO, platoon leader, battery gunnery sergeant, platoon sergeant or section chief)
- Verify that time-fuzed projectiles are not fired with fuze settings that are less than the minimum time prescribed on the Safety T. (XO, platoon leader, battery gunnery sergeant, platoon sergeant or section chief)
- On all commands that are unsafe to fire, command **CHECK FIRING** and give the reason(s) why the command(s) is (are) unsafe. (Any person)
- Recompute and issue updated Safety Ts, as required, under the following conditions: (FDO or chief computer/ops chief)
  - When a registration is completed.
  - When met conditions change.
- Suspend firing when any unsafe condition exists. (Any person who sees an unsafe act) Examples of unsafe conditions are as follows:
  - Propellant or unused increments exposed to fire.
  - Personnel smoking near howitzers or ammunition.
  - Improper handling of ammunition.
  - Time fuze previously set and not reset to safe.
  - Personnel or aircraft directly in front of the howitzers line of fire.
  - Primer inserted into the firing assembly before the breech is closed (separate-loading ammunition).
  - Failure to inspect the powder chamber and bore after each round is fired.
  - Failure to swab powder chamber after each round of separate-loading ammunition is fired.

15-14. Specific duties of safety personnel **after** firing are, but are not limited to, the following:

  - Unused powder increments are disposed of at an approved location and in the correct manner. (XO, platoon leader, battery gunnery sergeant or platoon sergeant)

- All unfired ammunition is properly accounted for, repacked and transported to the ammunition depot. (XO, platoon leader, battery gunnery sergeant or platoon sergeant)
- All trash is policed and disposed of properly. (All personnel)
- Collect up and destroy old Safety Ts. (FDO or chief computer/ops chief)

15-15. All safety personnel will perform their duties in a manner that ensures compliance with all safety regulations and limits.

SAFETY AIDS

15-16. From the range safety card, two safety certified individuals (normally the FDO and chief computer/ops chief) prepares a safety diagram, computes safety data, and Safety T's for use by the battery personnel. Safety aids are used to ensure that only safe data are fired from the position. The most common safety aids are safety stakes and Safety Tape. These aids are then used as a visual check to ensure that the howitzer is laid within safety limits.

EMPLACE SAFETY AIDS ON THE M119 SERIES HOWITZER AS FOLLOWS:

15-17. For deflection safety aids—

- Determine the left deflection limit. Set off the left deflection limit on the pantel by using the deflection counter.
- Traverse the tube to the left as much as possible.
- Traverse the carriage (shift trails) until the correct left deflection limit sight picture on the aiming point is established.
- Place a left limit safety stake against the right side of the spade.
- Mark the right deflection limit in the same manner, but emplace the safety stake on the left side of the spade.

15-18. For quadrant elevation aids–

- Use the stationary bracket on the elevation gear box as an index mark.
- Set off the maximum QE on the fire control quadrant. Elevate the tube until the bubbles center in the elevation level vials.
- Mark the elevation arc with a piece of tape in line with the stationary bracket on the elevation gear box.
- Mark the minimum QE in the same manner.

EMPLACE SAFETY TAPE ON THE M198 OR M777 SERIES HOWITZER AS FOLLOWS:

15-19. For deflection safety aids–

- With the tube parallel to the azimuth of lay, place a piece of tape over the azimuth counter (bottom carriage).
- Set off the left deflection limit on the pantel by using the deflection counter. Traverse the tube to establish the proper sight picture on the aiming point.
- Using a straight edge, draw a line on the tape placed on the bottom carriage directly below the azimuth counter index mark found on the upper carriage. Record the left deflection limit next to that line.
- Mark the right deflection limit in the same manner.

15-20. For quadrant elevation safety aids–

- With the tube elevated to 0 mils, place a piece of tape on the trunnion support and draw a straight line as an index.
- Set off the minimum QE on the fire control quadrant. Elevate the tube until the bubble centers in the elevation level vial.
- Place a piece of tape on the quadrant mount, and draw a line across from the index line established on the trunnion support. Record the minimum QE next to that line.

- Mark the maximum QE in the same manner.

EMPLACE SAFETY AIDS ON THE M109 SERIES HOWITZER AS FOLLOWS:

15-21. Deflection safety aids. These may be marked on the exterior and/or interior of the hull.

- Make an index mark on the top carriage with a piece of tape.
- Set off the left deflection limit on the pantel by using the reset counter. Traverse the tube to establish a proper sight picture on the aiming point.
- Place a piece of tape on the bottom of the carriage directly under the index mark.
- Mark the right deflection limit in the same manner.

15-22. Quadrant elevation safety aids. These may be marked on the exterior or the interior of the weapon. To emplace the safety aids on the interior of the weapon, perform the following steps:

- With the tube elevated to 0 mils, place a piece of tape on the trunnion support and draw a straight line as an index.
- Set off the minimum QE on the fire control quadrant. Elevate the tube until the bubble centers in the elevation level vial.
- Place a piece of tape on the quadrant mount, and draw a line across from the index line established on the trunnion support. Record the minimum QE next to that line.
- Mark the maximum QE in the same manner.

15-23. To mark the exterior of the weapon, perform the following steps:

- Mark an index on the tube with a piece of tape.
- Set off the maximum QE on the fire control quadrant. Elevate the tube until the bubble centers in the elevation level vial.
- Place a mark on the top carriage in line with the index mark. Mark the minimum QE in the same manner.

SECTION II: MANUAL COMPUTATIONS OF SAFETY DATA

15-24. Minimum and maximum quadrant elevations, deflection limits, and minimum fuze settings must be computed to ensure that all rounds fired impact or function within the target area. These data are presented and arranged in a logical manner on a Safety T. This section describes the manual computation of safety data by use of tabular and graphical equipment. As stated earlier, the range control officer gives the OIC the lateral safety limits and the minimum and maximum ranges of the target areas. These data must be converted to fuze settings, deflections, and quadrants. The computations discussed in this section should be done by two safety-certified personnel working independently.

MANUAL COMPUTATIONAL PROCEDURES

15-25. Manual safety computations are accomplished in four steps, beginning with receipt of the range safety card and ultimately ending with the production of the Safety T. These steps are listed in table 15-1.

Table 15-1. Four Basic Steps of Manual Safety Production.

STEP	*ACTION*
1	Receive the Range Safety Card (Produced by unit or from Range Control).
2	Construct the Basic Safety Diagram in accordance with table 15-2, page 15-7.
3	Construct and complete the computation matrix using figure 15-3 (page 15-11) for Low Angle Safety and figure 15-12 (page 15-26) for High Angle Safety.
4	Construct the Safety T and disseminate in accordance with unit standard operating procedure.

RANGE SAFETY CARD

15-26. A Range Safety Card (figure 15-1), which prescribes the hours of firing, the area where firing will take place, the location of the firing position, limits of the target area (in accordance with DA PAM 385-63) and other pertinent data is approved by the range control officer and provided to the OIC of firing. The OIC of firing provides a copy of the safety card to the FDO or Chief Computer/Ops Chief, who constructs the safety diagram based on the prescribed limits.

Note: The range safety card depicted in figure 15-1 is used for all safety computation examples in this chapter.

RANGE SAFETY CARD

UNIT: **A 1-30** SCHEDULE DATE IN: **05/30/13** SCHEDULE DATE OUT: **05/30/13**
TIME IN: **0600** TIME OUT: **2359**

FIRING POINT: 185 (6026 4110 ALT 370) IMPACT AREA: S. CARLTON IMPACT
WEAPON: M109A6 (155MM) AMMUNITION: M107, M110A2, M825A1, M485A2, M231, M739A1, M767, M762, M732

TYPE OF FIRE **LOW ANGLE: HE, WP, M825, ILLUM**
HIGH ANGLE: HE, WP, M825, ILLUM

Direction Limits (REF GN): LEFT: 1340 MILS RIGHT: 1900 MILS AOL:

Low Angle PD Minimum Range:	**3900**	METERS	Min Charge	1L
Fuze TI Range and High Angle Minimum Range:	**4200**	METERS	Min Charge	1L
To Establish Min Time for Fuze VT Apply +5.5 seconds to the Low Angle PD Min RG				
Maximum Range to Impact:	**6800**	METERS	Max Charge	1L

COMMENTS

FROM AZ 1340 TO AZ 1500 THE MAXIMUM RANGE IS 5700 METERS

SPECIAL INSTRUCTIONS

1. UN-CLEARED AMMUNITION (FUZES, PROJECTILES, POWDER) WILL NOT BE USED UNLESS CLEARANCE IS GIVEN BY RANGE CONTROL.
2. WHEN SHOOTING FUZE M564 IN PD MODE THE SETTING WILL BE 90.0 NO MATTER WHAT THE MANUFACTURED DATE.

Legend: AZ – azimuth; REF – reference; GN – grid north; TI – time; HE – high explosive; VT – variable time; ILLUM – illumination; WP – white phosphorous; PD – point detonating

Figure 15-1. Example of a Range Safety Card

BASIC SAFETY DIAGRAM

15-27. The FDO, on receipt of the range safety card, constructs a basic safety diagram. The basic safety diagram is a graphical portrayal of the data on the range safety card or is determined from the surface danger zone (DA PAM 385-63, Chapter 10) and need not be drawn to scale. The basic safety diagram reflects the minimum and maximum range lines; the left, right, and intermediate (if any) azimuth limits; the deflections corresponding to the azimuth limits; the azimuth of lay; and pertinent data from the range safety card (firing position location, authorized charge, projectiles and fuzes, angle of fire and azimuth of lay).

15-28. The steps for constructing a basic safety diagram are shown in table 15-2. An example of a completed safety diagram is shown in figure 15-2 on page 15-8.

Table 15-2. Construction of a Basic Safety Diagram.

STEP	***ACTION***
1	On the top third of a sheet of paper, record a line representing the AOL for the firing unit. Label this line with its azimuth and the common deflection for the weapon system.
	Note: If the AOL is not provided, use the following procedures to determine it: Subtract the maximum left azimuth limit from the maximum right azimuth limit. Divide this value by two, add the result to the maximum left azimuth limit, and express the result to the nearest 100 mils. Expressing to the nearest 100 mils makes it easier for the aiming circle operator to lay the howitzers.
2	Record lines representing the lateral limits in proper relation to the AOL. Label these lines with the corresponding azimuth from the range safety card.
3	Record lines between these lateral limits to represent the minimum and maximum ranges. Label these lines with the corresponding ranges from the range safety card. These are the Diagram Ranges.
	Note: If the minimum range for fuze time is different from the minimum range, record a dashed line between the lateral limits to represent the minimum range for fuze time. Label this line with the corresponding range from the range safety card. This is the minimum time Diagram Range.
4	Compute the angular deviations from the AOL to each lateral limit. On the diagram, record arrows indicating the angular measurements and label them.
5	Apply the angular deviations to the deflection corresponding to the AOL (Common Deflection) and record the result. These are the Diagram Deflections. The Diagram Deflections will be added to the Drift and GFT Deflection Correction determined in the Safety Matrices to produce the Deflection Limits on the Safety T.
	Note: If no GFT Deflection Correction has been determined, then the Deflection Limits = Drift + Diagram Deflection. If a GFT setting has been determined, then the Deflection Limits = Drift + GFT Deflection Correction + Diagram Deflection. Drift is applied to the Basic Safety Diagram by following the “least left, most right” rule. The lowest (least) drift is applied to all left deflection limits, and the highest (greatest) drift is applied to all right deflection limits.
6	Label the diagram with the following information from the range safety card: firing point location (grid and altitude), charge, shell, fuze, angle of fire, and azimuth of lay.
Legend: AOL – azimuth of lay GFT – graphical firing table	

15-29. When the basic safety diagram is complete, it will be constructed to scale, in red, on the firing chart. Plot the firing point location as listed on the range safety card. Using temporary azimuth indexes, an RDP and a red pencil, record the outline of the basic safety diagram. To perform this, first record the azimuth limits to include doglegs. Then, by holding the red pencil firmly against the RDP at the appropriate ranges, connect the azimuth lines.

15-30. Once the basic safety diagram is constructed on the firing chart, base piece location may be plotted and deflection indexes be constructed. If the diagram was constructed from the base piece location, it would be invalid unless the base piece was located over the firing point marker.

15-31. After the basic safety diagram has been recorded on a sheet of paper and on the firing chart, it is recorded on a map of the impact area or situational map using a Range Azimuth Fan and a red pencil/marker. These limits must be constructed accurately, because they will be used to determine altitudes for vertical intervals. Determine the maximum altitude along the minimum range line. This is used to ensure that the quadrant fired will cause the round to clear the highest point along the minimum range line and impact (function) within the impact area. At the maximum range, select the minimum altitude to ensure that the round will not clear the lowest point along the maximum range and impact (function) within the impact area. Once the altitudes have been selected, label the basic safety diagram with the altitudes for the given ranges.

Note: The rule for determining the correct altitude for safety purposes is called the mini-max rule. At the minimum range, select the maximum altitude; at the maximum range, select the minimum altitude. If the contour interval is in feet, use either the GST or divide feet by 3.28 to determine the altitude in meters. (Feet ÷ 3.28 = Meters) This rule applies to both manual and automated procedures.

15-32. The following altitudes were used for the construction of the Basic Safety Diagram:

RANGE	MIN ALT	MAX ALT
3900M	340M	393M
5700M	355M	400M
6800M	345M	390M

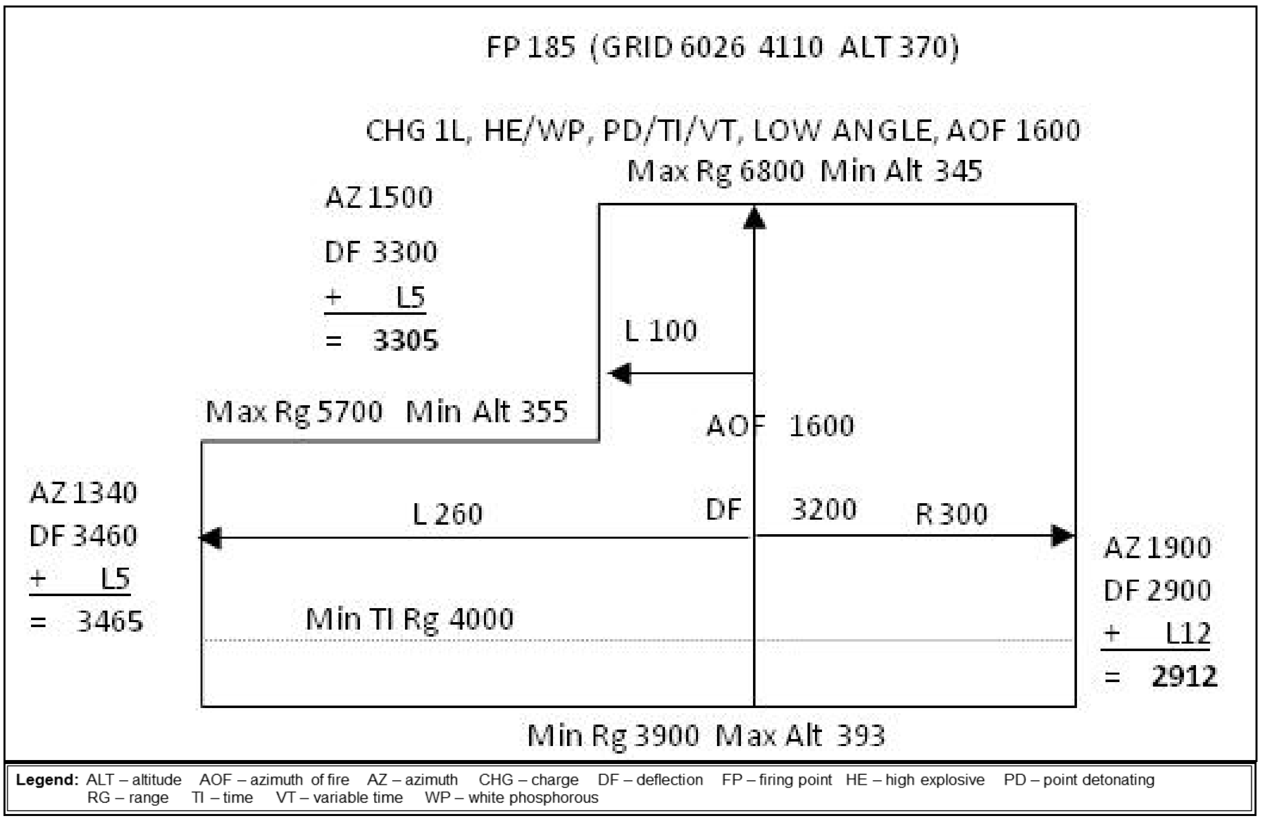


Figure 15-2. Example of a Completed Safety Diagram, HE/WP.

COMPUTATION OF LOW ANGLE SAFETY DATA

15-33. Use the steps outlined in table 15-3 (page 15-9) and in the matrix in figure 15-3 (page 15-11) as examples for organizing computations. The Low Angle Safety Matrix is used for all munitions. Paragraph 15-34 describes M712 safety computations. The data are determined by either graphical or tabular firing tables. In the case of expelling charge munitions, the Safety Table located in the Firing Tables or Firing Table Addendums is utilized to determine Elevation, Time of Flight, Fuze Setting, and Drift. Use artillery expression for all computations except where noted.

Table 15-3. Low Angle Procedures.

STEP	***ACTION***
1	On the top third of a blank sheet of paper, construct the basic safety diagram
2	In the middle third of the sheet of paper, construct the Low Angle Safety Matrix (See figure 15-3, page 15-11)
3	Record the Diagram Ranges from the basic safety diagram.
4	Enter the Range Correction, if required. This range correction is only necessary if a nonstandard condition exists and is not already accounted for in a GFT setting, such as correcting for the always heavier than standard White Phosphorous projectile. See figure 15-3, paragraph (b) to determine range correction. **If a range correction is required, it is expressed to the nearest 10 meters. If no range correction is required, enter 0 (zero).**
4a	A Range Correction may be necessary before determining data for particular projectile when the cannon tube to be fired is not the base cannon tube for the TFT for which safety data is to be determined. If this is the situation, a Range correction due to muzzle velocity differences between cannon tubes must be applied throughout the Safety Matrix. For example, if firing Charge 2L from a M777A2, a range correction must be applied to compensate for the +1 m/s muzzle velocity difference between the M284 cannon tube (base tube for AM-3) and the M776. This muzzle velocity variation will also have to be algebraically added to the range correction for WP as well to determine WP safety data. This correction can be found at the introduction of the TFT.
5	Determine the Total Range. Total range is the algebraic sum of the Diagram Range and the Range Correction. **Total Range is expressed to the nearest 10 meters**.
6	Enter the Range K. Range K is only required if a GFT setting has been obtained but cannot be applied to a GFT (i.e., determining Illumination safety with a HE GFT setting). Range K is simply the Total Range Correction from the GFT setting expressed as a percentage. This percentage, when multiplied by the Total Range, produces the Entry Range. If no GFT setting is available (i.e., initial safety), then enter 1.0000 as Range K. If a GFT setting is available, (i.e., updated safety), then enter Range K expressed to four decimal places (i.e., 1.1234).
6a	To determine Range K, divide Range @ Adjusted Elevation by the Achieved Range from the GFT setting: Range @ Adjusted Elevation = Range K (expressed to four decimal places) Achieved Range
6b	If a GFT Setting has been applied to a GFT, Range K will remain 1.0000 as the Elevation Gauge Line represents Range K. If Range K and a GFT Setting were to be used in conjunction with each other, this would double the Range Correction and cause and egregious error.
7	Determine the Entry Range. Multiply the Total Range by Range K to determine the Entry Range. If Range K is 1.0000, then the Entry Range will be identical to the Total Range. **Entry Range is expressed to the nearest 10 meters.**
8	Record the Charge from the range safety card.

Table 15-3. Low Angle Procedures (continued).

STEP	***ACTION***
9	Following the Mini-Max rule, determine the Vertical Interval by subtracting the unit altitude from the altitude corresponding to the Diagram Range, and record it. (Note: Diagram Range is used for computations of VI and Site because this is the actual location of the minimum range line. VI is not computed for minimum time range lines because the data determined for minimum time range lines is based off of graze burst data and the fuze will function safely beyond our minimum Diagram Range. The Range Correction, Total Range, and Range K are used to compensate for nonstandard conditions, and represent the aimpoint which must be used to cause the round to cross the Diagram Range.) **VI is expressed to the nearest whole meter**.
10	Compute and record Site to the Diagram Range. Use the GST from the head of the projectile family whenever possible. Site is expressed to the nearest whole mil.
11	Determine the Elevation from Table C (base ejecting) or TFT/GFT (bursting), and record it. (Note: When utilizing Range K, a GFT Setting will not be used to determine Elevation, as Range K represents total corrections, and to use a GFT setting as well would double the effects of those corrections). If a GFT Setting has been applied, place the MHL on the Entry Range and determine the Elevation from the Elevation Gauge Line on the GFT and record it. **Elevation is expressed to the nearest whole mil.**
12	Compute the Quadrant Elevation and record it. Quadrant Elevation is the algebraic sum of Elevation and Site. Quadrant Elevation is expressed to the nearest whole mil.
13	Determine and record the minimum fuze setting for MTSQ/ET fuzes. These fuze settings correspond to the Entry Range and are extracted from Table C (base ejecting) or TFT/GFT.
	Note: Minimum Fuze Settings are only determined for minimum range lines, and may be computed for separate minimum fuze range lines. If a GFT Setting has been applied, utilize the procedures from Appendix F to determine the Fuze Setting at the adjusted elevation**. Fuze Settings are expressed to the nearest tenth of a second.**
14	Determine and record the Time of Flight corresponding to the entry range from Table C, (base ejecting) or TFT/GFT. If a GFT Setting has been applied, utilize the procedures from Appendix F to determine the TOF at the adjusted elevation. **Time of Flight is expressed to the nearest tenth of a second.**
15	Determine the minimum fuze setting for VT fuzes. Add 5.5 seconds to the time of flight, and express to the next higher whole second. The VT fuze is designed to arm 3.0 seconds before the time set. They have been known to arm up to 5.5 seconds before the time set. That is why this value is added and always expressed up to the next whole second.
	Note: Minimum Fuze Settings are only determined for minimum range lines, and may be computed for separate minimum fuze range lines. If a GFT Setting has been applied, utilize the procedures from Appendix F to determine the TOF at the adjusted elevation. Add 5.5 seconds to the TOF and express the value to the next higher second. **VT Fuze Settings are expressed up to the next higher whole second.**
16	Determine and record Drift corresponding to the Entry Range from Table C (base ejecting) or TFT/GFT. Drift is applied to the Basic Safety Diagram by following the “least left, most right” rule. The lowest (least) drift is applied to all left deflection limits, and the highest (greatest) drift is applied to all right deflection limits. If a GFT Setting has been determined, the GFT Deflection Correction must be applied to all deflection limits. **Drift is expressed to the nearest whole mil**.
17	Ensure computations are verified by a second safety-certified person. See figure 15-4 on page 15-12 for a completed safety matrix example.
18	On the bottom third of the sheet of paper, record the data on the Safety T.
Legend: GFT – graphical firing table MTSQ – mechanical time super quick TFT – tabular firing table TOF – time of flight VI – vertical interval VT – variable time WP – white phosphorus	

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
DIAGRAM RG	+ RG CORR	= TOT RG	x RG K	= ENTRY RG	CHG	VI	SI	+ EL	= QE	MTSQ/ ET	TOF	+ 5.5	= VT	DFT

(a) This is the minimum or maximum range from the basic safety diagram.

(b) This is the range correction for nonstandard conditions from Table F, if required. Used typically for initial safety or corrections for nonstandard conditions not included in the GFT Setting or Range K factor in column (d), such as WP [] weight. Examples of nonstandard conditions accounted for in (b) include, but are not limited to, difference in projectile square weight, difference in muzzle velocity, or any nonstandard condition accounted for prior to determining a GFT Setting or Range K factor. If there is no change from standard, or all nonstandard conditions are accounted for in the GFT Setting or Range K factor, this value is zero (0). To determine a range correction from Table F, use the following formula:

RANGE CHG	NONSTANDARD CONDITION	-	STANDARD CONDITION	=	CHANGE IN STANDARD	x	RG CORR FACTOR	=	RANGE CORRECTION

I This is the algebraic sum of the Diagram Range and the Range Correction. If there is no range correction, then the Total Range will be the same as the Diagram Range.

(d) This is the Range K factor determined by using Technique 2, Appendix G, Page G-5 in the TC 3-09.81. This is for updated safety. It represents total corrections for a registration, MET + VE, or other subsequent MET technique. It represents all nonstandard conditions (unless a separate nonstandard condition such as change in square weight for WP is listed separately in column (b)). It is multiplied times the Total Range to determine Entry Range. If there is no Range K, enter 1.0000.

(e) This is the product of the Total Range multiplied by the Range K factor. If there is no Range K factor, then the Entry Range will be the same as the Total Range. Entry Range is the range for which Elevation, Time Fuze Settings, Time of Flight and Drift are determined.

(f) This is the charge from the range safety card for this set of safety computations.

(g) This is the Vertical Interval from the basic safety diagram.

(h) This is the site determined to the Diagram Range by using the GST or TFT from the head of the projectile family; e.g., site for the M110 WP projectile is determined with the AM-3 and M825 site is computed using the AR-2. Site is computed to the Diagram Range, as that is where the Vertical Intervals are determined.*

(i) This is the elevation from Table C (base ejecting) or GFT/TFT (bursting).*

(j) This is the algebraic sum of Elevation and Site. It is the minimum or maximum Quadrant Elevation corresponding to the Minimum or Maximum Range.

(k) This is the Minimum Fuze Setting for a Mechanical Time/Super Quick (MTSQ) or Electronic Time (ET) fuze from Table C (base ejecting), or GFT/TFT (bursting), corresponding to the Entry range. */** (NOTE: This column can be used to also compute for M564/M565 MT Fuzes, care must be taken to annotate whether MTSQ/ET or MT Fuze Settings are determined.)

(l) This is the Time of Flight from Table C (base ejecting), or GFT/TFT (bursting), corresponding to the Entry Range. */**

(m) This is the safety factor applied to the Time of Flight to determine VT fuze data. **

(n) This is the sum of TOF + 5.5. It is the Minimum Fuze Setting for M728/M732 VT fuzes. **

(o) This is the Drift corresponding to the Entry Range from Table C (base ejecting), or GFT/TFT (bursting). Drift is applied to the basic safety diagram by using the "Least, Left; Most Right, "rule. The "least" or lowest drift is applied to all left deflection limits, and the "most" or greatest drift is applied to all right deflection limits.

* - See Table 15-4 on page 15-13 to determine the correct source table or addendum for computations.

** - Computed only for minimum Entry Ranges, and only if applicable to the ammunition and the range safety card.

Figure 15-3. Low Angle Safety Matrix.

4 [] HE Low Angle Chg 1L

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= VT	DFT
3900	+	0	=	3900	X	1.0000	=3900	1L	+23	+6	+233	=239	--	14.0	+19.5	= 20.0	L5
4000	+	0	=	4000	X	1.0000	=4000	1L	--	--	+--	=--	14.4	--	+--	= --	--
5700	+	0	=	5700	X	1.0000	=5700	1L	-15	-3	+377	=374	--	--	+--	= --	--
6800	+	0	=	6800	X	1.0000	=6800	1L	-25	-5	+496	=491	--	--	+--	= --	L12

UNK [] WP Low Angle Chg 1L (assume worse case)

RANGE	CHG	NONSTANDARD CONDITION	-	STANDARD CONDITION	=	CHANGE IN STANDARD	X	RG CORR FACTOR	=	RANGE CORRECTION
3900	1L	8[]	-	4[]	=	I 4[]	X	+27	=	+108 ~ +110
4000	1L	8[]	-	4[]	=	I 4[]	X	+27	=	+108 ~ +110

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= VT	DFT
3900	+	+110	=	4010	X	1.0000	=4010	1L	+23	+6	+240	=246	--	--	+--	= --	--
4000	+	+110	=	4110	X	1.0000	=4110	1L	--	--	+--	=--	14.8	--	+--	= --	--

Legend: CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-4. Completed Low Angle Safety Matrix, HE/WP.

SAFETY T

15-34. The Safety T is a convenient method of arranging safety data and is used to verify the safety of fire commands (figure 15-5, page 15-13). The information needed by the FDO, XO, or platoon leader, and section chief is organized in an easy to read format. The Safety T is labeled with a minimum of firing point location, charge, projectiles(s), fuze(s), angle of fire, and AOL. Other optional entries are subject to unit SOP. Any time new safety data are determined, new Safety Ts are constructed and issued only after the old Safety Ts have been collected (that is, after a move or after a registration or MET + VE). Use only one charge per Safety T. (Note: The examples in this demonstrate which data is transferred from the Safety Matrix to the Safety T. This data is in bold type in the matrix and the associated Safety T).

15-35. It is the FDO's responsibility to ensure that all data transmitted from the FDC is within the limits of the Safety T. It is the section chief's responsibility to ensure that all data applied to the ammunition or howitzer is within the limits of the Safety T. The FDO must ensure that deflection to fire is between the deflections listed on the Safety T. He then must determine if the quadrant elevation corresponding to that deflection is between the minimum and maximum QE on the Safety T. Finally, he must ensure that the fuze setting is equal to or greater than the minimum fuze setting listed on the Safety T for the specific fuze type.

Note: A reproducible copy of DA Form 7353 (Universal Safety T) is included at the end of this manual, in the reproducible forms section.

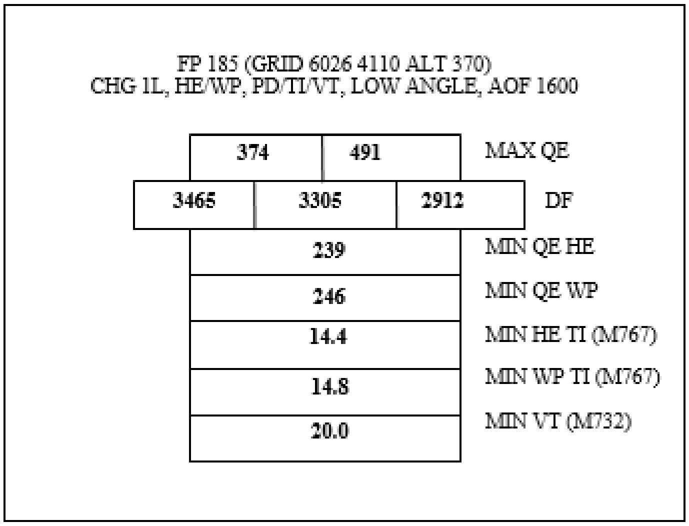


Figure 15-5. Example of a Completed Safety T.

Table 15-4. Tables and Addendums Required for Safety Computations.

Weapon System	***Safety Required for***	***Base Projectile***	***Firing Table for Base Projectile***	***Firing Table Addendum***
M119 A2/A3	M314	HE	105-AS-3	N/A
	M915	HE	105-AS-4	ADD-G-1
M198/	M485	M107	155-AM-2	Separate Tbl C
M109A4/A5/A6	M449	M107	155-AM-2	ADD-I-2
M777A2	M483A1	M107	155-AM-2	ADD-R-2
	M483A1	M107	155-AM-3	ADD-R-3
	M483A1	DPICM	155-AN-2	ADD-J-2
	M825/M825A1	M107	155-AM-2	ADD-T-1
	M825/M825A1	M107	155-AM-3	ADD-T-2
	M825/M825A1	DPICM	155-AN-2	ADD-Q-1 w/ch2
	M825/M825A1	M795	155-AR-2	ADD-AD-1
	M692/M731	DPICM	155-AN-2	ADD-L-2
	M692/M731	M795	155-AR-2	ADD-AB-1
	M718/M741	DPICM	155-AN-2	ADD-N-2
Legend: DPICM – dual-purpose improved conventional munition HE – high explosive				

UPDATING SAFETY DATA AFTER DETERMINING A GFT SETTING

15-36. After a GFT setting is determined (result of registration or Subsequent MET application), the FDO must determine if new safety data must be computed (see table 15-5 on page 15-15). The GFT setting represents all nonstandard conditions in effect at the time the GFT setting was determined (Chapter 10 and 11 discuss Total Corrections in detail). The effect on safety is that the data determined before the GFT setting was determined no longer represent the target area, and could result in an unsafe condition if not applied to safety computations. In order to update safety, new elevations are determined which correspond to the minimum and maximum ranges. Deflections are modified by applying the GFT deflection correction to each lateral limit. Minimum fuze settings are also recomputed. The basic safety diagram drawn in red on the firing chart **does not change**. It was recorded on the basis of azimuths and ranges derived from Surface Danger Zones determined via Range Control or higher, and it represents the actual target area limits.

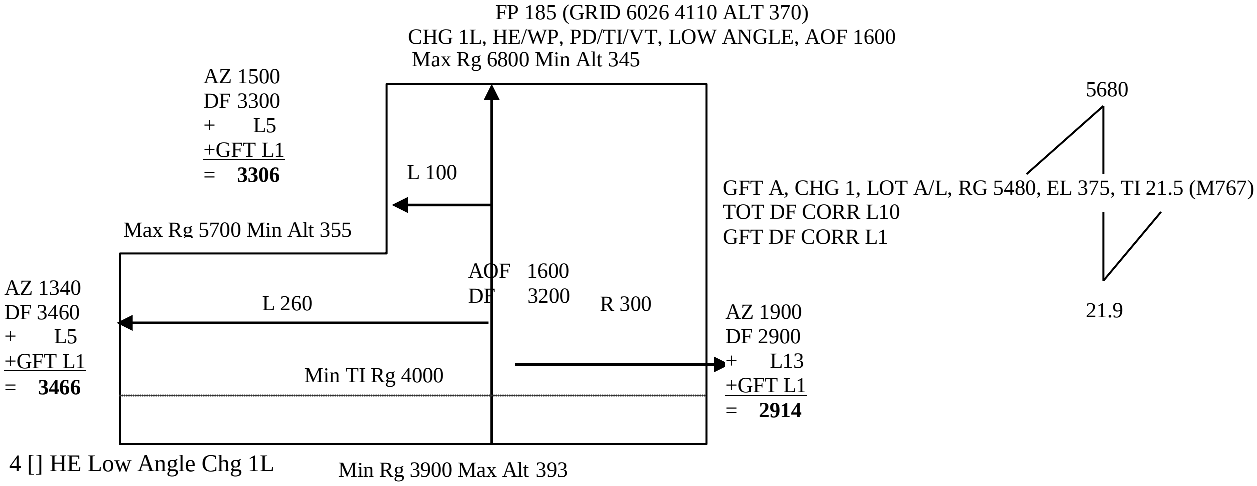
15-37. There are two techniques which can be used to update safety computations: The Range K Method and Applying a GFT setting to a GFT. Both methods use the same safety matrices, and apply to both low and high angle fire. The preferred technique for updating safety is to apply a GFT setting to the appropriate GFT. Unfortunately, not all munitions have associated GFTs. Application of Total Corrections is the same as for normal mission processing. The Total Corrections, in the form of a GFT setting or Range K, must be applied in accordance with the data on which they were determined (i.e., the GFT setting for a M107 registration applies to all projectiles in the M107 family, while a MET + VE for M795 would apply to all projectiles in the M795 family). Using Subsequent MET applications, a GFT Setting for the head of a projectile family utilizing graze burst data may be used to determine total corrections for all projectiles in that particular family. The principle difference between the two techniques is the manner in which minimum fuze setting is determined.

15-38. Determining Minimum Fuze Setting with a GFT with a GFT Setting Applied: When a GFT setting is applied and a fuze setting is to be determined, it is extracted opposite the Time Gauge Line (if it is the fuze listed on the GFT setting) or as a function of elevation (for all others). Use the procedures in table 15-3 (page 15-9) to update safety using a GFT with a GFT setting applied.

15-39. Determining Fuze Setting using the Range K Technique: **In order to simplify updating safety, the Range K technique determines all fuze settings as a function of elevation.** The difference between registered fuze settings and fuze settings determined using the Range K technique in actual firings and computer simulations varies by only zero to two tenths (0.0 – 0.2) of a Fuze Setting Increment/Second. The safety requirements in the DA PAM 385-63 and incorporation of Minimum Fuze Setting Range Lines adequately compensate for the difference in computational techniques. Figure 15-7 on page 15-17 demonstrates how to update safety when no GFT is available, utilizing the Range K technique. Use the procedures in table 15-3 on page 15-9 (Low Angle) or Table 15-8 on page 15-24 (High Angle) to update safety using the Range K method. Figure 15-8 on page 15-18 demonstrates how to compute low angle illumination safety and figure 15-9 on page 15-19 demonstrates how to update illumination safety when no GFT is available, utilizing the Range K technique.

Table 15-5. Determination for Updating Safety Based on Updated Non-Standard Conditions.

STEP	*ACTION*		
1	The FDO must be able to account for all 5 Requirements that weren't previously accounted for in the old safety. In manual mission processing, this is performed thru an updated GFT Setting.		
2	Perform a safety verification mission with the Base Piece location. For **LOW ANGLE:** Determine data from the base piece to the **UPPER RIGHT CORNER** of the target area (Maximum right deflection at the maximum range). For **HIGH ANGLE**: Determine data from the base piece to the **LOWER RIGHT CORNER** of the target area (Maximum right deflection at the minimum range).		
3	Compare the 'new' quadrant to the 'old' quadrant: If there is a change in quadrant that causes a change of 100 meters or 4-Per (whichever is greater) in the target area then new safety is required.		
	EXAMPLE: HE LOW ANGLE, CHARGE 3H (M232A1), Maximum Range 13500 Meters		
	OLD MAXIMUM QE = 529		NEW MAXIMUM QE = 539
	EXAMPLE	529 -539 ∆ 10 MILS	Now that the change in mils between the two quadrant elevations has been determined, the change in range for every 1 mil in elevation must be determined.
4	Determine the change in range for the change in quadrant.		
	EXAMPLE	∆ 10 MILS X 11M = 110 M	Enter the TFT-AM-3; CHARGE 3H (M232A1); TABLE F, COLUMN 5 to determine the change in range for every 1 mil change in elevation. (I.E. Range 13500 = 11 M). **THE ∆QE IS GREATER THAN 100 METERS WHICH MAY REQUIRE UPDATING SAFETY IF THE ∆QE IS GREATER THEN 4PER**
5	Determine the value of 4 Probable Errors in Range.		
	EXAMPLE	4 X 33 = 132 ~130 M	Enter the TFT-AM-3; CHARGE 3H (M232A1); TABLE G, COLUMN 3 to determine the probable errors in range. (I.E. Range 13500 = 33 M). **THE CHANGE IN QUADRANT CHANGES THE RANGE BY 110 METERS, WHICH IS LESS THAN 130 METERS (4 PER) THEREFORE THE QUADRANT DOESN'T REQUIRE THE SAFETY TO BE UPDATED.** **THE FDO SHOULD UPDATED SAFETY IF THE CHANGE IN RANGE IS GREATER THEN 4-PER.**
6	Compare the 'new' deflection to the 'old' deflection: If the change in deflection causes a change of 100 meters or greater in the target area then new safety is required.		
	EXAMPLE: HE LOW ANGLE, CHARGE 3H (M232A1), Maximum Range 13500 Meters		
	OLD DEFLECTION RIGHT DF = 2917		NEW DEFLECTION RIGHT DF = 2923
	EXAMPLE	2923 -2917 ∆6 Mils	Determine the change in mils from the new to the old, use the mil-relation formula to determine the distance that the change will cause in the target area.
		∆6 Mils X 13.500 1.0186 = 79.5 M ~80 M	**SINCE THE 80-METERS IS LESS THAN 100-METERS THERE IS NO NEED TO UPDATE SAFETY BASED ON THE ∆DF**. THE FDO SHOULD UPDATE SAFETY IF THE ∆DF CAUSES A ∆ GREATER THEN 100-METERS.
Legend: DF – deflection FDO – fire direction officer GFT – graphical firing table HE – high explosive PER – probable errors in range QE – quadrant elevation TFT – tabular firing table			



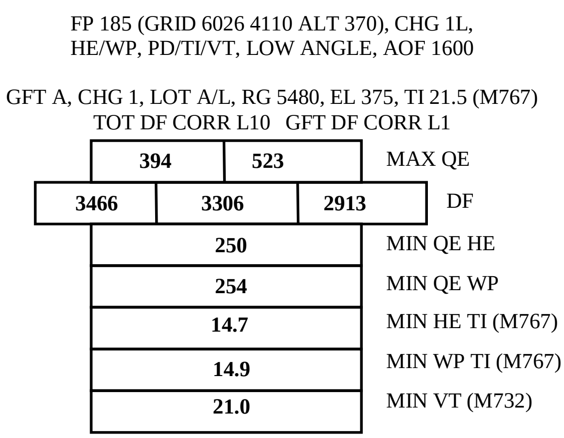
4 [] HE Low Angle Chg 1L

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= VT	DFT
3900	+	0	=	3900	X	1.0000	=3900	1L	+23	+6	+244	=250	--	14.6	+20.1	= 21.0	L5
4000	+	0	=	4000	X	1.0000	=4000	1L	--	--	+--	=--	14.7	--	+--	= --	--
5700	+	0	=	5700	X	1.0000	=5700	1L	-15	-3	+397	=394	--	--	+--	= --	--
6800	+	0	=	6800	X	1.0000	=6800	1L	-25	-5	+528	=523	--	--	+--	= --	L13

6 [] WP Low Angle Chg 1L

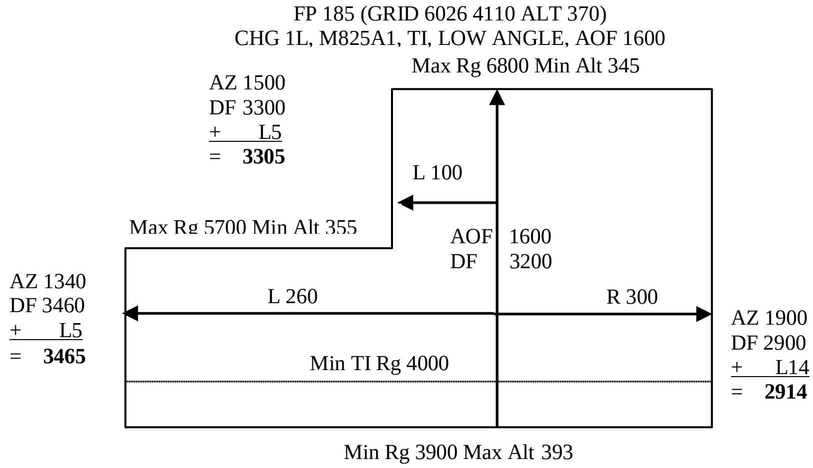
RANGE	CHG	NONSTANDARD CONDITION	-	STANDARD CONDITION	=	CHANGE IN STANDARD	X	RG CORR FACTOR	=	RANGE CORRECTION
3900	1L	6 []	-	4 []	=	I 2 []	X	+27	=	+54 ~ +50
4000	1L	6 []	-	4 []	=	I 2 []	X	+27	=	+54 ~ +50

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= VT	DFT
3900	+	+50	=	3950	X	1.0000	=3950	1L	+23	+6	+248	=254	--	--	+--	= --	--
4000	+	+50	=	4050	X	1.0000	=4050	1L	--	--	+--	=--	14.9	--	+--	= --	-



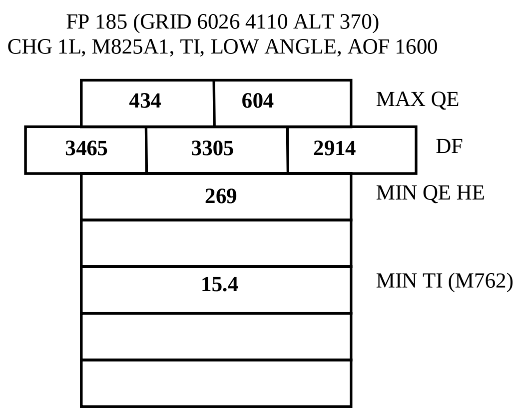
Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-6. Updated Low Angle Safety, GFT Setting Applied, HE/WP.



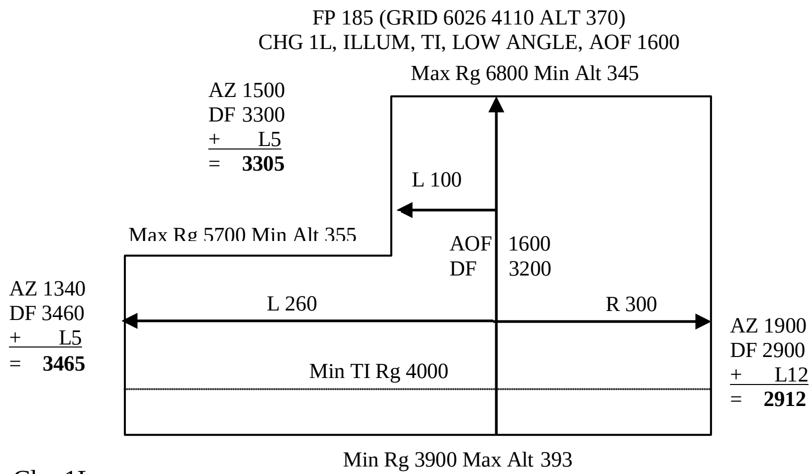
M825A1 Low Angle Chg 1L

DIAGRAM RG	+ RG CORR	= TOT RG	X RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= VT	DFT
3900	+ 0	= 3900	X 1.0000	=3900	1L	+23	+7	+262	=269	--	--	+--	= --	L5
4000	+ 0	= 4000	X 1.0000	=4000	1L	--	--	+--	=--	15.4	--	+--	= --	--
5700	+ 0	= 5700	X 1.0000	=5700	1L	-15	-3	+437	=434	--	--	+--	= --	--
6800	+ 0	= 6200	X 1.0000	=6200	1L	-25	-6	+613	=604	--	--	+--	= --	L14



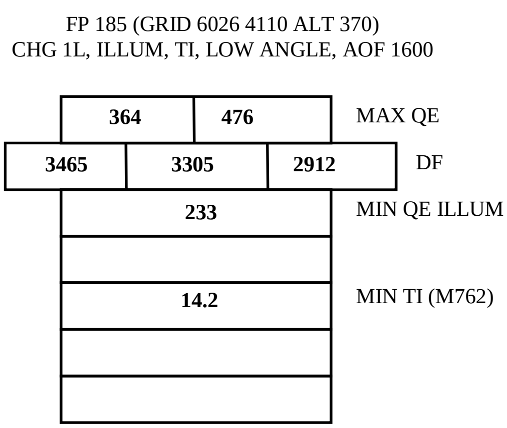
Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

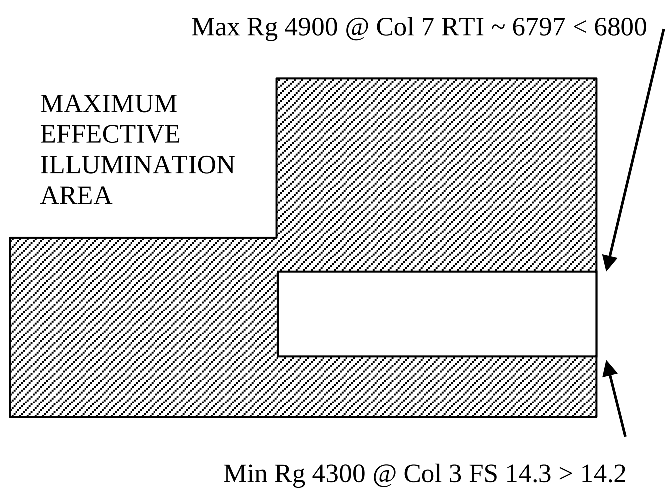
Figure 15-7. Example of Low Angle Safety Utilizing ADD-AD-1, M825A1.



ILLUM Low Angle Chg 1L

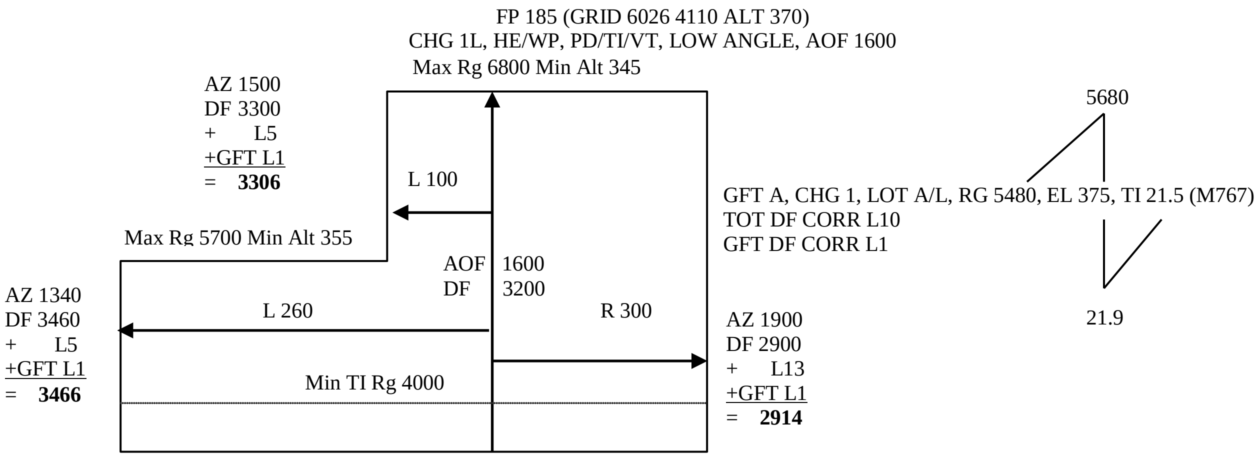
DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	=	M728/ M732	DFT
3900	+	0	=	3900	X	1.0000	=3900	1L	+23	+6	+227	=233	--	--	+--	=	--	L5
4000	+	0	=	4000	X	1.0000	=4000	1L	--	--	+--	=--	14.2	--	+--	=	--	--
5700	+	0	=	5700	X	1.0000	=5700	1L	-15	-3	+367	=364	--	--	+--	=	--	--
6800	+	0	=	6200	X	1.0000	=6200	1L	-25	-5	+481	=476	--	--	+--	=	--	L12





Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-8. Example of Initial Low Angle Safety, Shell Illum.



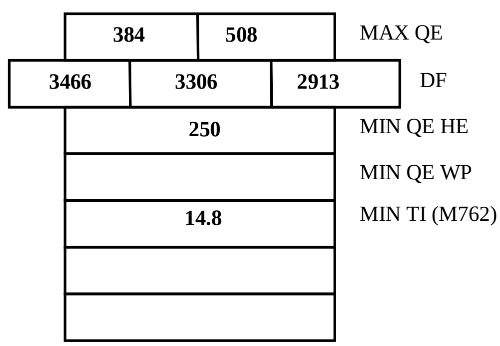
$$RG\ K = \frac{Range\ @\ ADJ\ EL}{Achieved\ Range} = \frac{5680}{5480} = 1.0365$$

4 [] HE Low Angle Chg 1L

DIAGRAM RG	+ RG CORR	= TOT RG	X RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= M728/ M732	DFT
3900	+ 0	= 3900	X 1.0365	=4040	1L	+23	+6	+236	=242	--	--	+--	= --	L5
4000	+ 0	= 4000	X 1.0365	=4150	1L	--	--	+--	=--	14.8	--	+--	= --	--
5700	+ 0	= 5700	X 1.0365	=5910	1L	-15	-3	+387	=384	--	--	+--	= --	--
6800	+ 0	= 6200	X 1.0365	=7050	1L	-25	-5	+513	=508	--	--	+--	= --	L13

FP 185 (GRID 6026 4110 ALT 370), CHG 1L,
ILLUM, TI, LOW ANGLE, AOF 1600

GFT A, CHG 1, LOT A/L, RG 5480, EL 375, TI 21.5 (M767)
TOT DF CORR L10 GFT DF CORR L1



Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-9. Example of Low Angle Safety with Range K, Shell Illum.

15-40. Figure 15-10 illustrates a range safety card for low angle safety with a muzzle velocity correction while figure 15-11 (page 15-21) demonstrates the low angle safety computations with a muzzle velocity correction.

RANGE SAFETY CARD

UNIT: **A 1-30** SCHEDULE DATE IN: **05/30/13** SCHEDULE DATE OUT: **05/30/13**
TIME IN: **0600** TIME OUT: **2359**

FIRING POINT: 198 (8673 0036 ALT:854.9) IMPACT AREA: S. CARLTON IMPACT
WEAPON: M777A2 (155MM) Ammunition M107, M110, M739A1, M767, M732

TYPE OF FIRE **LOW ANGLE**

Direction Limits (REF GN): LEFT: 5000 MILS RIGHT: 5900 MILS AOL:

Low Angle PD Minimum Range:	**6900**	METERS	Min Charge	2L
Fuze TI Range and High Angle Minimum Range:	**6900**	METERS	Min Charge	2L
To Establish MIN Time for Fuze VT Apply +5.5 seconds to the Low Angle PD Min RG				
Maximum Range to Impact:	**9000**	METERS	Max Charge	2L

COMMENTS

NONE

SPECIAL INSTRUCTIONS

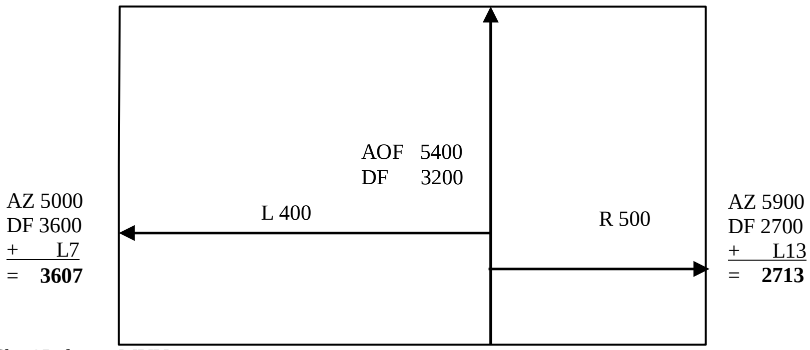
1. UN-CLEARED AMMUNITION (FUZES, PROJECTILES, POWDER) WILL NOT BE USED UNLESS CLEARANCE IS GIVEN BY RANGE CONTROL.
2. WHEN SHOOTING FUZE M564 IN PD MODE THE SETTING WILL BE 90.0 NO MATTER WHAT THE MANUFACTURED DATE.

RANGE	**MIN ALT**	**MAX ALT**
6900M	850M	900M
9800M	825M	1020M

Legend: ALT – altitude AOF – azimuth of fire AZ – azimuth CHG – charge DF – deflection FP – firing point HE – high explosive PD – point detonating RG – range TI – time VT – variable time WP – white phosphorous

Figure 15-10. Range Safety Card for Low Angle Safety with a Muzzle Velocity Correction, Shell HE/WP.

FP 198 (GRID 8673 0036 ALT 855)
CHG 2L, HE/WP, PD/TI/VT, LOW ANGLE, AOF 5400
Max Rg 9800 Min Alt 825



Min Rg 6900 Max Alt 900

Range Correction for Chg 2L due to MVV

RANGE	CHG	NONSTANDARD CONDITION	-	STANDARD CONDITION	=	CHANGE IN STANDARD	X	RG CORR FACTOR	=	RANGE CORRECTION
6900	2L	+1.0 m/s	-	0 m/s	=	I 1.0 m/s	X	-18.1	=	-18.1 ~ -20
9800	2L	+1.0 m/s	-	0 m/s	=	I 1.0 m/s	X	-21.2	=	-21.2 ~ -20

4 [] HE Low Angle Chg 2L

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= M728/ M732	DFT
6900	+	-20	=	6880	X	1.0000	=6880	2L	+45	+7	+274	=281	21.1	21.1	+26.6	= 27.0	L7
9800	+	-20	=	9780	X	1.0000	=9780	2L	-30	-4	+473	=469	--	--	+--	= --	L13

UNK [] WP Low Angle Chg 2L (assume worse case)

RANGE	CHG	NONSTANDARD CONDITION	-	STANDARD CONDITION	=	CHANGE IN STANDARD	X	RG CORR FACTOR	=	RANGE CORRECTION
6900	2L	8[]	-	4[]	=	I 4[]	X	+20	=	+80 + (-18.1) = +61.9 ~ +60

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	SI	+EL	=QE	MTSQ/ ET	TOF	+5.5	= M728/ M732	DFT
6900	+	+60	=	6960	X	1.0000	=6960	2L	+45	+7	+279	=286	21.4	--	+--	= --	--

FP 198 (GRID 8673 0036 ALT 825)
CHG 2L, HE/WP, PD/TI/VT, LOW ANGLE, AOF 5400

469		MAX QE
3607	**2713**	DF
281		MIN QE HE
286		MIN QE WP
21.1		MIN HE TI (M767)
21.4		MIN WP TI (M767)
27.0		MIN VT (M732)

Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-11. Example of Low Angle Safety with a Muzzle Velocity Correction.

DETERMINATION OF MAXIMUM EFFECTIVE ILLUMINATION AREA

15-41. All illumination safety data are for graze burst. Therefore, when illumination fire mission data are computed, the QE determined includes the appropriate HOB. This will prevent achieving a 600 meter HOB (750 meter HOB for 105 mm) at the minimum and maximum range lines. Before processing an illumination fire mission, it is beneficial to determine the maximum effective illumination area for the current range safety card. This area should be plotted on the firing chart to help determine if illumination can be fired and to inform Forward Observers where they can fire illumination safely effectively. This area will always be significantly smaller than the HE safety area. See table 15-6 for steps outlining the general procedure. This area can be increased by computing High Angle illumination safety data.

Note: The procedures used to determine the Maximum Effective Illumination Area can be used to for all expelling charge munitions to depict their Maximum Effective Engagement Area as well as determining an Engagement Area for VT fuzes.

Table 15-6. Procedures to Determine Maximum Effective Illumination Area.

STEP	***ACTION***
1	Enter the TFT, Part 2, Table A, Column 7 (RTI) with the nearest range listed without exceeding the maximum diagram range from the range safety card.
	Note: With 105mm Illumination, one must enter the TFT, Part 2, Table A, Column 6 in order to determine Range to Impact (RTI).
2	Determine the corresponding range to target in Column 1. This is the maximum range the unit can achieve a 600 meter (155mm) HOB and keep the projectile in the target area if the fuze fails to function.
3	Determine the minimum range for which a 600 meter (155 mm) HOB is achieved and have the fuze function no earlier than the minimum range line. Enter the TFT, Part 2, Table A, Column 3, with the nearest listed FS that is not less than the determined minimum FS determined from the minimum diagram range line or minimum diagram fuze range line from the range safety card. Column 3 is the Fuze Setting for the M565 Fuze, so if M577 is to be used, the fuze setting must be corrected by using Table B.
4	Determine the corresponding range to target in Column 1. This is the minimum range the unit can achieve a 600 meter (155mm) HOB and keep the functioning of the fuze within the safety box.
5	The area between these two lines is the maximum effective illumination area where a 600 meter HOB (155mm) is achieved, the fuze functions no earlier than the minimum range line, and the round does not exceed the maximum range line if the fuze fails to function. Note: High Angle fire produces a much greater effective illumination area. The FDO must use Part 2, Table A, Column 6, Range to Fuze Function, to determine the minimum effective illumination range line in order to ensure the fuze functions within the target area. This is performed by determining from Column 6 a Range to Fuze Function greater than the Minimum High Angle Range Line(s) on the Range Safety Card and then determining a range from Column 1. The maximum effective illumination range line is determined by using Column 7 and determining a Range to Impact that is less than the Maximum High Angle Range Line(s) on the Range Safety Card and then determining a range from Column 1.
	Note: Maximum Effective Illumination Area is computed from initial safety data and only needs to be determined once. The ranges determined will represent the physical limitations that can be recorded on the FDO's situation map to assist in the determination of high or low angle illumination fires.
Legend: FDO – fire direction officer FS – fuze setting HOB – height of burst mm – millimeter RTI – range to impact TFT – tabular firing table	

SAFETY CONSIDERATIONS FOR M549/M549A1 RAP

15-42. RAP safety data are computed using the Low Angle Safety or High Angle Safety matrix, as appropriate. The only difference is that a safety buffer must be incorporated for rocket failure or rocket cap burn through. For firing in the Rocket-Off Mode, a 6000 meter buffer (4000 meters for 105mm) must be constructed beyond the maximum range line to preclude the projectile exceeding the maximum range line. For firing in the Rocket-On Mode, a 6000 meter buffer (4000 meters for 105mm) must be constructed short of the minimum range line to preclude the projectile falling short of the minimum range line. These safety buffers will be incorporated into the construction of the Surface Danger Zone.

SAFETY CONSIDERATIONS FOR M864 BASE BURN DPICM/M795A1 BASE BURN HE

15-43. Base Burn safety data are computed using the Low Angle Safety or High Angle Safety matrix, as appropriate. The only difference is that a safety buffer must be incorporated for Base Burn Element Failure. A 5000 meter buffer must be constructed short of the minimum range line to preclude the projectile falling short of the minimum range line. These safety buffers will be incorporated into the construction of the Surface Danger Zone.

COMPUTATION OF HIGH ANGLE SAFETY

15-44. The safety data for high angle fire is computed in much the same manner as that for low angle fire except for the ballistic variations caused by the high trajectory. Site is computed differently (by using the 10 mil Site Factor and the Angle of Site/10), and mechanical or electronic fuze settings are not determined. (Note: It is the FDO’s responsibility to ensure that all High Angle Fuze Settings will cause the fuze to function within the safety box). Table 15-8 on page 15-34 contains the steps required for computation of High Angle Safety.

15-45. Use the steps outlined in table 15-7 and in the matrix in figure 15-12 (page 15-26) as examples for organizing computations. The High Angle Safety Matrix is used for all munitions. The data are determined by either graphical or tabular firing tables. In the case of expelling charge munitions, the Safety Table located in the Firing Tables or Firing Table Addendums is utilized to determine Elevation, Time of Flight, Fuze Setting, and Drift. (Note: The Safety Tables which are used to compute the High Angle examples are located after the Low Angle Safety examples). Use artillery expression for all computations except where noted.

Table 15-7. High Angle Procedures.

STEP	***ACTION***
1	On the top third of a blank sheet of paper, construct the basic safety diagram in accordance with the range safety card. (See Table 15-1, page 15-5 for procedures)
2	In the middle third of the sheet of paper, construct the High Angle Safety Matrix (Figure 15-12, page 15-26)
3	Record the Diagram Ranges from the basic safety diagram.
4	Enter the Range Correction, if required. This range correction is only necessary if a nonstandard condition exists which requires a change in aimpoint and is not already accounted for in a GFT setting, such as correcting for the always heavier than standard White Phosphorous projectile. See figure 15-12, paragraph (b) to determine range correction. **If a range correction is required, it is artillery expressed to the nearest 10 meters. If no range correction is required, enter 0 (zero).**

Table 15-7. High Angle Procedures (continued).

STEP	***ACTION***
4a	A Range Correction may be necessary before determining data for particular projectile when the cannon tube to be fired is not the base cannon tube for the TFT for which safety data is to be determined. If this is the situation, a Range correction due to muzzle velocity differences between cannon tubes must be applied throughout the Safety Matrix. For example, if firing Charge 2L from a M777A2, a range correction must be applied to compensate for the +1 m/s muzzle velocity difference between the M284 cannon tube (base tube for AM-3) and the M776. This muzzle velocity variation will also have to be algebraically added to the range correction for WP as well to determine WP safety data.
5	Determine the Total Range. Total range is the algebraic sum of the Diagram Range and the Range Correction. **Total Range is expressed to the nearest 10 meters**.
6	Enter the Range K. Range K is only required if a GFT setting has been obtained but cannot be applied to a GFT (i.e., determining Illumination safety with a HE GFT setting). Range K is simply the Total Range Correction from the GFT setting expressed as a percentage. This percentage, when multiplied by the Total Range, produces the Entry Range. **If no GFT setting is available (i.e., initial safety), then enter 1.000 as the Range K. If a GFT setting is available, (i.e., updated safety), then enter the Range K expressed to four decimal places (i.e., 1.1234).**
6a	To determine Range K, divide Range @ Adjusted Elevation by the Achieved Range from the GFT setting: Range @ Adjusted Elevation = Range K (expressed to four decimal places) Achieved Range
6b	If a GFT Setting has been applied to a GFT, Range K will remain 1.0000 as the Elevation Gauge Line represents Range K. If Range K and a GFT Setting were to be used in conjunction with each other, this would double the Range Correction and cause and egregious error.
7	Determine the Entry Range. Multiply the Total Range by Range K to determine the Entry Range. If Range K is 1.0000, then the Entry Range will be identical to the Total Range. **Entry Range is expressed to the nearest 10 meters**.
8	Record the Charge from the range safety card.
9	Following the Mini-Max rule, determine the Vertical Interval by subtracting the unit altitude from the altitude corresponding to the Diagram Range, and record it.
	Note: Diagram Range is used for computations of VI and Site because this is the actual location of the minimum range line. The Range Correction, Total Range, and Range K are used to compensate for nonstandard conditions, and represent the aimpoint which must be used to cause the round to cross the Diagram Range. **VI is expressed to the nearest whole meter.**
10	Determine and record the Angle of Site divided by 10 (∡SI/10) to the Diagram Range. This is performed by dividing the Angle of Site (use the appropriate GST, if possible) by 10. **∡SI/10 is expressed to the nearest tenth of a mil, and has the same sign as the VI.**
11	Determine and record the 10 mil Site Factor from the GFT or TFT which heads the projectile family.
	Note: Use the Diagram Range to compute 10 mil Si Fac. **10 mil Si Fac is expressed to the nearest tenth of a mil and is always negative.**
12	Compute and record Site. Site is the product of ∡SI/10 multiplied by 10 mil Si Factor. Site is artillery expressed to the nearest whole mil.

Table 15-7. High Angle Procedures (continued).

STEP	*ACTION*
13	Determine the Elevation from Table C (base ejecting) or TFT/GFT (bursting), and record it.
	Note: When utilizing Range K, GFT Settings are not used to determine Elevation, as Range K represents total corrections, and to use a GFT setting would double the effects of those corrections. If a GFT Setting has been applied, place the MHL on the Entry Range and determine the Elevation from the Elevation Gauge Line on the GFT and record it. **Elevation is artillery expressed to the nearest whole mil.**
14	Compute the Quadrant Elevation and record it. Quadrant Elevation is the algebraic sum of Elevation and Site. **Quadrant Elevation is artillery expressed to the nearest whole mil.**
15	Determine and record Drift corresponding to the Entry Range from Table C (base ejecting) or TFT/GFT. Drift is applied to the Basic Safety Diagram by following the "left least, right most" rule. The lowest (least) drift is applied to all left deflection limits, and the highest (greatest) drift is applied to all right deflection limits. If a GFT Setting has been determined, the GFT Deflection Correction must be applied to all deflection limits. **Drift is expressed to the nearest whole mil.**
16	Ensure computations are verified by a second safety-certified person.
17	On the bottom third of the sheet of paper, record the data on the Safety T.
Legend: GFT – graphical firing table GST – graphical site table SI – site TFT – tabular firing table VI – vertical interval WP – white phosphorus	

Note: Minimum fuze settings are not computed for High Angle safety. It is the FDO's responsibility to ensure that all fuze settings will cause the projectile to function in the impact area.

15-46. Figures 15-13 through 15-15 on pages 15-27 through 15-29 illustrate examples of high angle safety computations for shells HE/WP, M825A1, and illumination.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(I)	(j)	(k)	(l)	(m)
DIAGRAM RG	RG + CORR	TOT = RG	RG x K	ENTRY = RG	CHG	VI	∡SI/10	X10mil Si Fac	= SI	+ EL	= QE	DRIFT

(a) This is the minimum or maximum range from the basic safety diagram.

(b) This is the range correction for nonstandard conditions from Table F, if required. This is typically for initial safety or corrections for nonstandard conditions not included in the GFT Setting or Range K factor in column (d), such as WP [] weight. Examples of nonstandard conditions accounted for in (b) include, but are not limited to, difference in projectile square weight, difference in muzzle velocity, or any nonstandard condition accounted for prior to determining a GFT Setting or Range K factor. If there is no change from standard, or all nonstandard conditions are accounted for in the GFT Setting or Range K factor, this value is zero (0). To determine a range correction from Table F, use the following formula:

	NONSTANDARD		STANDARD		CHANGE IN		RG CORR		RANGE
RANGE CHG	CONDITION	-	CONDITION	=	STANDARD	x	FACTOR	=	CORRECTION

I This is the algebraic sum of the Diagram Range and the Range Correction. If there is no range correction, then the Total Range will be the same as the Diagram Range.

(d) This is the Range K factor determined by using Technique 2, Appendix G, Page G-5 in the TC 3-09.81. This is for updated safety. It represents total corrections for a registration, MET + VE, or other subsequent MET technique. It represents all nonstandard conditions (unless a separate nonstandard condition such as change in square weight for WP is listed separately in column (b)). It is multiplied times the Total Range to determine Entry Range. If there is no Range K, enter 1.0000.

(e) This is the product of the Total Range multiplied by the Range K factor. If there is no Range K factor, then the Entry Range will be the same as the Total Range. Entry Range is the range for which Elevation, Time Fuze Settings, Time of Flight and Drift are determined.

(f) This is the charge from the range safety card for this set of safety computations.

(g) This is the Vertical Interval from the basic safety diagram.

(h) This is the Angle of Site divided by 10 (∡SI/10), is determined by dividing Vertical Interval by Diagram Range in Thousands. This quotient is then divided by 10 and expressed to the nearest tenth of a mil.

(i) This is the 10 mil Site Factor, determined from the GFT or TFT at the Diagram Range from the head of the projectile family; e.g., if determining safety for MACS charges, 10 mil Site Factor for the M110 WP projectile would be determined with the AM-3, M825 10 mil Site Factor would be computed using the AR-2. *

(j) This is Site, the product of ∡SI/10 X 10 Mil Site Factor (Note: Site is determined for the Diagram Range). *

(k) This is the elevation to impact from Table C (base ejecting), or GFT/TFT (bursting). *

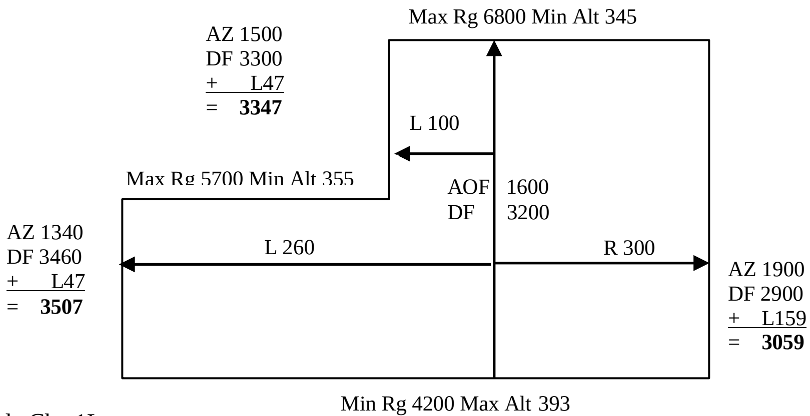
(l) This is the algebraic sum of Elevation and Site. It is the minimum or maximum Quadrant Elevation corresponding to maximum or minimum range.

(m) This is the Drift corresponding to Table C (base ejecting), or GFT/TFT (bursting), Drift is applied to the basic safety diagram by using the "Least, Left; Most, Right;" rule. The "least" or lowest drift is applied to all left deflection limits, and the "most" or greatest drift is applied to all right deflection limits.

* - see Table 15-4 to determine the correct source table or addendum for computations.

Figure 15-12. High Angle Safety Matrix.

FP 185 (GRID 6026 4110 ALT 370)
CHG 1L, HE/WP, PD/TI/VT, HIGH ANGLE, AOF 1600



4 [] HE High Angle Chg 1L

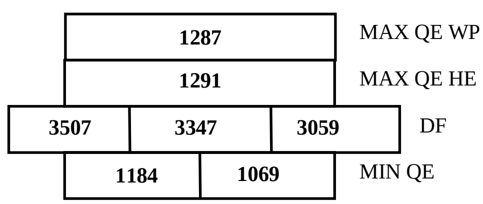
DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	=ENTRY RG	CHG	VI	∡SI/10	X10 mil SI Fac	= SI	+EL	=QE	DFT
4200	+	0	=	4200	X	1.0000	=4200	1L	+23	+0.6	X-0.7	= 0	+1291	=1291	L159
5700	+	0	=	5700	X	1.0000	=5700	1L	-15	-0.3	X-1.8	= +1	+1183	=1184	--
6800	+	0	=	6200	X	1.0000	=6200	1L	-25	-0.4	X-3.7	= +1	+1068	=1069	L47

UNK [] WP High Angle Chg 1L (assume worse case)

RANGE	CHG	NONSTANDARD CONDITION	-	STANDARD CONDITION	=	CHANGE IN STANDARD	X	RG CORR FACTOR	=	RANGE CORRECTION
4200	1L	8[]	-	4[]	=	I 4[]	X	+18	=	+72 ~ +70

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	=ENTRY RG	CHG	VI	∡SI/10	X10 mil SI Fac	= SI	+EL	= QE	DFT
4200	+	+70	=	4270	X	1.0000	=4270	1L	+23	+0.6	X-0.7	= 0	1287	= 1287	--

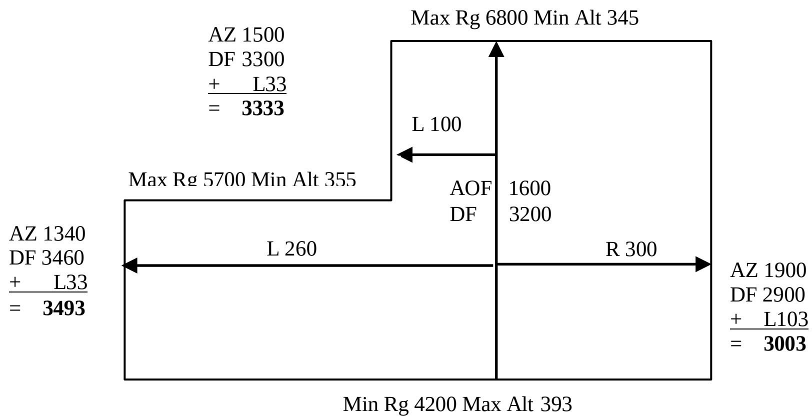
FP 185 (GRID 6026 4110 ALT 370)
CHG 1L, HE/WP, PD/TI/VT, HIGH ANGLE, AOF 1600



Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-13. Example of Initial High Angle Safety, Shell HE/WP.

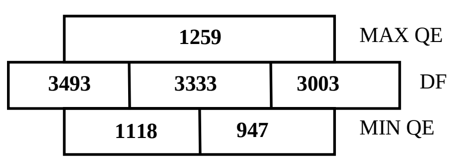
FP 185 (GRID 6026 4110 ALT 370)
CHG 1L, M825A1, TI, HIGH ANGLE, AOF 1600



4 [] M825A1 High Angle Chg 1L

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	=ENTRY RG	CHG	VI	∡SI/10	X10 mil SI Fac	=	SI	+EL	=QE	DFT
4200	+	0	=	4200	X	1.0000	=4200	1L	+23	+0.6	X-1.0	=	-1	+1260	=1259	L103
5700	+	0	=	5700	X	1.0000	=5700	1L	-15	-0.3	X-3.2	=	+1	+1118	=1119	--
6800	+	0	=	6200	X	1.0000	=6200	1L	-25	-0.4	X-7.2	=	+3	+944	=947	L33

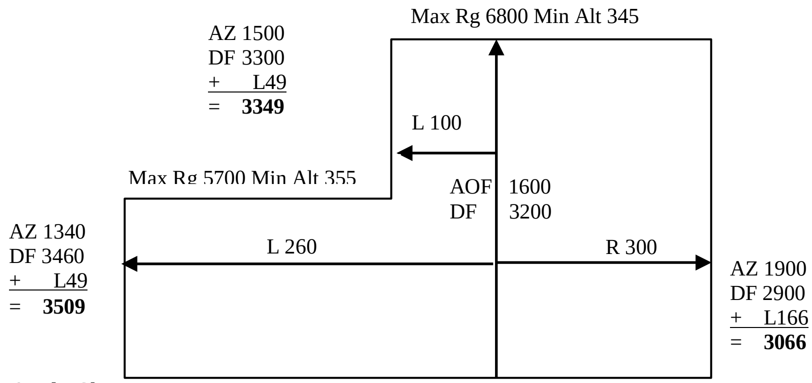
FP 185 (GRID 6026 4110 ALT 370)
CHG 1L, M825A1, TI, HIGH ANGLE, AOF 1600



Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-14. Example of Initial High Angle Safety Utilizing ADD-AD-1, Shell M825A1.

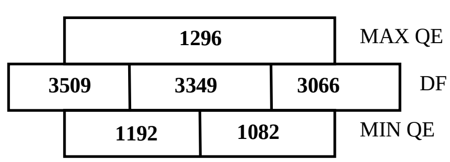
FP 185 (GRID 6026 4110 ALT 370)
CHG 1L, ILLUM, TI, HIGH ANGLE, AOF 1600

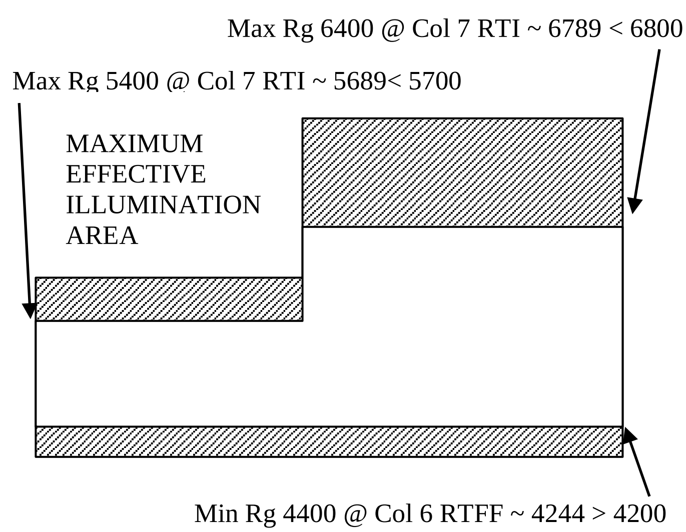


4 [] ILLUM High Angle Chg 1L

DIAGRAM RG	+	RG CORR	=	TOT RG	X	RG K	ENTRY =RG	CHG	VI	∡SI/10	X10 mil SI Fac	=	SI	+EL	=QE	DFT
4200	+	0	=	4200	X	1.0000	=4200	1L	+23	+0.6	X-0.7	=	0	+1296	=1296	L166
5700	+	0	=	5700	X	1.0000	=5700	1L	-15	-0.3	X-1.8	=	+1	+1192	=1193	--
6800	+	0	=	6200	X	1.0000	=6200	1L	-25	-0.4	X-3.7	=	+1	+1082	=1083	L49

FP 185 (GRID 6026 4110 ALT 370)
CHG 1L, ILLUM, TI, HIGH ANGLE, AOF 1600





Legend: AOF – azimuth of fire CHG – charge CORR – correction DFT – drift EL – elevation ET – electronic time HE – high explosive MTSQ – mechanical time super-quick QE – quadrant elevation RG – range SI – site TI – time TOF – time of flight TOT – total UNK – unknown VI – vertical interval VT – variable time WP – white phosphorous

Figure 15-15. Example of Initial High Angle Safety, Shell Illum.

SECTION III: MINIMUM QUADRANT ELEVATION

15-47. The XO or platoon leader is responsible for determining the lowest QE that can be safely fired from his position that will ensure projectiles clear all visible crests (minimum QE).

ELEMENTS OF COMPUTATION

15-48. A minimum quadrant for EACH howitzer is ALWAYS determined. The maximum of these minimum quadrants is the XO's minimum quadrant. Use of the rapid fire tables is the fastest method of computing minimum QE. The QE determined is always equal to or greater than (more safe) than manual computations. Manual computations are more accurate than the rapid fire tables and are used if the sum of the site to crest and the angle needed for a 5-meter vertical clearance is greater than 300 mils. Figure 15-16 on page 15-31 shows the elements of minimum QE.

15-49. **Piece-to-crest range (PCR)** is the horizontal distance between the piece and the crest, expressed to the nearest 100 meters. Procedures for measurement are discussed in paragraph 15-17.

Note: All angles are determined and expressed to the next higher mil.

15-50. **Angle 1** (figure 15-16, page 15-31) is the angle of site to crest measured by the weapons. See paragraph 15-16 for procedures.

15-51. **Angle 2** (figure 15-16, page 15-31) is the vertical angle required to clear the top of the crest. For quick, time, and unarmed Variable Time (VT) fuzes, a vertical clearance of 5 meters is used. For armed VT fuzes, see paragraph 15-19.

15-52. **Angle 3** (figure 15-16, page 15-31) is the complementary angle of site. It is the complementary site factor (TFT, Table G) for the appropriate charge at the piece to crest range multiplied by the sum of angles 1 and 2. Site is the sum of angles 1, 2, and 3.

Note: The entry argument for Table G is PCR. If it is not listed, do not interpolate, use the next higher listed value

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15-53. **Angle 4** (figure 15-16, page 15-31) is the elevation (TFT, Table F) for the appropriate charge corresponding to the PCR.

15-54. **Angle 5** (figure 15-16, page 15-31) is a safety factor equivalent to the value of 2 forks (TFT, Table F) for the appropriate charge at the piece-to-crest range (PCR).

15-55. The sum of angles 1 through 5 (figure 15-16, page 15-31) is the minimum QE for the weapon and the charge computed.

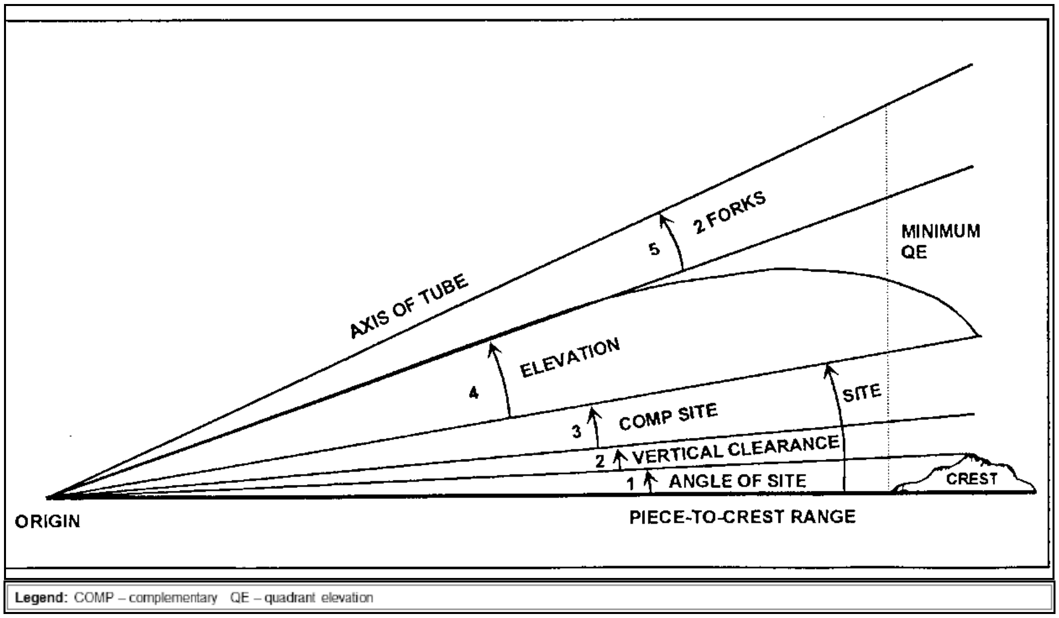

Figure 15-16. Angles of Minimum QE.

MEASURING ANGLE OF SITE TO CREST

15-56. As soon as the piece is "safed", prefire checks conducted, and ammunition prepared, position improvement begins with verification of site to crest as measured by the advance party. There are two procedures to determine angle of site to crest. The first involves the advance party measuring angel of site to crest with an M2 compass or aiming circle. The second involves the section chief measuring the angle of site to crest and reports it to the XO or platoon leader. To measure the angle of site to crest, the section chief sights along the bottom edge of the bore, has the tube traversed across the probable field of fire, and has the tube elevated until the line of sight clears the crest at the highest point. The section chief then centers all bubbles on the elevation mount and reads the angle of site to the crest from the elevation counter. This angle of site and the PCR are reported as part of the section chief's report.

MEASURING PIECE-TO-CREST RANGE

15-57. There are six methods that can be used to measure piece-to-crest range:

- **Laser Range Finder**. This is a very quick and accurate method.
- **Taping**. This is the most accurate manual method; however, it is normally too time-consuming.
- **Subtense**. This method is fast and accurate.
- **Map Measurement**. This method is fast and accurate if the obstacle can be accurately located (for example, a lone tree will not appear on a map).
- **Pacing**. This method is time-consuming and depends on the distance and accessibility to the crest.
- **Estimation**. This method is least accurate, but it is used when other methods are not feasible.

15-58. Regardless of the method used to measure PCR, the XO or platoon leader must verify PCR before they compute QE. He can do this by using any of the six methods.

COMPUTATION OF FUZES OTHER THAN ARMED VT

15-59. Table 15-8 (page 15-32) lists the steps and solves an example of an XO's or platoon leader's manual computations.

Table 15-8. Manual Minimum QE Computations.

STEP	***ACTION***
1	Howitzer 1 (M109A6) reports a site to crest of 16 mils at a PCR of 1,100 meters. Charge 3GB is used.
2	∡1 = site to crest = **16 mils**
3	∡2 = (VI x 1.0186) ÷ PCR (in 1,000s) = (5 x 1.0186) ÷ 1.1 = 4.6 ~ **5 mils** This VI is a 5-meter vertical clearance safety factor. It can also be computed using one of the following methods: Use the GST. Solve in the same way as angle of site **(4.6 ~ 5).**
4	∡3 = (∡1 + ∡2) x CSF = (16 + 5) x 0.010 = (0.210) ~ **1 mil**
5	∡4 = EL = 74.1 ~ **75 mils**
6	∡5 = 2 Forks (TFT, Table F, Column 6) = 2 x 2 = **4 mils**
7	Min QE = ∡1 + ∡2 + ∡3 + ∡4 + ∡5 = 16 + 5 + 1 + 75 + 4 = **101 mils**
Legend: CSF – complementary site factor GST – graphical site table PCR – piece to crest range QE – quadrant elevation TFT – tabular firing table VI – vertical interval	

15-60. One howitzer section may report a site to crest that is unusually high. If the XO or platoon leader determines that it is the result of a single narrow obstruction (such as a tree), the piece can be called out of action when firing a deflection that would engage the obstruction. This would enable the platoon to use the next lower site to crest. Other alternatives are to remove the obstruction or move the weapon.

15-61. Table 15-9 illustrates why minimum QE is computed for all guns, regardless of which has the largest site to crest.

Table 15-9. RFT Example for Howitzer Platoon.

GUN	***CHG***	***PCR***	***SITE TO CREST***	**+**	***RFT***	**=**	***MIN QE***
1	3GB	800	128	+	64	=	192
2	3GB	1000	105	+	80	=	185
3	3GB	1500	92	+	116	=	208
4	3GB	1200	115	+	93	=	208
Legend: CHG – charge GB – green bag PCR – piece-crest range RFT – rapid fire tables QE – quadrant elevation							

15-62. The method of computing the XO’s minimum QE for firing a projectile fuzed with an M728 or M732 fuze depends on the method in which the fuze is used. **The Variable Time (VT) fuze is designed to arm 3 seconds before the time set on the fuze; however, some VT fuzes have armed as early as 5.5 seconds before the time set on the fuze. Because of the probability of premature arming, a safety factor of 5.5 seconds is added to the time of flight to the PCR.** Since time on the setting ring is set to the whole second, the time determined in computing minimum safe time is expressed up to the nearest whole second. A VT fuze is designed so that it will not arm earlier than 2 seconds into its time of flight, which makes it a bore-safe fuze. There are two situations in which different parameters are followed in order to determine XO’s Min QE for Armed VT fuzes: non-restrictive and restrictive. Non-restrictive situations entails that there are no intervening crests or FSCMs that may cause the fuze to function prematurely or prior to, respectively. Restrictive situations are any situations that will need special attention due to the fuze possibly functioning prior to its intended target, i.e. intervening crests or FSCMs.

15-63. In non-restrictive situations, the XO or platoon leader determines the minimum safe time by adding 5.5 seconds to the time of flight to the minimum range line as shown on the range safety card. The minimum QE determined for fuzes quick and time is also valid for fuze VT.

15-64. In restrictive situations, the XO or platoon leader determines the minimum QE and a minimum safe time for fuze VT. The minimum QE determined for PD fuzes is safe for VT fuzes if the fuze setting to be fired equals or is greater than the minimum safe time determined in paragraph (a) above; this is de-confliction by time. If the XO or platoon leader finds it necessary to fire a VT fuze with a time less than the minimum safe time, he must modify the minimum QE. He does this by increasing the vertical clearance to ensure that the fuze will not function as it passes over the crest; this is de-confliction by space. In addition, he must ensure the fuze will not function over any intervening crests along the gun-target line (See paragraph 15-21).

15-65. If the projectile is to be fired with the VT fuze set at a time less than the minimum safe time, allowance must be made for vertical clearance of the crest. Vertical clearances of the crest for armed M728 and M732 VT fuzes fired over ordinary terrain is 70 meters.

15-66. If the projectile is to be fired over marshy or wet terrain, the average height of burst will increase. The vertical clearance is increased to 105 meters. If the projectile is fired over water, snow, or ice, the vertical clearance is 140 meters.

15-67. The minimum QE for armed fuze VT when a fuze setting less than the minimum safe time is fired is based on the piece-to-crest range and a vertical clearance as indicated in paragraphs (d) and (e) above.

15-68. Figure 15-17 shows a decision tree for application of armed VT minimum QE.

For restrictive situation with a VT mission with the time setting of ________ and a QE of _______, ask the following questions.

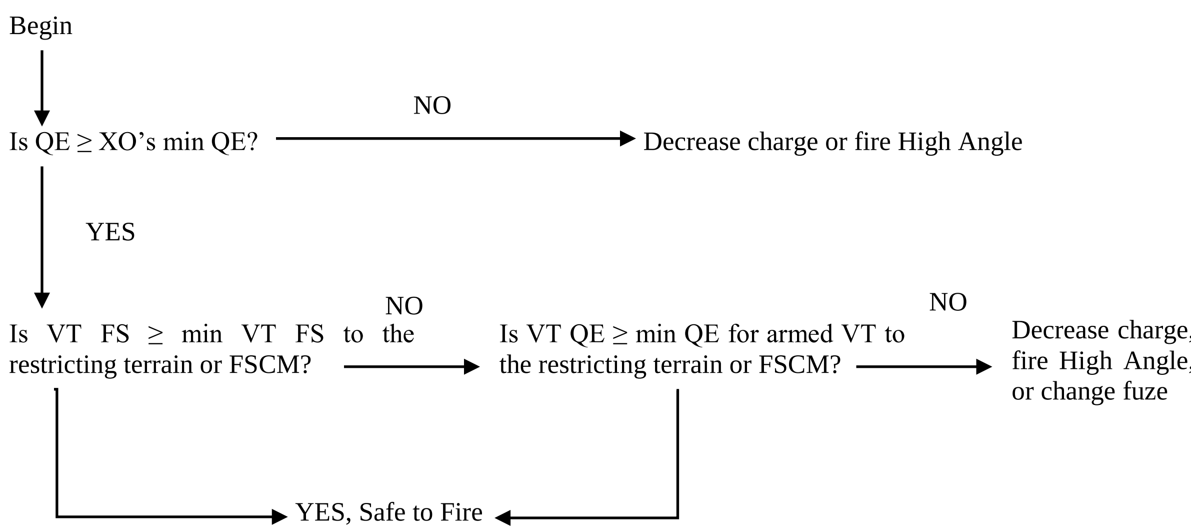

Figure 15-17. Armed VT Decision Tree.

15-69. Table 15-10 is an example of computations to determine minimum QE for an armed VT fuze.

Table 15-10. Manual Armed VT Minimum QE Computations.

STEP	***ACTION***
1	Howitzer 1 (M109A6) reports a site to crest of 16 mils at a PCR of 1,100 meters. Charge 3GB is used.

Table 15-10. Manual Armed VT Minimum QE Computations (continued).

2	∡1 = site to crest = **16 mils**
3	∡2 = (VI x 1.0186) ÷ PCR (in 1,000s) = (70 x 1.0186) ÷ 1.1 = 64.8 ~ 65 mils This VI is a 70-meter vertical clearance safety factor. It can also be computed by using the GST. Solve in the same way as angle of site **(64.7 ~ 65).**
4	∡3 = (∡1 + ∡2) x CSF (TFT, Table G) = (16 + 65) x 0.010 = 0.710 ~ **1 mil**
5	∡4 = EL = 74.1 ~ **75 mils**
6	∡5 = 2 Forks (TFT, Table F, Column 6) = 2 x 2 = **4 mils**
7	Min QE = ∡1 + ∡2 + ∡3 + ∡4 + ∡5 = 16 + 65 + 1 + 75 + 4 = **161 mils**
8	Determine minimum safe time. This value is the sum of TOF to PCR and 5.5 expressed up to the next higher second (**4.1 + 5.5 = 9.6 ~ 10.0 sec**).
Legend: CSF – complementary site factor EL – elevation GST – graphical site table PCR – piece to crest range QE – quadrant elevation TFT – tabular firing table TOF – time of flight VI – vertical interval	

15-70. If the VT fuze setting to be fired is equal to or greater than the minimum safe VT time, the minimum QE for fuzes quick and time applies. If the VT fuze setting to be fired is less than the minimum safe VT time, the minimum QE determined for armed VT applies.

USING MINIMUM QUADRANT ELEVATION

15-71. After computing minimum QE for each charge authorized, the XO or platoon leader must compare the minimum QE to the QE required to clear the minimum range line. The XO must then select the highest quadrant for each charge to be used as the minimum QE to be fired from that position per charge.

INTERVENING CREST

15-72. FDOs must ensure that artillery fires clear intervening crests. Intervening crests are defined as any obstruction between the firing unit and the target not visible from the firing unit. The following are the possible options, listed in order of preference.

- Determine firing data to the crest (including all nonstandard conditions) and add 2 forks (TFT, Table F, Column 6).
- Determine a minimum QE in a similar manner as XO's minimum QE.
- Use the trajectory tables in the appendix of the TFT.

15-73. Option 1 is preferred because it incorporates all current nonstandard conditions that will affect the projectile along the trajectory. The FDO has the responsibility to determine on the basis of availability of corrections for nonstandard conditions if this really is the best option. Table 15-11 lists the steps.

Table 15-11. Intervening Crest, Option 1.

STEP	***ACTION***
1	Upon occupation, the FDO analyzes the terrain for intervening crests.
2	Upon determining the altitude of this crest, he computes firing data to this point (QE). The best solution includes all available corrections for nonstandard conditions (current valid GFT setting).

Table 15-11. Intervening Crest, Option 1 (continued).

STEP	***ACTION***
3	Add the value of 2 forks (TFT, Table F, Column 6) based on PCR to the QE determined in Step 2 to ensure that round-to-round variations (probable errors) will clear the crest.
4	The FDO then records this QE and charge on his situation map as a check to ensure that rounds will clear the intervening crest.
5	Upon receipt of a fire mission, the FDO will compare his intervening crest QE to his fire mission quadrant. One of the three following situations will occur: 1) The target is located short of the intervening crest. The FDO does not consider the effects of the crest at this time. 2) The mission QE exceeds intervening crest QE by a significant margin, indicating the rounds will clear the crest. 3) Fire mission QE exceeds intervening crest QE by only a small margin or is less than intervening crest QE, indicating the round may or may not clear the crest. The FDO must determine if the round will clear after considering the following: Have all nonstandard conditions been accounted for? How old is the current met message? Are registration corrections being applied to this mission? Upon realizing that the round may not or will not clear the crest, the FDO can either fire high angle or a reduced charge. The quickest choice would be to fire high angle, but tactical situations may prevent this. Firing a lower charge will increase dispersion more than high angle. For example, at a range of 7,000 meters, the following applies: Low angle, charge 2L: Probable error in range = 16 meters. High angle, charge 2L: Probable error in range = 15 meters. Low angle, charge 1L: Probable error in range = 27 meters. If a lower charge is selected, steps 2 through 5 must be repeated.
6	If VT fuzes are to be fired (M700 series), the FDO must take additional steps to ensure that the VT fuze does not arm before passing over the crest. Follow the steps for determining armed VT minimum QE and FS in paragraph 15-19.
Legend: FDO – fire direction officer FS – fuze setting GFT – graphical firing table PCR – piece to crest range QE – quadrant elevation VT – variable time	

15-74. The least preferred option is using the trajectory charts in the appendix of the TFT. This offers a quicker but less accurate method to clear the intervening crest since it is based off of standard conditions. The FDO must make a judgment call when to use these charts. The FDO must use caution when making this decision.

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Appendix A

Battery or Platoon Fire Direction Center SOP

The organization of the FDC generally is standard throughout the Field Artillery. The actual organization will vary depending upon unit size and their particular mission. However, the FDC in any unit must meet certain standards and be able to function on a continuous 24-hour basis. This requires that each individual within the FDC be cross-trained in every job in the FDC and understand that their primary function is to process all fire missions received with the maximum speed consistent with safety by using the most accurate data available, while ensuring necessary checks to preclude errors which might endanger friendly personnel. The FDC also receives operational and intelligence information for the platoon. In autonomous operations, the FDC will communicate directly with the observer in receiving the above-mentioned information.

Note: The following SOP is to be used only as a guideline to help the FDO or Fire Direction Section Chief in developing an SOP for their unit.

OPERATIONAL CONCEPTS

A-1. The organization of the FDC must allow for the following goals to be accomplished:

- Continuous, accurate, timely, and safe artillery fire support under all weather conditions and terrain.
- Ability to engage all types of targets over a wide area.
- Massing of fires of all available units within range.
- Processing simultaneous missions.
- Dissemination of pertinent information.
- Efficient division of duties.
- Adherence to standard techniques and procedures.
- Teamwork and adherence to a definite specified sequence of operations to avoid and eliminate errors and to save time.
- Efficient use of communications.

FIRE DIRECTION CENTER OPERATIONS CHECKLIST

A-2. The following checklists are provided to help the FDO or section chief in preparation and sustainment during any major field exercise.

ACTIONS BEFORE DEPARTING GARRISON.

A-3. Design physical setup of the FDC to allow the FDO and section chief to observe the work of all personnel with a minimum amount of movement and provide each individual ready access to the equipment, forms, and information necessary to perform his duties.

A-4. Ensure all necessary supplies and equipment are located within the FDC (For a list of recommended equipment in a standard FDC, refer to the end of this appendix).

A-5. Ensure muzzle velocity logbook is present.

A-6. Ensure an adequate supply of expendable forms are on hand. The following forms are used in all FA units:

- DA Form 4982, Muzzle Velocity Record.
- DA Form 4982-1, M90 Velocimeter Work Sheet.
- DA Form 4504, Record of Fire.
- DA Form 4200, Met Data Correction Sheet.
- DA Form 3677, Computer Met Message.
- DA Form 4757, Registration and Special Correction Work Sheet,
- DA Form 4201, High Burst (Mean Point of Impact) Registration.
- DA Form 7353, Universal Safety T.
- DA Form 4655-R, Target List Work Sheet.

Note: The following forms are only for use in 155-mm units:

- DA Form 5032, Field Artillery Delivered Minefield Planning Sheet.

A-7. Ensure that the fire direction vehicle is loaded in accordance with your unit load plan. The load plan located at the end of this appendix may be used as a guideline.

A-8. Ensure the communications system has been verified as operational.

ACTIONS UPON OCCUPATION OF A POSITION.

A-9. These actions are listed based on the Five Requirements for Accurate Fire and are formatted as a FDC occupation checklist:

Accurate Target Location and Size

- Establish communications with observer
- Request POSREP
- Transmit FIRECAP and Safety Box

Accurate Firing Unit Location

- Verify location
- Verify AOL
- Establish communication with gunline
- Announce and post Fire Order and Fire Command Standards

Accurate Weapon and Ammo

- Obtain hourly propellant temperatures
- Verify projectile square weight
  - Establish lots
- Determine MVVs
  - Logbook
    - Entire Battery
    - Subsequent lot-inferred
  - Predictive
    - SS+PE=MVV
    - Gun Book
      - SS= EFC+POG
    - Propellant Efficiencies
  - Subsequent lot-inferred
  - Calibrate Battery
    - Update Logbook/Pes

Accurate Meteorological Information

- Establish communications with MET
- Receive and validate MET

Accurate Computational Procedures
- Complete/Verify safety computations
- Verify XO's Min QE
- Update FDO SITMAP
- Identify intervening crests
- Distribute Safety Ts
- Transmit FIRECAP
- Transmit Safety Box grids

Surveyed Firing Chart Construction
Verify the following information:
- 1st Requirement
  - Observer location and altitude
  - Azimuth indices
  - Known points plotted
  - Planned targets plotted

- 2nd Requirement
  - Base Piece location
  - Azimuth of Fire
  - Primary DF index
  - Supplementary DF indices

- 5th Requirement
  - Safety box construction
  - Chart-to-chart Checks
  - FSCMs plotted
  - Ensure 6400 mil capable
  - All other units plotted

Advanced Field Artillery Tactical Data System (AFATDS) Database Construction
Verify the following information:
- Start Up
  - System Time hack
  - AFATDS time hack
  - Verify Activation Unit and Role
  - Turn comms on

- 1st Requirement
  - Verify Observer location and altitude
  - Verify Known Points
  - Verify Planned Targets

- 2nd Requirement
  - Verify FDC
  - Verify Guns
    - Construct a weapon
    - Verify Center of Battery
  - Verify AOL
  - Verify howitzer location
- 3rd Requirement

    - Verify ammunition for each unit
    - Verify Projectile Square Weight
    - Verify propellant lots
    - Verify MVVs

- 4th Requirement
    - Establish Comms with MET
    - Verify MET
    - Make Current

- 5th Requirement
    - Attack analysis = Detailed
    - AMC response time
    - Target Block
    - GFT Settings/TGPCs

Administrative information
- Wet code from Range Control (when required)
- Verify radio frequencies and radio check procedures
- Verify generator is started
- Establish vehicle startup procedures

ACTIONS BEFORE DISPLACEMENT.

A-10. These actions are as follows:
- Ensure FDC is set up for emergency missions.
- Clean off old GFT settings from GFT.
- Ensure start point has been reported to battalion.
- Ensure communications check has been performed with battalion prior to movement.
- Ensure all sensitive items have been accounted for.
- Ensure chart has been prepared for the next position.
- Ensure checkout information has been obtained from Range Control.
- Always keep copies of ROFs and safety computations for permanent records.
- File forms in an orderly manner.

FIRE DIRECTION CENTER JOURNAL (LOGBOOK)

A-11. To maintain a record of FDC activities during field operations, it is recommended that a journal be kept of each day's activities. This journal, or logbook (i.e. DA Form 1594, *Daily Staff Journal or Duty Officer's Log*), will reflect all significant events that have occurred during all field operations. These significant events include, but are not limited to, the following:
- Check firings
- Reports
- All Range Control information.
- Receipt of all messages (date, time, and content).
- Met Messages.
- GFT Settings determined.
- The journal should be closed out every 24 hours so as to prevent any unnecessary confusion.

FIRE DIRECTION CENTER EQUIPMENT AND CONFIGURATIONS

A-12. Although this appendix focuses on the manual FDC, it should be noted that the following is the priority in determining the method to be used in the computation of firing data:

- Automated systems, such as AFATDS, are the primary means of computing technical firing data within the platoon.
- Other automated systems, such as CENTAUR, can serve as a backup means of computing technical firing data.
- The ability to perform manual fire direction must be maintained, should a need to transition to manual fire direction techniques occur at any time. Each FDC should maintain at least one firing chart with the appropriate fire direction equipment and manuals to support all manual cannon gunnery operations. The firing charts should serve as an emergency backup for AFATDS and CENTAUR.

A-13. Each FDC should be authorized the following: fire direction set 3, artillery (NSN1290-00-299-6892), 30,000 meters maximum range (line item number [LIN] H55843), 19200 (table A-l); fire direction set 4, artillery (NSN 1290-00-299-6893), 15,000 meters maximum range (LIN H55706) (table A-2); and plotting set, artillery fire control JSN 6675-00-641 -3630)(LIN P09818) (table A-3).

A-14. Figures A-1 and A-2 (pages A-8 and A-9) show suggested layouts of battery FDCs, including manual, automated, and howitzer improvement program (HIP) configurations. Applicability of these configurations will depend on the inherent mission and equipment of the unit concerned.

Table A-1. Content of Fire Direction Set 3.

ITEM	*NSN*	*QTY*
Carrying case, field artillery fire direction center equipment: Canvas, 50 inches long, 40 inches high, 8 inches thick folded.	1290-00-694-5190	1 each
Drawing board and trestle: 48 inches long, 36 inches wide, nonslope, folding trestle, 36 inches high	5675-00-248-1244	1 each
Plotting sheet 1,000 meters grid, 47 inches long, 35 inches wide	7530-00-656-0811	12 each
Protractor, fan range-deflection: 30,000 meters range, 11834239(19200)	1290-00-266-6891	1 each

Table A-2. Content of Fire Direction Set 4.

ITEM	*NSN*	*QTY*
Carrying case, field artillery fire direction center equipment: Canvas, 45 inches long, 33 inches high, 8 inches thick folded.	1290-00-694-5191	1 each
Drawing board and trestle: 48 inches long, 31 inches wide	5675-00-248-1243	1 each
Plotting sheet 1,000 meters grid, 41 ½ inches long, 30 inches wide	7530-00-656-0813	12 each
Protractor, fan range-deflection: 25,000 meters range	1290-00-266-6890	1 each

Table A-3. Contents of Plotting Set.

COMPONENT NSN	*ITEM DESCRIPTION*	*AUTH QTY*
5110012414373	SHEARS, STRAIGHT TRIMMERS: AMBIDEXTROUS; 8 ¼ INCH LENGTH; STEEL BLADES PLASTIC HANDLES, BLADE END TYPE, 1 BEVELED/1 SHARP POINTED OR 2 SHARP POINT BLADE END,	2 each
6675000495132	CHEST,PLOTTING EQUI,CHEST, PLOTTING EQUIPMENT: RECTANGULAR; 2-1/64 FT LONG; 1.318 FEET WIDE; 11-1/2 INCH HIGH,	1 each
6675002830018	SCALE,PLOTTING: PLASTIC; FLAT; EIGHT BEVELED EDGE TYPE HOLLOW SQUARE VIEW SHAPE; 50,000 MAP RATIO, SCALE INSCRIPTION IN METERS AND YARDS; 4 INCHES LENGTH	4 each

Table A-3. Contents of Plotting Set (continued).

COMPONENT NSN	*ITEM DESCRIPTION*	*AUTH QTY*
6675002830040	SCALE, PLOTTING: WOOD AND PLASTIC; TRIANGULAR, RELIEVED FACET; 62,500 MAP RATIO, SCALE INSCRIPTION IN INCHES AND YARDS; 12 INCHES LENGTH; SHEATH INCLUDED	4 each
7510001743205	PENCIL: RED; EXTRA THICK ROUND LEAD; 6 ¼ INCH LONG. GLAZED SURFACE; 12 PER BOX,	1 dozen
7510001985831	TAPE, PRESSURE SENSITIVE ADHESIVE,	60 rolls
7510002237044	ERASER,RUBBER: RECTANGULAR; GUM TYPE FOR MYLAR DRAFTING FILMS; 2 ¼ INCH LONG; 12 PER BOX,	1 dozen
7510002332021	PENCIL: THIN RECTANGULAR LEAD; RED; FOR BLUEPRINT CHECKING; 12 PER PACKAGE,	2 dozen
7510002332027	PENCIL: THIN RECTANGULAR LEAD; BLUE NONINDELIBLE GRAPHITE; FOR BLUEPRINT CHECKING; 12 PER PACKAGE,	2 dozen
7510002374926	PENCIL POINTER: WOOD HOLDER, 7-1/4 INCH LONG	2 each
7510002401526	PENCIL: BLACK; EXTRA THICK ROUND LEAD; 6 ¼ INCH. LONG. 12 PER CARTON,	1 dozen
7510002644610	PENCIL: GREEN; THIN ROUND LEAD; FOR ELECTROGRAPHIC WORK; 12 PER CARTON OR WRAPPER,	2 dozen
7510002644614	PENCIL: THIN LEAD; NONINDELIBLE GRAPHITE, HARDNESS H; FOR ELECTROGRAPHIC WORK; WITH ERASER; 12 PER BOX,	2 dozen
7510002726887	THUMBTACK	1 box
7510002815234	PENCIL: GENERAL WRITING NO.2	1 dozen
7510004365210	PENCIL: BLUE; EXTRA THICK ROUND LEAD; 6 ¼ INCH LONG 12 PER CARTON,	1 dozen
7510005519824	TAPE, PRESSURE SENSITIVE ADHESIVE,	72 rolls
7510007872430	PENCIL:ORANGE; THIN ROUND LEAD; FOR ELECTROGRAPHIC WORK; 12 PER BOX,	2 dozen
7510011345506	PENCIL: THIN LEAD; 4H HARDNESS W/ERASER; 12 PER BOX,	24 dozen
7510012693836	MAPTACK: RED; STEEL; SPHERICAL HEAD; PLASTIC HEAD; 1 1/8 INCH PIN; ¼ INCH. HEAD DIAMETER; 50 PER BOX,	4 boxes
7510012693837	MAPTACK: ORANGE; STEEL; SPHERICAL HEAD; PLASTIC HEAD; 1 1/8 INCH PIN; ¼ IN. HEAD DIAMETER; 50 PER BOX,	4 boxes
7510012693838	MAPTACK: BLUE; STEEL; SPHERICAL HEAD; PLASTIC HEAD; 1 1/8 INCH PIN; ¼ INCH. HEAD DIAMETER; 50 PER BOX,	1 box
7510012693839	MAPTACK: BLACK; STEEL; SPHERICAL HEAD; PLASTIC HEAD; 1 1/8 INCH PIN; ¼ INCH. HEAD DIAMETER; 50 PER BOX,	4 boxes
7510012699747	MAPTACK: GREEN; STEEL; SPHERICAL HEAD; PLASTIC; 1 1/8 INCH PIN; ¼ INCH. HEAD DIAMETER; 50 PER BOX,	4 boxes
7510012947979	PENCIL: THIN LEAD; 6H HARDNESS W/ERASER; 12 PER BOX	2 each
7520002271451	SHARPENER,PENCIL	1 each
7520002815918	CLIPBOARD FILE	1 each
7520002956170	LEAD REPOINTER, PENCIL: REMOVABLE PLASTIC COVER; FOR POINTING LEAD IN DRAFTING HOLDERS; BASE CONTAINS 2 SPARE BLADES; PACKED 12 PER BOX,	1 each

Table A-3. Contents of Plotting Set (continued).

COMPONENT NSN	*ITEM DESCRIPTION*	*AUTH QTY*
7530002354033	PAPER,TRACING: 18 INCHES LONG, 12 INCHES WIDE; HIGH TRANSPARENCY; WHITE SUBSTANCE; 100 SHEETS PER PAD,	1 pad
7530002369305	PAPER,TRACING: 21 INCHES WIDE, 20 YARDS PER REEL, WHITE SUBSTANCE; SPECIAL FEATURES 15 ½ TO 17 ½ LBS PER 500 SHEETS, 17X22 INCH,	1 roll
7530011245660	PAD,WRITING PAPER	4 dozen
9330002861231	PLASTIC SHEET	1 roll
9330012845609	PLASTIC SHEET: POLYESTER; CLEAR; 0.004 INCH. THICK; 20.000 INCH. WIDE; 600.000 INCH. LONG ROLL,	1 roll
Legend: AUTH QTY – authorized quantity NSN – national stock number		

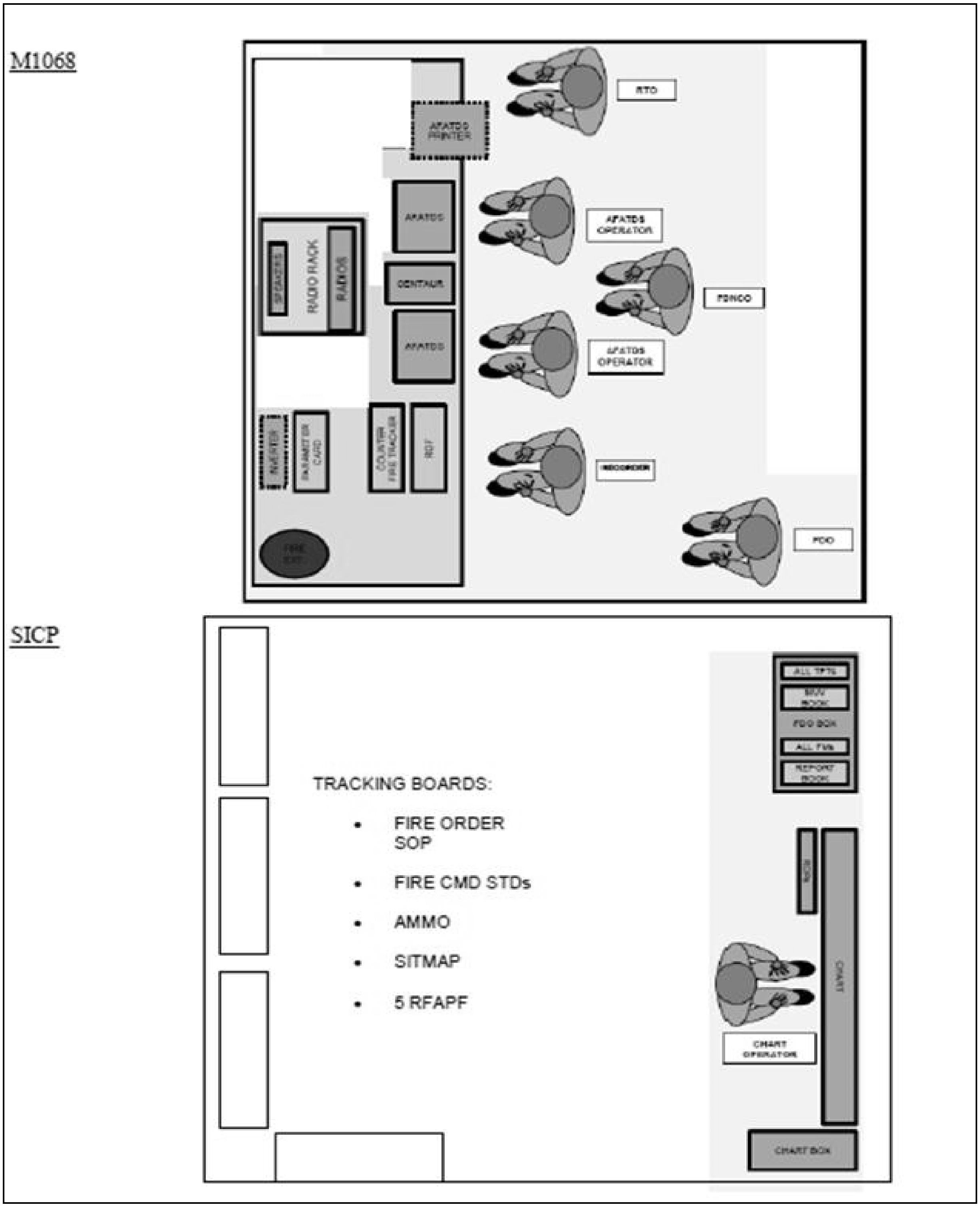

Figure A-1. Internal Top View of Battery FDC in an M1068 Command Post Vehicle and SICP.

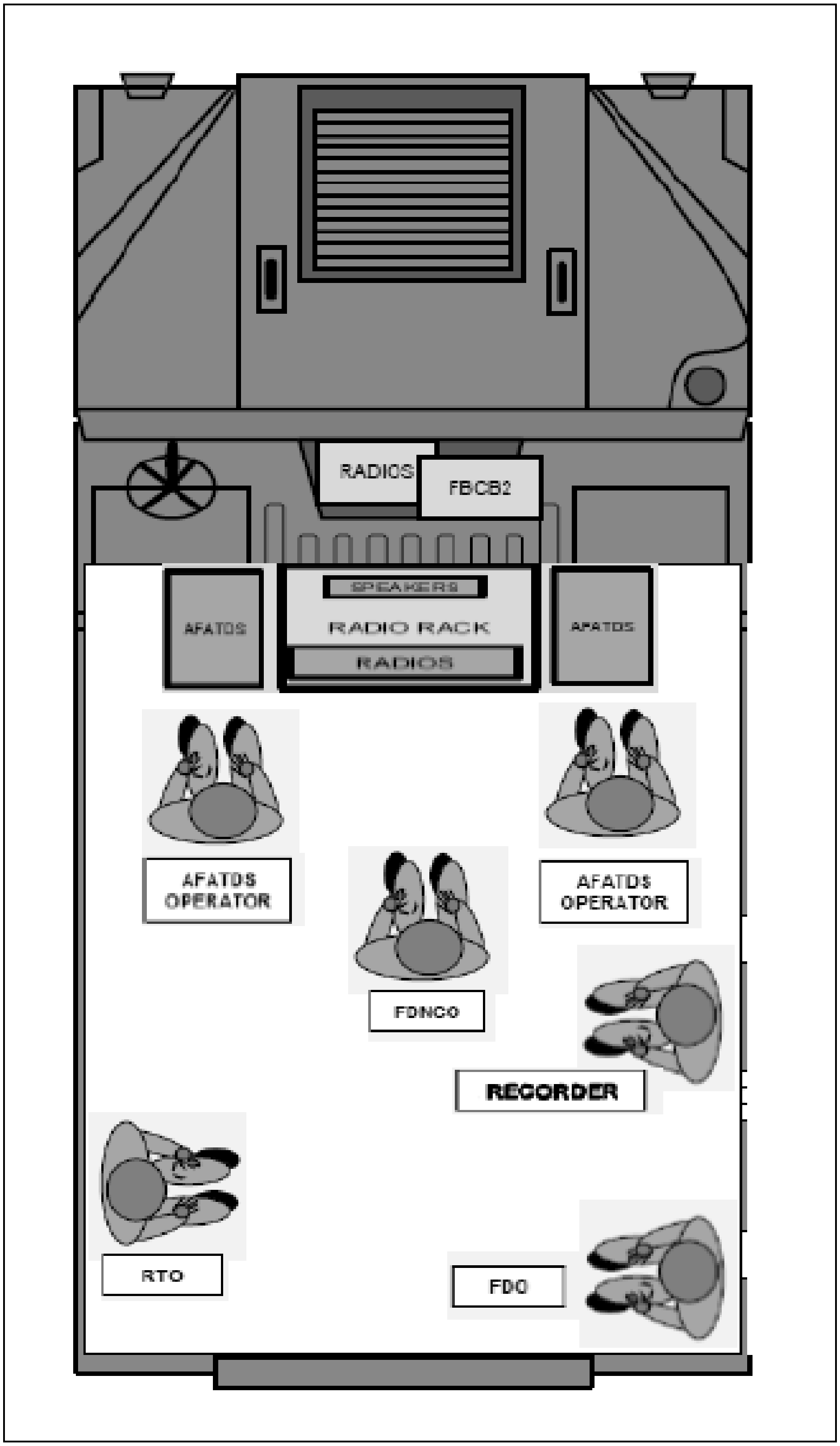

Figure A-2. Internal Top View of Battery FDC in HMMWV (for SICP, see Fig A-1).

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Appendix B
Troubleshooting

If the gunnery team fails to achieve effects on the target, they need to determine and understand why. In a manual environment, the FDC will verify firing charts, GFT settings, and firing data. In an automated environment, the FDC will verify the database for accuracy. Once the error is determined, they correct it in order to provide accurate fires. Accurate firing data produces effects on the target. Unit leaders or Investigating Officers need to be able to evaluate firing data and supervise corrective action for inaccuracies.

ACCURATE FIRING DATA

B-1. Accurate firing data enables the firing unit to achieve the desired effects on target. If the observer is reporting that we are not achieving accuracy, then the FDC needs to determine the errors and correct them. The observer is the source for spotting; it provides spotting in relation to the gun target line (GTL) and/or cardinal direction. Errors can affect range, lateral, or both range and lateral. Using and understanding the five requirements for accurate fire, what errors affect each requirement? Errors in target location are caused by inaccurate observer location or inaccurate observer direction. Errors in computational procedures are caused by map mod/ chart, met message in use, propellant temperature, and projectile square weight. These are just a few examples that we will discuss to determine where our error could originate.

B-2. Troubleshooting is a complicated task that requires an understanding of ballistics, firing tables, and the automated systems. To simplify the process, the Troubleshooting Matrix is provided (figure B-3). However, to really understand the Troubleshooting Matrix, you have to understand the 'error' and how the automated systems or Computer is correcting for it. There are two types of 'errors' in troubleshooting.

- Incorrectly accounting for non-standard conditions /not accounting for a non-standard condition.
- Applying incorrect data to fire computations.

B-3. The FDC should have a good understanding of how failing to account for a non-standard condition will affect the impact of the projectile. Obviously, if the FDC does not account for a negative muzzle velocity, the round will impact short of the target. The more difficult problem is to determine where a round will impact when a negative muzzle velocity is incorrectly accounted for in the computations or database. An easy example to explain this problem is a howitzer that is ***actually*** firing the standard muzzle velocity, but a ***negative muzzle velocity*** is stored in the automated systems or used in the computations. What can the FDC expect to see in the impact area? For simplicity, assume all other conditions are standard and only focus on the muzzle velocity. From the howitzer's perspective (figure B-1), the target is the aim-point and its round will impact at the aim-point (target).

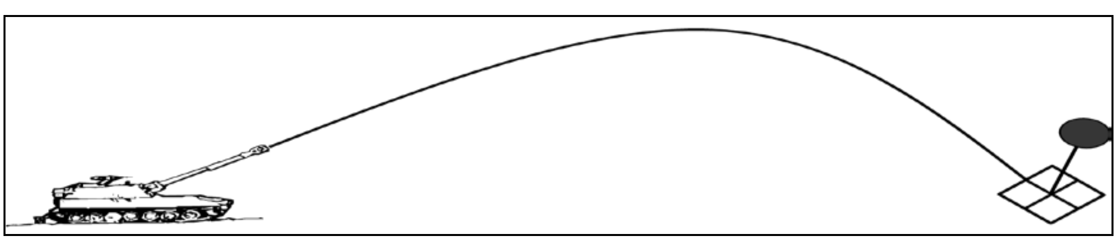


Figure B-1. Howitzer Standard Muzzle Velocity.

B-4. However, from automated system's perspective, the howitzer has a negative muzzle velocity; therefore, the Computer or automated system corrects the howitzer's aim-point beyond the target (in reference to the GTL) to compensate for the negative muzzle velocity. From the automated system's perspective the howitzer is aimed at the chart-pin, but the projectile will follow the dashed-line to the target (figure B-2). Remember the error only exists in the computations or automated systems. What can be expected in the impact area?

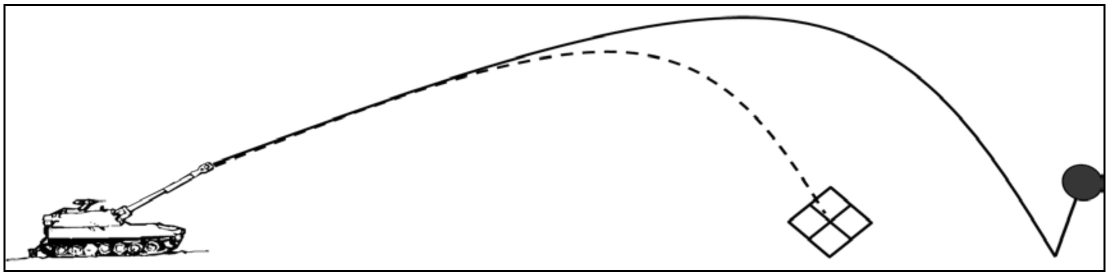


Figure B-2. Computer or Automated Systems Accounting for a Negative Muzzle Velocity.

B-5. As it can be identify, the round will impact at the aim point, beyond the target (reference the GTL). The error has the opposite effect that we initially assume it will have. A negative muzzle velocity error in the computation or database will cause the round to impact over the target and positive muzzle velocity error in the computation or database will cause the round to impact short of the target. Identifying an error and determining how it was corrected can be a long process. To make the process simple the FDC can use the Troubleshooting Matrix (figure B-3).

B-6. The following Troubleshooting Matrix (figure B-3) will help the firing unit to separate the source of the error based on the spotting provided by the observer. In order to identify the magnitude of the error the following formula it is used:

WHAT DATA WAS FIRED

\- WHAT DATA SHOULD HAVE BEEN FIRED

= ERROR ≈ ±10 Meters

B-7. Errors will be identified in relation to the GTL. Range errors will be identified as **Over** or **Short**. Lateral errors will be identified as **Left** or **Right**. When required, cardinal directions will be provided: North, South, East or West.

RAPF*	RANGE ONLY	LATERAL ONLY	RANGE AND/OR LATERAL
1	SITE		TARGET LOC OBS LOC / DIR
2		AOL	ORSTA / HOWITZERS LOC
3	[] WT PTEMP MVV		
4	AIR TEMP AIR PRESS MDP ALT		MET WIND DIR WIND SPEED
5	QE CHG	DF	

* RAPF= Requirements for Accurate Predicted Fire

Figure B-3. Troubleshooting Matrix.

FIVE REQUIREMENTS FOR ACCURATE FIRE

B-8. The five requirements for accurate fire form the basis for troubleshooting firing data in both manual and automated fire direction. **Thus, the presentation of the solution is designed around discussing each**

requirement of the five requirements of accurate predicated fire. If the FDC can meet the five requirements, then it will be able to compute accurate firing data and achieve accurate first round fire for effect. If FDC are meeting the five requirements but not having effects on target, it needs to determine why (troubleshoot) and make corrections**.** The methodology for troubleshooting is to isolate the problem and use a systematic approach to correct the error. In the process of correcting the error, the FDO must ask the following questions:

- Is the error found on one specific howitzer or the entire battery?
- Is a lateral or a range error?
- Once an error is isolated, was the error of the correct magnitude and in the correct direction?
- Are there any other errors?
- Has the database been verified?
- Has the gun line been verified?

Note: The magnitude of the error is ALWAYS EXPRESSED TO THE NEAREST 10 METERS.

Note: The procedures discussed in this appendix are also used by range control or investigating officers to determine whether or not your unit fired unsafe data.

Note: For simplicity, each error described below will be addressed independently. It will be assumed all other conditions are standard. It is important to understand that in real situation errors could be compounded.

ACCURATE TARGET AND FIRING UNIT LOCATION ERRORS

B-9. Accurate target and firing unit location are the first two requirements for accurate fire. These requirements are used to determine an accurate deflection and range to the target, which is the basis for all firing data. An error in target location may produce both lateral and range errors for all howitzers. Target location is used by automated systems or the HCO to determine a range and deflection from the battery/platoon location. Firing data is based on range and deflection from the battery/platoon location to the target location. Common survey between the firing position area and the target area will reduce the effects of erroneous survey since the errors are equal at both ends of the trajectory and cancel each other out.

- Common survey between the observation post (or radar) and firing position area will reduce the effects of target location error when using the polar method of target location.
- Common survey between known points and the firing position area will reduce errors when using the shift from a known point method of target location. Known points/targets which are established using an accurate polar method of target location from a surveyed observation post (OP) are considered common.
- Errors in target location may be caused by observer and known point input errors, inaccurate target area survey, and observer procedural errors.

B-10. To achieve accurate battery location, the survey section uses different equipment to provide accurate survey information. If the survey team makes an error in the battery location, this error can cause both lateral and range errors for the entire battery or a single howitzer.

- Accurate directional control is critical. Errors in direction generally cause azimuth of lay errors. Errors in azimuth of lay cause lateral errors along the gun target line. The error in the point of impact will increase as the range to the target increases.
- Errors in position may cause both lateral and range errors along the GTL. Errors in the point of impact will remain constant as the range to the target increases. Errors in position may occur if the fire direction center uses an inaccurate survey point or inaccurate azimuth to locate the howitzers.
- Automated systems use location information (map mod) to determine rotation corrections. Errors in the first three digits of northing and sphere may cause both lateral and range errors.

B-11. Causes. Not only could survey make a mistake that would cause these errors, but the firing unit could be mislaid. Section chiefs could also use sloppy gunnery techniques during the lay process. For example, announce ready for recheck prior to re-sighting on the aiming circle. The computer could also input an incorrect orienting station (ORSTA) location, howitzer location, or target location into the database/chart.

B-12. Target area survey which is common to position area survey reduces the effect of target location error. Common survey between the position areas and the target area reduces the effect of erroneous survey since the same error in position and direction exists at both ends of the trajectory. Target location errors may be reduced for radar and polar missions if common survey exists between the OP and the firing positions. Common survey between the position areas and the known points reduce errors using the shift from a known point method of target location. Errors can be reduced when using the same map sheet and specify the correct altitude of the target. Other errors which may exist between the firing position and the target area include: transposition and transmission errors, observer procedural errors, wrong known point or target, and observer location errors.

SITE ERROR

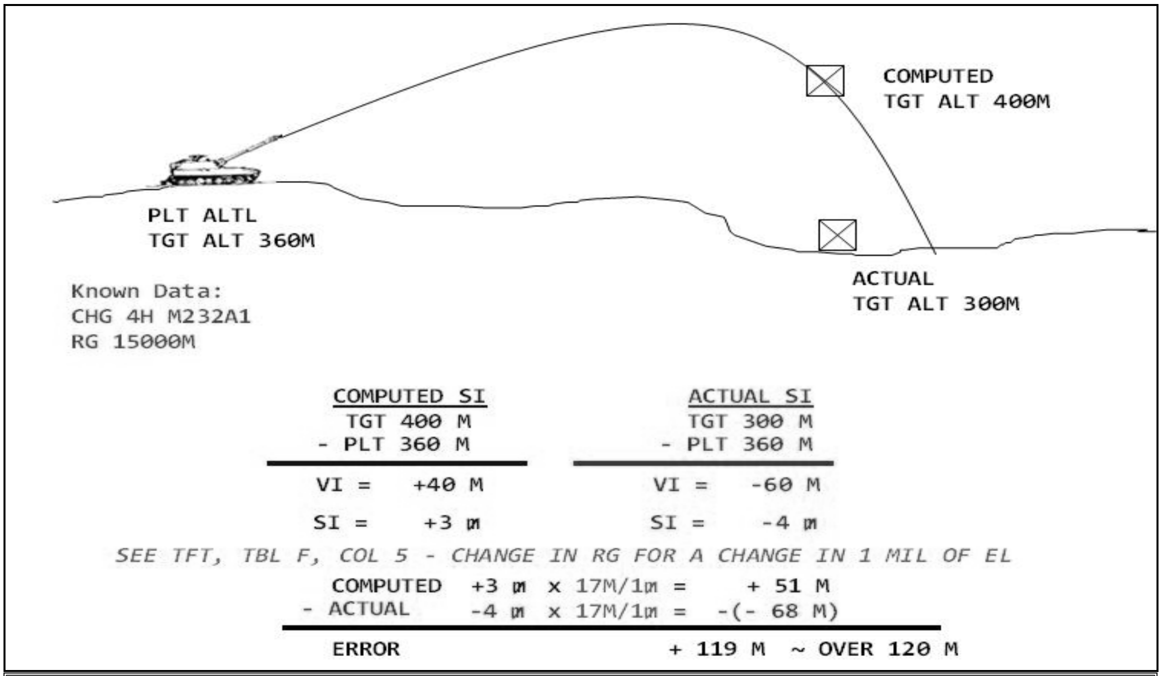
B-13. Site allows the firing unit to account for the difference in altitude between the firing unit and the target. Errors in site would cause a range error along the GTL from the FDC perspective. Site errors could be caused by different reasons. There are many instances in which bad target location is not necessarily the fault of the observer. Instead, wrong spotting on the map while determining target altitude during a call-for-fire. Computer operator enters the wrong altitude to automated systems or extracting wrong numbers from the GST.

B-14. The following diagram (figure B-4 on page B-5) shows the importance of accurate altitude/site. Note that the round impacts OVER the target in this example. In low-angle missions, a negative site will decrease the quadrant elevation and a positive site will increase the quadrant elevation. In this case the operator uses the wrong altitude during site computations resulting in a positive site.

B-15. . The following equation is used to determine the magnitude and direction of the error:

  WHAT DATA WAS FIRED (Computed)
- WHAT DATA SHOULD HAVE BEEN FIRED (Actual)

= ERROR ≈ ±10 Meters



Legend: ALT – altitude CHG – charge COL – column EL - elevation PLT – platoon RG – range SI – site TBL – table TFT – tabular firing table TGT – target VI – vertical interval

Figure B-4. Site Error.

ORIENTING STATION ERROR (ORSTA).

B-16. Location errors in survey will affect firing data. The error will remain constant in terms of cardinal direction and magnitude, i.e. 600 meters west. No matter which direction howitzers are firing, the error remains the same. See figures B-5 thru B-7. This error could be caused by improper procedures while setting the aiming circle or gun laying & positioning system (GLPS). Also by inputting or utilizing (transpose numbers) inaccurate data during computations of firing data.

Note: since the direction of fire could change the direction from a range to a lateral error, cardinal directions are used to identify the direction. Use East, West, North, or South when identifying ORSTA errors.

B-17. The following diagram (figures B-5 through B7, pages B-6 and B-7) shows the importance of accurate ORSTA. Note that regardless of the direction of fire (DOF), the error will remain constant. It however, change the way is identify in relation to the GTL when comparing from a lateral or a range error.

B-18. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Computed)

\- WHAT DATA SHOULD HAVE BEEN FIRED (Actual)

= ERROR ≈ ±10 Meters

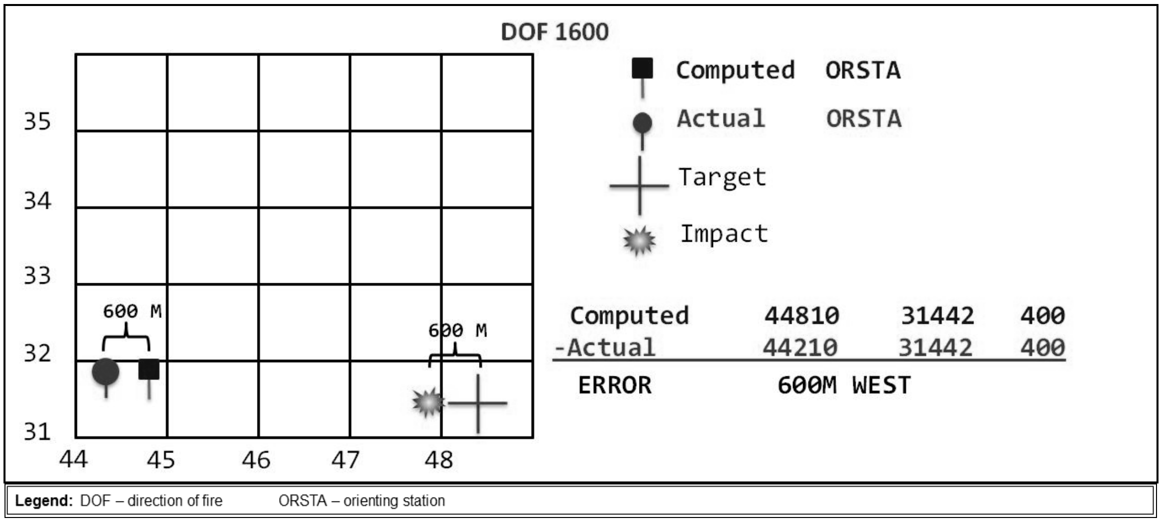


Figure B-5. ORSTA Error DOF 1600.

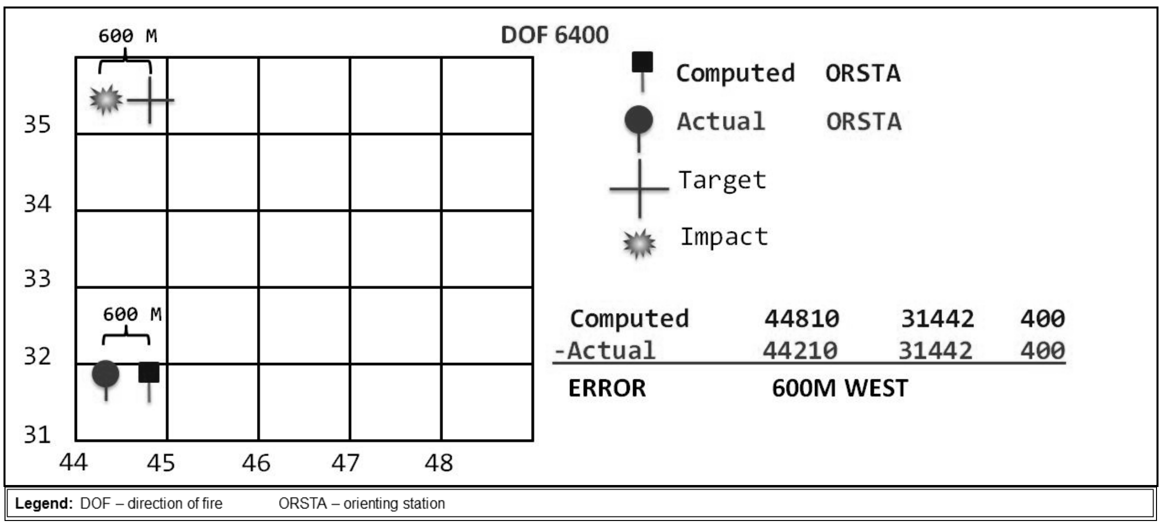
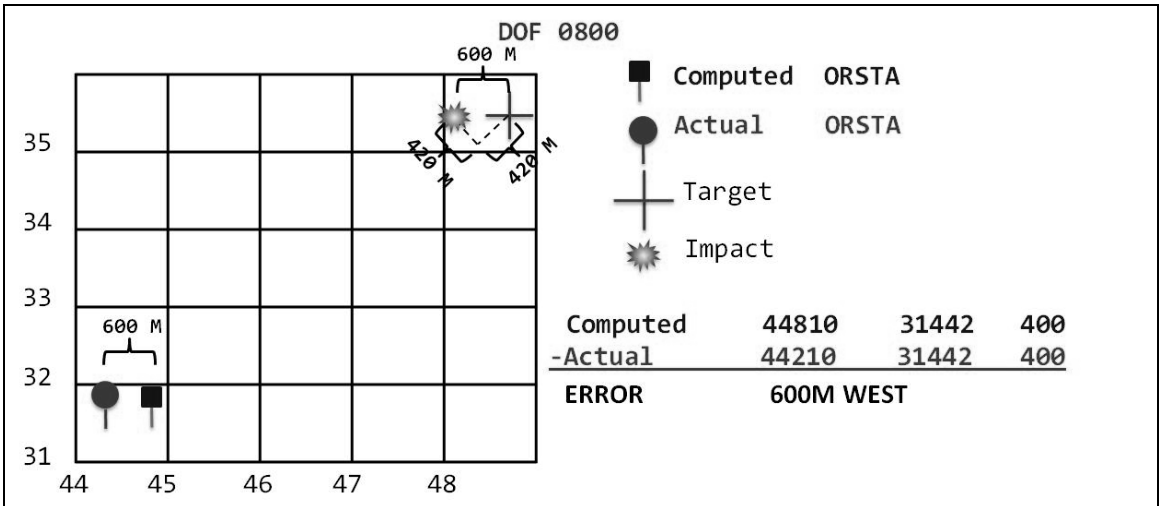


Figure B-6. ORSTA Error DOF 6400.



Legend: DOF – direction of fire ORSTA – orienting station

Figure B-7. ORSTA Error DOF 0800.

AZIMUTH OF LAY ERROR (AOL).

B-19. The azimuth of lay (AOL) is the direction assigned to the common deflection. Errors in the azimuth of lay cause lateral errors along the gun target line. The error in the point of impact will increase as the range to the target increases. Errors in azimuth of lay cause lateral errors across one howitzer or the entire battery depending on the origin of the error from the fire direction perspective. Errors in the azimuth of lay can be quite common in a unit that is not well trained.

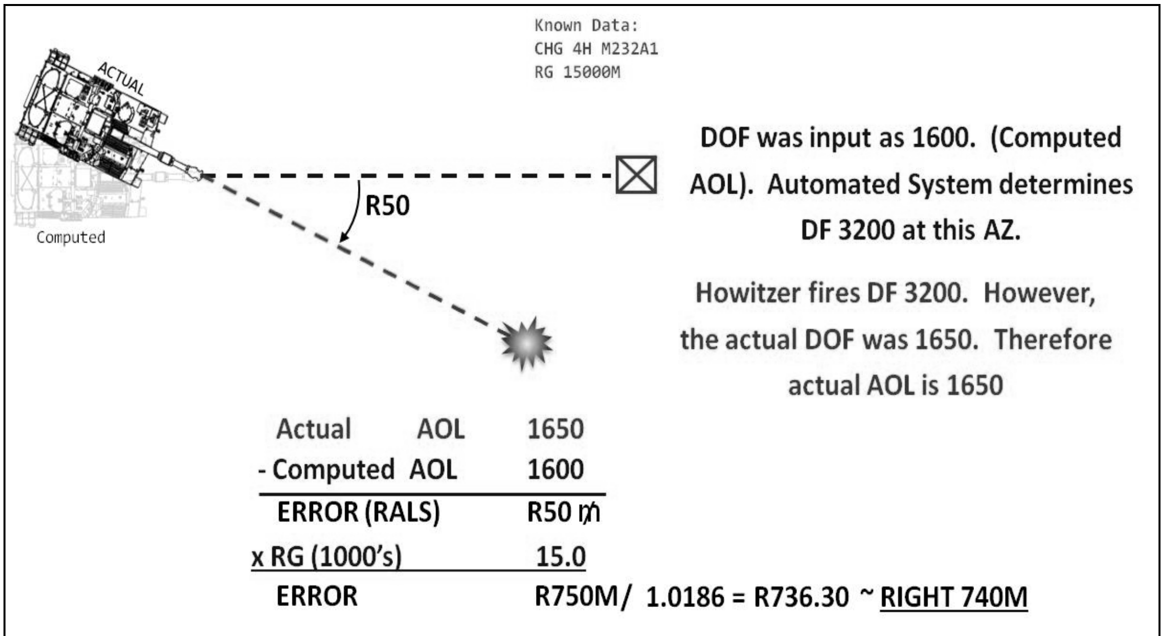
B-20. For example**,** if a battery commander who issued his movement order telling the XO and FDO that the azimuth of fire (AOF) would be 1600 in the next location. The Battery Commander (BC) changed the AOF when he arrived at the position to 1650 because of trees blocking the line of fire. The BC told the XO, but not the FDO. The XO never turned-in the Xos report and nobody verified the FDCs data base. The guns ended up laid on an AOF of 1650, but the FDC computed the data using 1600.

B-21. The following diagram (figure B-8, on page B-8) shows the importance of accurate AOL. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Actual)

\- WHAT DATA SHOULD HAVE BEEN FIRED (Computed)

= ERROR ≈ ±10 Meters



Legend: AOL – azimuth of lay AZ - azimuth CHG – charge DF – deflection DOF – direction of fire ORSTA – orienting station RALS – right add left subtract RG - range

Figure B-8. AOL Error.

B-22. This principle is based upon the Mil Relation Formula which states that $W = \frac{m * R\,(1000s)}{1.0186}$. Division by 1.0186 of the resultant is necessary to convert the mils to meters.

> Note: 1.0186 is a correction factor utilized when a certain range or distance measured in meters is converted into an angular measurement in mils. In this case we want to convert our angular deviation to meters therefore is divided.

ACCURATE AMMUNITION AND WEAPON INFORMATION ERRORS

B-23. Automated systems use this information to account for ammunition specific, howitzer specific, and weapon system characteristics. Errors in ammunition and weapon system information may cause range errors. Ammunition and weapon information which affect firing data include: tabular firing table and weapon system, MVV, projectile weight, propellant temperature, and ammunition lot designators. These may affect the entire battery or gun specific.

PROJECTILE SQUARE WEIGHT ERROR

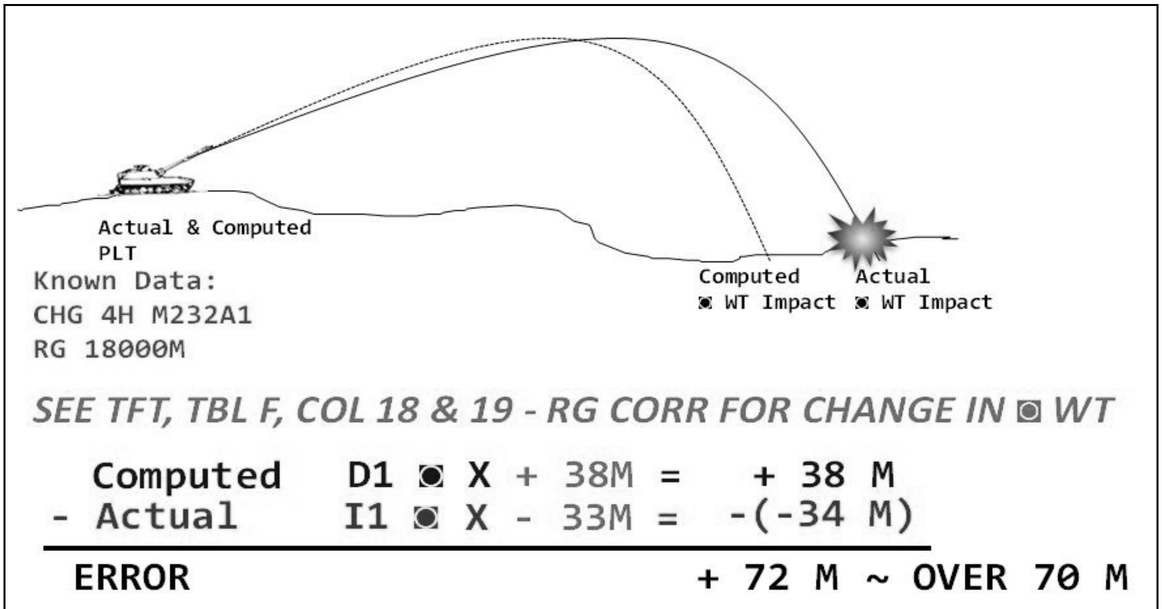
B-24. Projectile square weight allows the computer to correct for projectile weights on the gun line which deviate from standard. Errors in projectile square weight cause range errors for all howitzers from the fire direction perspective. Errors may exist on an individual howitzer due to poor ammunition reporting procedures, or if the howitzer fires the wrong projectile lot of ammunition. Incorrect reporting by either the cannon section or Platoon Leader/Executive Officer, incorrect automated entry of projectile weights, improper projectile lot management by the FDO, or an incorrect lot fired by a cannon section are all possible causes of projectile weight error.

B-25. The following diagram (figure B-9, page B-9) shows the importance of accurate projectile weight. The example below describes a situation in which the FDO did not verify the automated system containing a high explosive 3◙ but the ammunition on the gun line is 5◙. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Computed)

\- WHAT DATA SHOULD HAVE BEEN FIRED (Actual)

= ERROR ≈ ±10 Meters



Legend: CHG – charge COL – column CORR - correction PLT – platoon RG – range TBL – table TFT – tabular firing table WT - weight

Figure B-9. Projectile Square Weight Error.

PROPELLANT TEMPERATURE ERROR

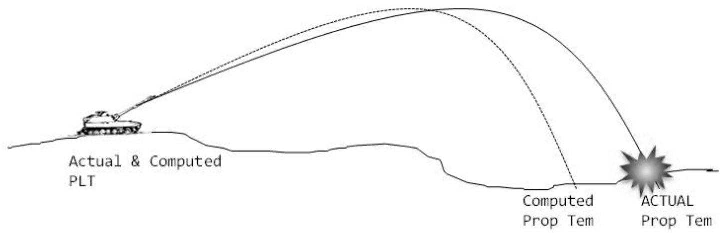
B-26. Propellant temperature allows the computer to correct for propellant temperatures on the gun line which deviate from standard. Errors in propellant temperature usually cause range errors for all howitzer from the fire direction perspective. Errors may exist on individual howitzers due to poor ammunition handling/reporting procedures. This error could also be caused by incorrect reporting by Platoon Leader/Executive Officer, incorrect averaging or automated system entry, or failing to periodically update the automated system with the most current conditions. Propellant temperature error is a two step solutions the first step is to identify the effect on velocity for propellant temperature and then identify the magnitude of the error based on the effects on velocity.

B-27. The following diagram (figure B-10 on page B-10) shows the importance of accurate propellant temperature. The example below describes a situation in which the Computer operator did not enter the correct temperature reported by the howitzer. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Computed)

\- WHAT DATA SHOULD HAVE BEEN FIRED (Actual)

= ERROR ≈ ±10 Meters



SEE TFT, TBL E – EFFECT ON MV FOR CHANGE IN PTEMP

Computed 84°F = +2.5 M/S
Actual 48°F = -3.6 M/S

SEE TFT, TBL F, COL 10 & 11 - RANGE CORR FOR +/-1M/S CHANGE IN MUZZLE VELOCITY

	Computed	I 2.5 M/S	x	- 26.1 M =	- 65.2 M
-	Actual	D 3.6 M/S	x	+ 27.0 M =	-(+ 97.2 M)
	ERROR				- 162.4 M ~ Short 160M

Legend: COL – column CORR - correction MV – muzzle velocity PLT – platoon PTEMP – propellant temperature TBL – table TFT – tabular firing table

Figure B-10. Propellant Temperature Error.

MUZZLE VELOCITY VARIATION ERROR

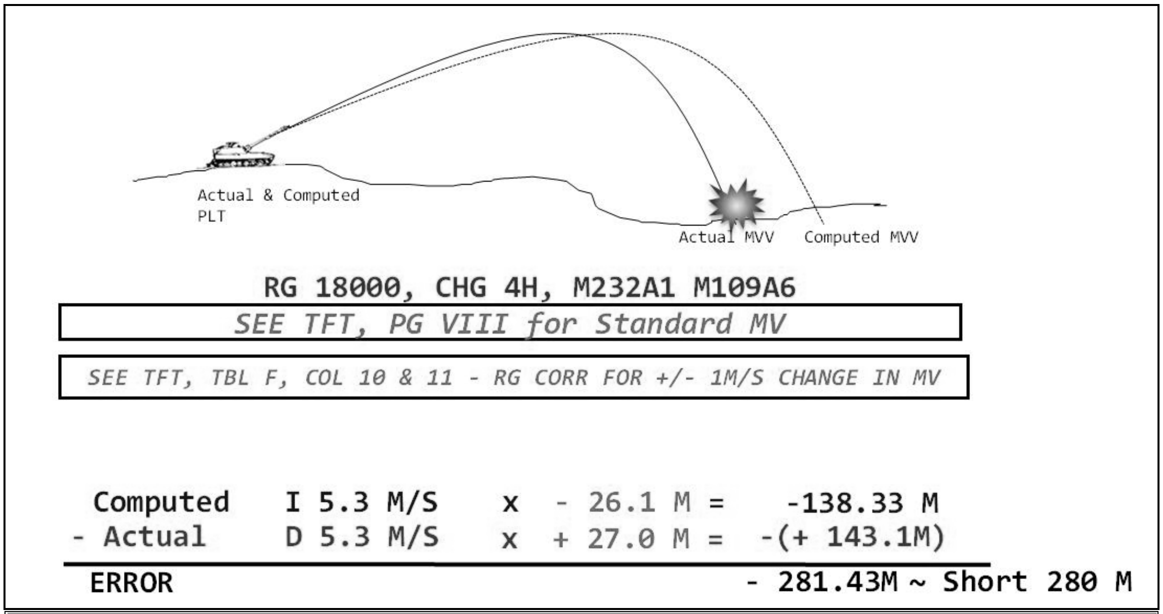
B-28. This error is commonplace in many FDCs. It is caused primarily by improper MVV Management on the part of the FDO. Due to the inability of the automated systems to store more than 28 MVVs by lot, the FDC can erroneously apply a MVV from one lot to another of the same propellant type. If the FDO does not ensure that **only** MVVs for lots on each individual gun are stored, errors in firing data can occur. This error can additionally be caused by incorrect reporting by either the cannon section or Platoon Leader/Executive Officer, by math errors on the MV forms, or by the incorrect lot fired by the cannon section.

B-29. The example below described a situation in which the Computer operator did not enter the sign (negative) when entering the MVV as a result the automated system uses a positive causing the error. The following diagram (figure B-11 on page B-11) shows the importance of accurate MVV data. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Computed)

\- WHAT DATA SHOULD HAVE BEEN FIRED (Actual)

= ERROR ≈ ±10 Meters



Legend: CHG – charge COL – column CORR - correction MV – muzzle velocity PG – page PLT – platoon RG - range TBL – table TFT – tabular firing table

Figure B-11. MVV Error.

ACCURATE METEOROLOGICAL INFORMATION ERRORS

B-30. Automated systems use MET message information to account for atmospheric conditions which deviate from standard. If the MET message does not accurately reflect actual weather conditions, then errors will exist in firing data. Fire direction officers must check all MET messages for validity. Time and location of the MDP drive MET message validity. Station height is used by automated systems as a reference point to apply corrections for air temperature/pressure in a computer met. Errors in station height cause errors in range corrections which will produce quadrant and charge selection errors for all howitzers. Errors in wind direction and speed will cause both lateral and range correction errors for all howitzers. Errors in air temperature and pressure in a computer met will cause range correction errors for all howitzers.

B-31. There are many causes of this error: Met is not valid or does not represent actual weather conditions, input type errors, transmission errors, errors at the met stations, computational errors, or inappropriate met in use.

ACCURATE COMPUTATIONAL PROCEDURES ERRORS

B-32. Accurate computational procedures assume that if all database information is correct then the automated systems will accurately correct for all nonstandard conditions and will produce reliable firing data. Thus, Fire direction officers and computer operators must be well trained to ensure proper entries are being made and must be aware of all programming faults and workarounds. Computational errors can, however, occur in the application of firing data by the cannon section. In many instances, the errors can result in a firing incident.

B-33. Errors on the gun line. Automated systems will compute accurate firing data assuming the database reflects actual conditions on the gun line. Incorrect procedures, mechanical failures, and inconsistent reactions to the stress of firing may cause errors in direction, position, elevation, fuze setting, and muzzle velocity. Three of the common errors that cause inaccuracies and firing incidents are deflection, quadrant elevation, and charge errors:

DEFLECTION ERROR

B-34. This error can result by improper lay procedures, improper announcing or recording of firing commands, or simple human error (i.e. 100 mils on the sight). The error in the point of impact will increase as the range to the target increases.

B-35. The following diagram (figure B-12) shows the importance of accurate deflections. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Actual)

\- WHAT DATA SHOULD HAVE BEEN FIRED (Computed)

= ERROR ≈ ±10 Meters

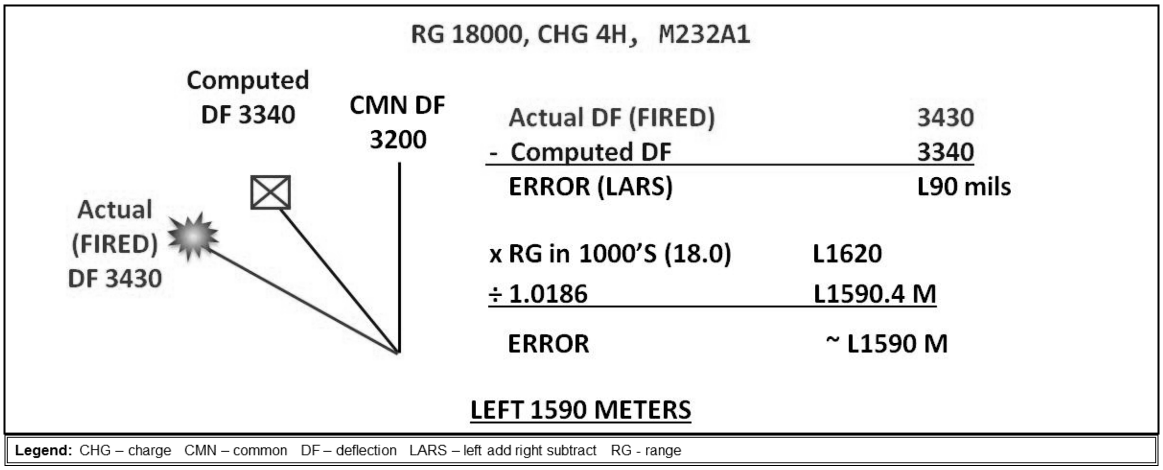


Figure B 12. Deflection Error.

B-36. This principle is based upon the Mil Relation Formula which states that $W = \frac{m * R\,(1000s)}{1.0186}$. Division by 1.0186 of the resultant is necessary to convert the mils to meters.

Note: 1.0186 is a correction factor utilized when a certain range or distance measured in meters is converted into an angular measurement in mils. In this case we want to convert our angular deviation to meters therefore is divided.

QUADRANT ELEVATION ERROR

B-37. This error can result from improper announcing or recording of firing commands, or simple human error. For example, the computed fire commands determined the quadrant elevation to be 350m̸. During the mission one gun lost digital communications and voice fire commands were transmitted to that howitzer. During the transmission the computer operator transposed number and announce quadrant 530m̸. As a result the following quadrant elevation error.

B-38. The following diagram (figure B-13) shows the importance of accurate quadrant elevation. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Actual)

\- <u>WHAT DATA SHOULD HAVE BEEN FIRED (Computed</u>)

= ERROR ≈ ±10 Meters

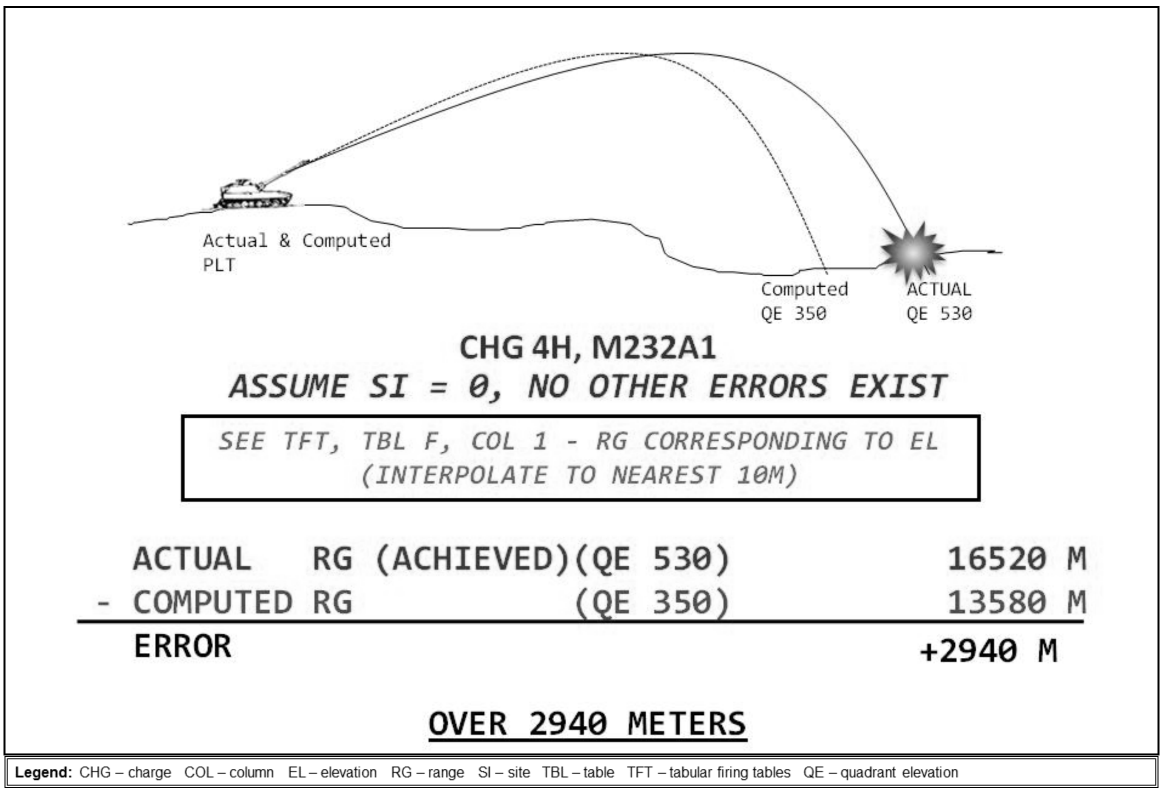


Figure B-13. Quadrant Error.

CHARGE ERROR

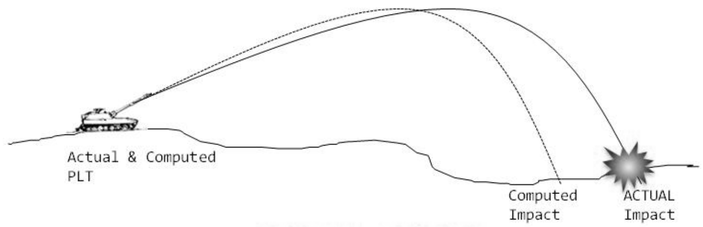
B-39. Numerous firing incidents have resulted from charge errors. This error can occur as a result of improper supervision of the cannon section chief, wrong charge announced in firing commands, or computed firing data for wrong charge. Also, poor ammunition management could cause this error. In the Example below (Figure B-14) The Section chief did not segregate properly the two lots of M232 propellant, causing this charge error.

B-40. The following diagram (figure B-14 on page B-14) shows the importance of the proper selection of charge. Use the following equation to determine the magnitude and direction of the error:

WHAT DATA WAS FIRED (Actual)

- WHAT DATA SHOULD HAVE BEEN FIRED (Computed)

= ERROR ≈ ±10 Meters



CHG 4H, M232A1

ASSUME SI = 0, NO OTHER ERRORS EXIST

Fire Commands for Howitzer #1: Fire Mission, #1 1 round, Shell HE Lot A/H Charge 4 Fuze Q, Deflection 3206, QE 530

SEE TFT, TBL F, COL 1 - RG CORRESPONDING TO EL (INTERPOLATE TO NEAREST 10M)

ACTUAL RG ACHIEVED (4 M232)	16140 M
- AFATDS RG COMPUTED (4 M232A1)	16520 M
ERROR	-380 M

Short 380 METERS

Legend: AFATDS – advanced field artillery tactical data system CHG – charge COL – column HE – high explosive PLT – platoon Q – quick RG – range SI – site TBL – table TFT – tabular firing tables QE – quadrant elevation

Figure B-14. Charge Error.

INHERENT ERRORS

B-41. Inherent errors cause dispersion from round to round even when firing the exact same firing data. The magnitudes of inherent errors are a function of probable error in range, deflection, and height of burst. Fire direction computers cannot account for these errors, but by being aware of them will avoid wasted time trying to correct them. The effects of inherent errors can be minimized by firing the most accurate charge and angle of fire for a given range. The effects of inherent errors are generally greatest when forcing a charge or lower than optimum. Some examples of inherent errors are discussed bellow:

- Conditions in the Bore
  - Variations in the projectile
    - Projectile Weight
    - Form of Rotating Band
    - Projectile Surface Finish
  - Variations in Propellant
    - Moisture Content
    - Arrangement of Powder Grains
    - Rate of Ignition
    - Propellant Temperature
  - Variations in Ram
    - Density and Depth
    - Centering
    - Bore Temperature
- Conditions in Carriage
  - Play in mechanisms (DF & QE)

  - Physical limitations in setting of scales
  - Non-uniform reaction to firing stress
- Conditions During Flight
  - Variations in air resistance
  - Projectile Weight
  - Muzzle Velocity
  - Form of Projectile
  - Variations in MET between firings
  - Changes in Wind
  - Changes in Air Density
  - Changes in Air Temperature

FIRING INCIDENT INVESTIGATIONS

B-42. Accurate and safe firing data is a function of procedure, training, discipline, and chain of command. If all factors are performed correctly, the result is accurate and safe firing data and accomplishment of the missions assigned artillery units. Independent checks are proactive, meaning that a majority of the checks occur prior to receiving a fire mission. This ensures the requested fires are timely as well as accurate.

B-43. When a forward observer requests fire on a specific target location, someone (other than the requester) checks the target plot as it relates to the location of friendly units and positively clears the fires and all fire support coordination measures on the situation map.

B-44. A verification of database information for the firing position means someone, normally the Battery XO, performs an independent verification of the firing position information prior to providing the data to the FDC.

B-45. As described earlier, independent checks are performed on each howitzer by the section chief to verify lay of the howitzer, emplaced retaining pins, prefire checks, charges, fuze settings, and set deflection and quadrant, as well as ensuring the announced firing data is applied as announced.

B-46. Independent checks are also performed in the FDC where the database must be verified, either as the information is input or as a total review once the entire database has been constructed. The checks are continuous since the FDC must verify any additions, changes, or deletions to the database as they occur.

B-47. This system of independent checks must be a continuous process, a discipline lived by all artillerymen rather than a simple set of rules. A review of recent accidents reveals that firing accidents fall into two main categories:

- Failure on the gunline to independently verify elements of a fire command prior to firing a round, especially charge and fuze setting.
- Failure within the FDC to maintain an accurate data base, or loss of situational awareness, particularly the location of lead elements.

B-48. Failure on the gunline to independently verify elements of a fire command prior to firing a round, especially charge and fuze setting. Section Chiefs and gunline supervisors too often are overwhelmed by a sense of competition and mission urgency. While both competition and speed of execution can be healthy motivators, it is unacceptable to sacrifice any aspect of gunline safety procedures to get a round down range faster. Unsupervised speed kills. Battery commanders and Platoon Leaders must supervise the gunline to ensure that safe firing practices and procedures are being followed.

B-49. Failure within the FDC to maintain an accurate data base, or loss of situational awareness, particularly the location of lead elements. Within the FDC there will always be multiple distractions to FDOs and Chiefs. It is very easy to neglect verification or accurately update activities, and in our haste to complete the mission, errors are made. The following information can be used to collect data during the course of an investigation. See DOD Instruction 6055.07 for specific and detailed direction on the procedure to be used in reporting/responding/investigating friendly fire incidents

- Description of the incident.
- Firing point information.
  - Accurate Firing Unit Location.
  - Range safety card firing point number.
  - Range safety card 13 April 2016.
  - Grid and altitude.
  - Are all howitzers within 200 meters of the firing point grid?
  - If not, was safety computed separately for the howitzer(s) outside of the 200 meter radius?
  - Was a quadrant of at least 267 mils established as the minimum quadrant (155mm only)?
  - Number of howitzers firing by type.
  - Accurate Weapon and Ammunition Information (FDC and Platoon Sergeant [PSG]).
  - Determine ammunition fired from FDC.
  - DA Form 581 from gunline and determine ammunition signed for.
  - Determine ammo remaining in battery area—on firing point, ammo trucks, etc.
  - Are there any discrepancies between what was signed for, what was fired, and what remains on hand?
  - Are there any restrictions on ammo, fuzes, or range by range control?
  - Is the ammo cleared for overhead firing (if applicable)?
  - Did range control restrict any rounds from being fired (Incendiary rounds because of wind speed or dry conditions)?
- Data on burst or impact from observer(s).
  - Accurate target location and size (OP).
  - Observer location and altitude.
  - Spottings.
  - Was it an impact or air burst?
  - How many rounds?
  - Azimuth to burst or back azimuth from crater.
  - If Azimuth—how was it obtained?
  - Height of Burst.
  - Estimated grid and altitude of burst.
  - Fragments of round or crater.
- Graphically portray information on a grid sheet as it is obtained (i.e. Plot information on chart in FDC).
  - Range safety card information.
  - Location of howitzer(s).
  - Location of burst.
- Data from FDC.
  - Were all personnel out of the FDC?
  - Secure current mission record of fire (DA Form 4504).
  - Secure previous mission record of fire forms.
  - Who has the last check before data leaves the FDC?
  - Secure Safety T.
  - Where is the Safety T displayed?
  - What was the primary and back-up means of computing data?
  - Registration corrections determined—secure record of fire (if applicable).
  - When was registration conducted?
  - Were registration corrections applied to safety data?
  - Accurate meteorological information.

  - Was MV Data in computer for the shell and charge fired?
  - Compare the record of fire data to data in AFATDS, CENTAUR, or chart.
  - General condition and organization of the FDC.
  - Compare the MET message to the MET entered in the computer.

Note: Remember, the key information from the FDC sent to the howitzers; "Was this data safe according to the current safety data and "T." The above information may be indicators to comment on or help determine why a mistake was made.

- Data from howitzers.
  - Were all personnel to the rear of the piece?
  - Secure the safety T on the howitzer and verify it is same as the FDC safety T.
  - Secure any other safety T's on the howitzers.
  - Was the correct safety "T" used?
  - Was the Section Chief safety certified?
  - 13 April 2016 Certified/Chief Name.
  - Secure the recorder's DA Form 4513-R; compare this to the FDC record of fire.
  - Record deflection on pantel. Bubbles level?
  - Record any correction counter data.
  - Record quadrant set off on howitzer. Bubble level?
  - When was the last time the chief performed the end for end and micrometer test?
  - Is there a correction factor to the sections gunners' quadrant?
  - Measure the quadrant using M1 gunner's quadrant.
  - Did the Section Chief use of the gunner's quadrant for the first mission?
  - Verify the sight picture.
  - Large values of displacement?
  - Note aiming point used, record the deflection corrections.
  - Secure the gunner's reference card, record and check information.
  - When was the last fire control alignment test performed? Check the DA Form 2408-4.
  - Check borescope date.
  - How was boresight verified?
  - Did Safety card authorize the shell and fuze fired?
  - Did they fire a restricted shell or fuze?
- Accurate weapon and ammunition information.
  - Was ammunition segregated by type, lot?
  - Were there any rounds prepared for firing?
  - Were any charges precut?
  - Were any fuzes preset?
  - Were any charges out of canisters?
  - Where were they stored?
- Lay and safety circles.
  - Secure the range safety card for the position.
  - Secure the safety computations.
  - Were two methods to compute safety completed?
  - Who computed safety?
  - Was he/she qualified to compute safety?
  - Secure survey data if applicable.
  - Who laid the battery?

  - Who safed the battery?
  - Was he/she safety qualified?
  - Was boresight verified? If so by who?
  - Were the lay and safety circles declinated?
  - Were the lay and safety circle "bumped"?
  - Were circles level and over OS?
  - Record AOF.
  - Were circles oriented using different methods?
  - Verify deflection between lay and safety circle.
  - Verify position with map spot: (location of OS, EOL, and battery).
  - For each howitzer list the XO's minimum quadrant, <Si, and PCR.
- Additional checks (if necessary).
  - If a time fuze was used, verify the sections proficiency in setting a time.
  - Compare the number of powder increments there with what should be there.
  - How long has the unit been in the position, and how long have they been firing?
  - Have they fired that shell and fuze combination prior to the incident?
  - Did the howitzer lose power just prior to the incident? If so, was power rammer checked when power was resumed (may have had partial ram.)?
  - Does the tube lose elevation after set?
  - Where did the round impact, detonate, in relationship to the gun target line?

Appendix C

Planning Ranges

C-2. This Appendix provides information on the minimum and maximum ranges for planning purposes for the following weapon systems:

- 105-mm (table C-1).
- M109A6 155-mm (table C-2).
- M777 155-mm (table C-3, page C-4).
- Multiple launch rocket system (MLRS)/High Mobility Artillery Rocket System (HIMARS) (table C-4, page C-6).

Table C-1. 105-mm Planning Ranges.

Projectile Category	*Projectile Model*	*Propellant Type*	*Indirect Fire*		*Direct Fire*
			Min Range (Meters)	*Max Range (Meters)*	*Min Range (Meters)*
HE	M1	M67	600	11400	600
HE	M760	M200	600	14000	600
WP	M60	M67	600	11400	600
Smoke	M84HC	M67	600	11400	600
ILLUM	M314A3	M67	800	9600	N/A
HE RAP	M548	M176	600	1500	600
HE RAP	M913	M229	600	20000	600
DPICM	M915	M200	1800	14200	N/A
Legend: HE – high explosive DPICM – dual purpose improved conventional munitions ILLUM – illumination MAX – maximum MIN – minimum RAP – rocket assisted projectile					

Table C-2. M109A6/M198 155-mm Planning Ranges.

Projectile Category	*Projectile Model*	*Propellant Type*	*Indirect Fire*	
			Min Range (Meters)	*Max Range (Meters)*
HE	M107 DC	M3A1	2700	9800
	M107 NC	M4A2	3100	14700
		M119A1	9700	18000
		M119A2	9700	18100
		M231	3400	11900
		M232/A1	7100	18100
	M795	M3A1	2200	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M203/A1	12300	22300
		M231	5200	11300

Table C-2. M109A6/M198 155-mm Planning Ranges (continued).

Projectile Category	***Projectile Model***	***Propellant Type***	***Indirect Fire***	
			***Min Range** (Meters)*	***Max Range** (Meters)*
		M232/A1	7200	22500
WP	M110WP M110A1WP M110A2WP	M3A1	2700	9800
		M4A2	3100	14700
		M119A1	9700	18000
		M119A2	9700	18100
		M231	3400	11900
		M232/A1	7100	18100
SMOKE	M116A1HC	M3A1	2700	9800
		M4A2	3100	14700
		M119A1	9700	18000
		M119A2	9700	18100
		M231	3400	11900
		M232/A1	7100	18100
APICM	M449A1	M3A1	2700	9800
		M4A2	3100	14700
		M119A1	9700	18000
		M119A2	9700	18100
		M231	3400	11900
		M232/A1	7100	18100
DPICM	M483A1	M3A1	2300	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M231	3000	11300
		M232/A1	7200	18200
ILLUM	M485A1 M485A2	M3A1	3000	9300
		M4A2	3500	14200
	M1066(IR)	M119A1	6300	17500
		M119A2	6500	17600
		M231	3800	11200
		M232/A1	5300	17400
HE RAP	M549	M4A2	7800	19500
		M119A1	10200	23400
		M119A2	10300	23500
		M232/A1	7700	23600
	M549A1	M4A2	7800	19500
		M119A1	10200	23400
		M119A2	10300	23500
		M203/A1	13400	29900

Table C-2. M109A6/M198 155-mm Planning Ranges (continued).

Projectile Category	*Projectile Model*	*Propellant Type*	*Indirect Fire*	
			Min Range (Meters)	*Max Range (Meters)*
		M232/A1	7700	29900
ADAM	M692 M731	M3A1	2300	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M231	3000	11300
		M232/A1	7200	18200
RAAM	M718 M718A1 M741	M3A1	2300	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M231	3000	11300
		M232/A1	7200	18200
WP2	M825 M825A1	M3A1	2200	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M203/A1	12300	22300
		M231	5200	11300
		M232/A1	7200	22500
DPICM-BB	M864	M4A2	3900	17000
		M119A1	4500	21600
		M119A2	4500	21600
		M203/A1	5400	27400
		M232/A1	7600	27700
SADARM	M898	M3A1	2200	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M203/A1	12300	22300
		M231	5200	11300
		M232/A1	7200	22500

Legend: ADAMS – area denial artillery minefield system APICM – anti-personnel improved conventional munition
BB – base bleed DPICM – dual-purpose improved conventional munition HE – high explosive DC – deep cavity
DPICM – dual purpose improved conventional munitions ILLUM – illumination MAX – maximum MIN – minimum
NC – normal cavity RAAMS – remote anti-armor artillery minefield system RAP – rocket assisted projectile
SADARM – sense and destroy armor WP – white phosphorous

Table C-3. M777 155-mm Planning Ranges.

Projectile Category	*Projectile Model*	*Propellant Type*	*Indirect Fire*	
			Min Range (Meters)	*Max Range (Meters)*
HE	M107 DC M107 NC	M3A1	2800	9900
		M4A2	3200	14800
		M119A1	12200	18200
		M119A2	12300	18200
		M231	3400	11900
		M232/A1	7200	18200
	M795	M3A1	2200	9000
		M4A2	2900	14500
		M119A1	9600	17800
		M119A2	9600	17900
		M203/A1	12300	22300
		M231	5200	11300
		M232/A1	7200*	22500
WP	M110WP M110A1WP M110A2WP	M3A1	2800	9900
		M4A2	3200	14800
		M119A1	12200	18200
		M119A2	12300	18200
		M231	3400	11900
		M232/A1	7200	18200
SMOKE	M116A1HC	M3A1	2800	9900
		M4A2	3200	14800
		M119A1	12200	18200
		M119A2	12300	18200
		M231	3400	11900
		M232/A1	7200	18200
APICM	M449A1	M3A1	2800	9900
		M4A2	3200	14800
		M119A1	12200	18200
		M119A2	12300	18200
		M231	3400	11900
		M232/A1	7200	18200
DPICM	M483A1	M3A1	2400	9200
		M4A2	3000	14600
		M119A1	12200	18000
		M119A2	12200	18100
		M231	3000	11300
		M232/A1	7300	18500

Table C-3. M777 155-mm Planning Ranges (continued).

Projectile Category	*Projectile Model*	*Propellant Type*	*Indirect Fire*	
			Min Range (Meters)	*Max Range (Meters)*
ILLUM	M485A1 M485A2 M1066(IR)	M3A1	3300	9200
		M4A2	3400	14300
		M119A1	10400	17600
		M119A2	10500	17700
		M231	3800	11200
		M232/A1	5600	17600
HE RAP	M549	M4A2	7900	19600
		M119A1	13000	23600
		M119A2	13000	23700
		M232/A1	7600	23800
	M549A1	M4A2	7900	19600
		M119A1	13000	23600
		M119A2	13000	23700
		M203/A1	16600	30300
		M232/A1	7600	30300
ADAM	M692 M731	M3A1	2400	9200
		M4A2	3000	14600
		M119A1	12200	18000
		M119A2	12200	18100
		M231	3000	11300
		M232/A1	7300	18500
RAAM	M718 M718A1 M741	M3A1	2400	9200
		M4A2	3000	14600
		M119A1	12200	18000
		M119A2	12200	18100
		M231	3000	11300
		M232/A1	7300	18500
WP2	M825 M825A1	M3A1	2400	9200
		M4A2	3000	14600
		M119A1	12200	18000
		M119A2	12200	18100
		M203/A1	15400	22500
		M231	3000	11300
		M232/A1	7300	22800
DPICM-BB	M864	M4A2	7800	17100
		M119A1	14200	21800
		M119A2	14200	21800

Table C-3. M777 155-mm Planning Ranges (continued).

Projectile Category	*Projectile Model*	*Propellant Type*	*Indirect Fire*	
			Min Range (Meters)	*Max Range (Meters)*
DPICM-BB	M864	M203/A1	18400	27800
		M232/A1	7700	28100
SADARM	M898	M3A1	2400	9200
		M4A2	3000	14600
		M119A1	12200	18000
		M119A2	12200	18100
		M203/A1	15400	22500
		M231	3000	11300
		M232/A1	7300	22800

Legend: ADAMS – area denial artillery minefield system APICM – anti-personnel improved conventional munition BB – base bleed DPICM – dual-purpose improved conventional munition HE – high explosive DC – deep cavity DPICM – dual purpose improved conventional munitions ILLUM – illumination MAX – maximum MIN – minimum NC – normal cavity RAAMS – remote anti-armor artillery minefield system RAP – rocket assisted projectile SADARM – sense and destroy armor WP – white phosphorous

Table C-4. MLRS/HIMARS Planning Ranges.

Projectile Category	*Target Types*	*Range (KM)*	*Payload (Sub-munitions)*	*Projectile Per Pod*
M26 Rocket	Personnel, Light armor, soft vehicles(stationary)	8-12	644 M77	6
M28A1	Practice firing on restrictive ranges	8-15	None	6
M26A1 Extended Range Rocket	Personnel, Light armor, soft vehicles(stationary)	15-45	522 M85	6
Guided Rocket	Personnel, Light armor, soft vehicles(stationary)	15-60	430 M85	6
MLRS Smart Tactical Rocket	Personnel, Light armor, soft vehicles (stationary & moving)	15-20	1-2 Smart Sub-munitions	6
ATACMS Block I	Personnel, Light armor, soft vehicles(stationary)	25-165	950 M74	1
ATACMS Block Ia	Personnel, and/or light materiel (stationary)	70-300	300 M74	1
ATACMS Block II	Moving Armor (BAT) Sitting armor/SSM TELs (P3I BAT)	35-140	13BATs or P3I BATs	1
ATACMS Block Iia	Moving Armor or Stationary (BAT) Sitting armor/SSM TELs (P3I BAT)	100-300	6 P3I BATs	1
M28 Practice Rocket	Practice Firing	8-32	None	6
M28A1 RRPR	Practice Firing on restrictive ranges	8-15	None	6

Legend: ATACMS **–** Army Tactical Missile System BAT – brilliant anti-tank KM – kilometer MLRS – multiple launch rocket system RRPR – reduced range practice rocket

Appendix D
Replot Procedures

In many instances, the refinement data transmitted by the observer after the FFE phase may not reflect the actual location of the target as defined by its grid coordinates and altitude. This inaccuracy results from errors in initial target location and errors in determining the initial site fired in an adjust-fire mission. For other units to mass fires on the same point and for the observer to accurately shift from a known point located by firing, the actual target location and altitude must be determined as accurately as possible. The replot process is used for this purpose. Targets are replotted on request of the observer or when directed by the FDO. Replot gives a deflection and range with which the target location can be polar plotted from the location of the firing unit. The manual replot procedures are the same for PD and VT fuzes. The procedures for the time fuze are somewhat different.

Note: The resulting target location reflects any errors that exist in the firing data and unit location. The replot grid and altitude may differ from the survey location of the same target for this reason.

REASONS FOR REPLOT

D-1. Inaccurate target location by the observer may result in an inaccurate altitude and an inaccurate site being determined by the FDC. For example, in figure D-1 on page D-2, the observer's inaccurate target location included an altitude greater than the actual target altitude. On the basis of the inaccurate target altitude, a false site is determined and used. The observer sends a subsequent correction of **DROP 400.** The firing data computed reflect the data needed to cause the round to impact at Point A. Because no adjustment has been made to altitude, the projectile continues beyond Point A and impacts over the target. As shown in figure D-2 on page D-2, the observer's next correction **(DROP 50)** results in accurate fire for effect. Figure D-2 also shows that there is a difference between the final pin location on the firing chart and the actual target location. Target replot is required to correct for this error. Replot procedures use successive approximation to determine the true site and the actual (replot) range and deflection to the target.

D-2. Requirements for replot are as follows:

- A map.
- Accurate refinement data from the observer.
- Valid GFT setting that accurately accounts for the nonstandard conditions existing at the time of firing.

D-3. These elements will ensure that the replot procedure is as accurate as possible. Should the GFT setting or firing chart be later corrected to more accurately reflect the conditions that existed when the mission was fired, the replot should be recomputed with the more accurate data.

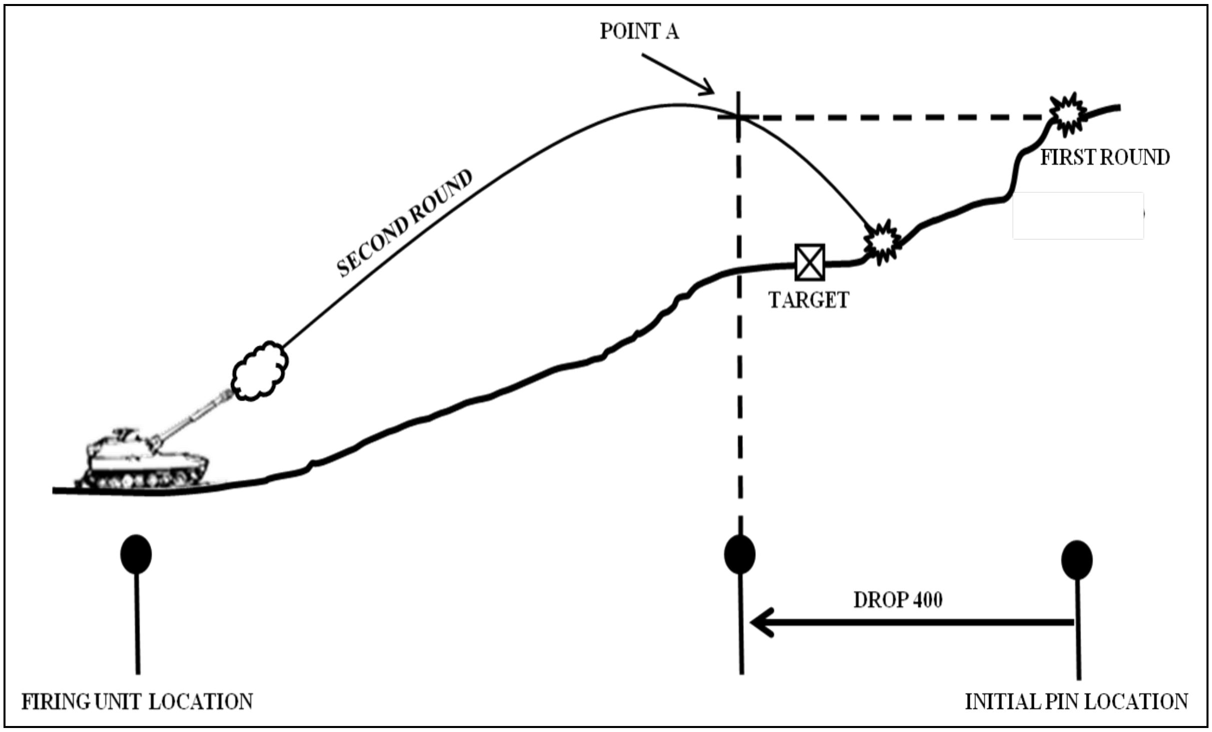


Figure D-1. Initial Target Location.

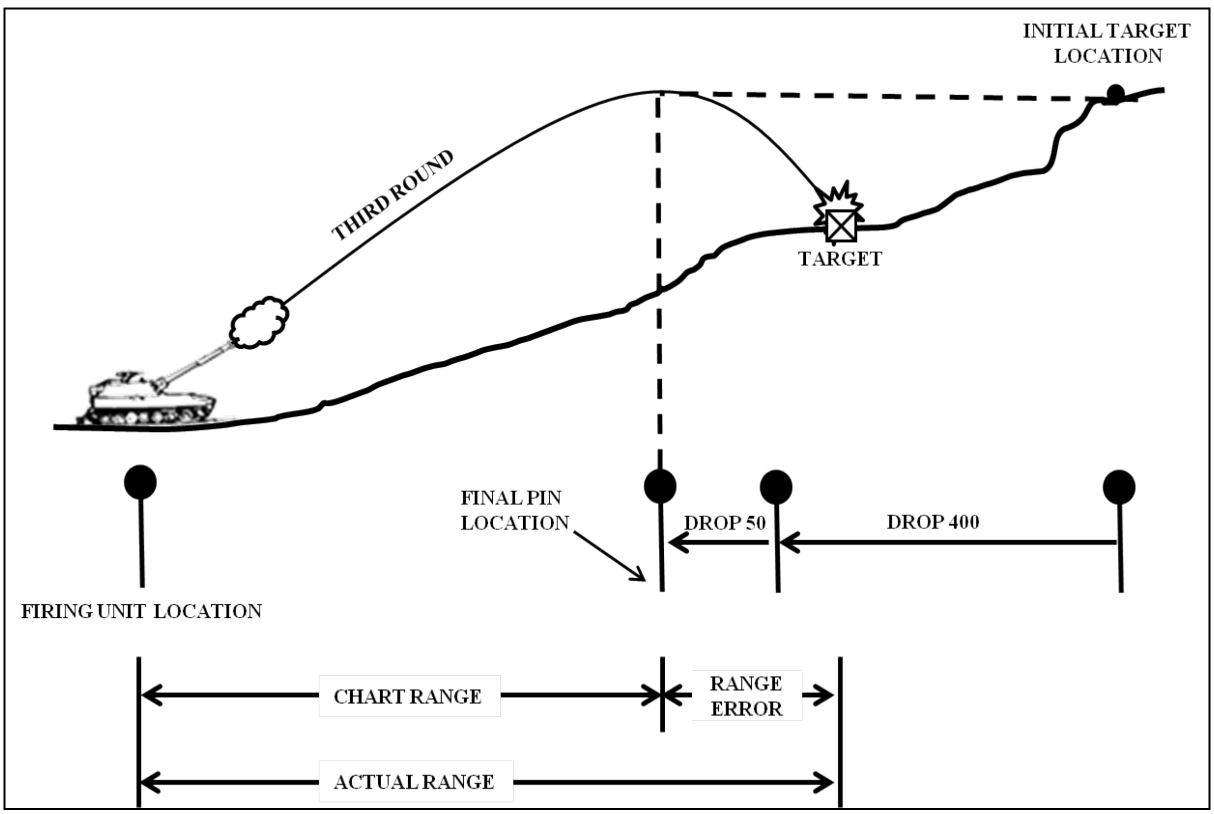


Figure D-2. Observer's Final Correction.

REPLOT WITH PD AND VT FUZES

D-4. **Replot Deflection**. The replot (true) deflection to the target may or may not be the final howitzer deflection. Because drift may have changed during the conduct of the adjustment, determine the true total deflection correction as shown in table D-1. (See figure D-3 on page D-4.)

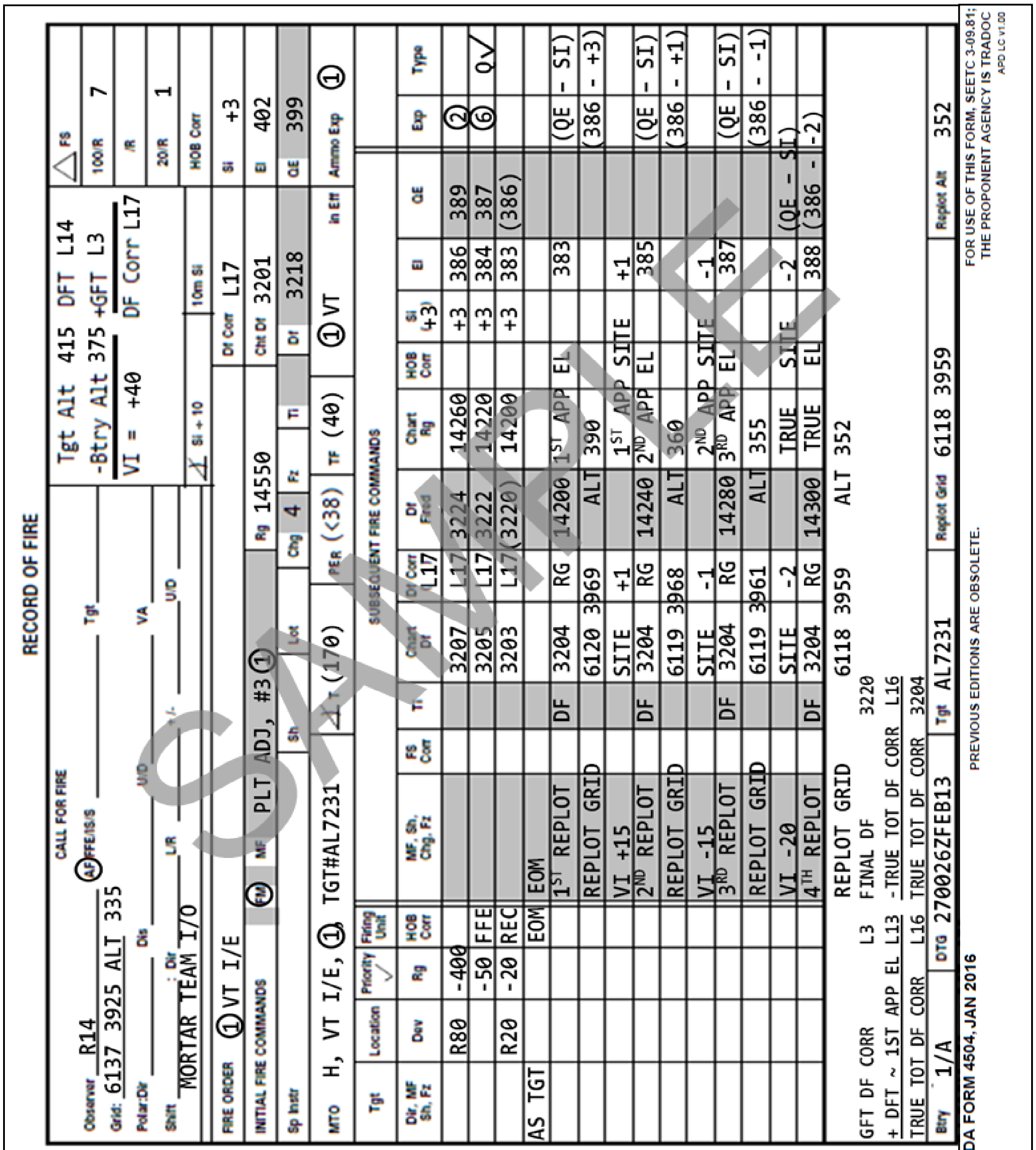
Table D-1. Determining Replot Deflection.

STEP	*ACTION*
1	HCO plots observer's refinement and determines and announces chart data.
2	Determine final firing data from the observer's refinement, and place the data in the subsequent fire commands blocks of the ROF in parentheses.
3	The computer determines the first apparent elevation by algebraically subtracting site from the final quadrant elevation.
4	The computer determines drift corresponding to the first apparent elevation.
5	The computer adds the drift determined in step 4 to the GFT deflection correction in the lower computational space. The result is the true total deflection correction. **GFT DF CORR + DRIFT AT 1ST AP EL = TRUE TOTAL DF CORR**
6	In the lower computational space, the computer determines the replot deflection by algebraically subtracting the true total deflection correction from the final deflection. **FINAL DF – TRUE TOTAL DF CORR = REPLOT DF**
Legend: CORR – correction DF – deflection EL – elevation GFT – graphical firing table HCO – horizontal control operator ROF – record of fire	

D-5. **Replot Grid and Altitude.** Determine the replot grid and altitude by successive approximation: The procedures are described in table D-2. See figure D-3 on page D-4 for an example ROF.

Table D-2. Determining Replot Grid and Altitude by Successive Approximation.

STEP	*ACTION*
1	The Computer determines the replot deflection as described in Table D-1 and announces it to the HCO.
2	Computer reads the range corresponding to the apparent elevation under the MHL with the EGL over the apparent elevation and announces this range to the HCO.
3	The HCO polar plots the target from the base piece at the deflection and range announced and determines and announces the grid to the VCO. The Computer/RTO records the grid in the subsequent fire commands block.
4	The VCO plots the replot grid and determines the map altitude of the replotted location. Using the new altitude and range last announced, the VCO determines the apparent site. The Computer/RTO records announced site in the subsequent fire commands block.
5	The computer determines if the apparent site is within 1 mil of the site fired. 1. If the apparent site is within 1 mil of the site fired, the apparent site is true site. To determine true elevation, algebraically subtract the true site from the final quadrant **(FINAL QE – TRUE SITE = TRUE ELEVATION).** The replot deflection remains the same throughout the process of successive approximation. Announce the final replot deflection and range to the HCO. The HCO determines and announces replot grid. The Computer/RTO records the replot grid and altitude used to determine true site in the administrative blocks in the lower computational space. This altitude is the replot altitude. 2. If the site is not within 1 mil of the last computed site, repeat steps 1 through 4 above until a true site is determined that is ± 1 mil of the last computed site. Subtract the computed site from the final quadrant elevation to determine the new apparent elevation.
Legend: HCO – horizontal control operator EGL – elevation gauge line MHL – manufacturer's hair line QE – quadrant elevation RTO – radio telephone operator VCO – vertical control operator	



RECORD OF FIRE

CALL FOR FIRE — Observer: R14; (AF) FFE/IS/S; Tgt: ; Grid: 6137 3925 ALT 335; Polar: Dir ; Dis ; U/D ; VA ; Shift: ; Dir ; L/R ; +/- ; U/D ; MORTAR TEAM I/O	Tgt Alt 415 DFT L14 -Btry Alt 375 +GFT L3 VI = +40 DF Corr L17 ∡ Si + 10; 10m Si	△ FS; 100/R 7; /R; 20/R 1; HOB Corr
FIRE ORDER ① VT I/E	Df Corr L17	Si +3
INITIAL FIRE COMMANDS (FM) MF PLT ADJ, #3 ①; Rg 14550	Cht Df 3201	El 402
Sp Instr; Sh; Lot; Chg 4; Fz; Ti	Df 3218	QE 399
MTO H, VT I/E, ①, TGT#AL7231; ∡T (170); PER (<38); TF (40)	① VT in Eff	Ammo Exp ①

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority ✓ / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart Df	Df Corr L17	Df Fired	Chart Rg	HOB Corr	Si (+3)	El	QE	Exp	Type
	R80	-400					3207	L17	3224	14260		+3	386	389	②	
		-50	FFE				3205	L17	3222	14220		+3	384	387	⑥	Q✓
	R20	-20	REC				3203	L17	(3220)	14200		+3	383	(386)		
AS TGT			EOM	EOM												
				1ST REPLOT		DF	3204	RG	14200	1ST APP	EL		383		(QE	- SI)
				REPLOT GRID			6120	3969	ALT	390					(386	- +3)
				VI +15			SITE	+1		1ST APP	SITE		+1			
				2ND REPLOT		DF	3204	RG	14240	2ND APP	EL		385		(QE	- SI)
				REPLOT GRID			6119	3968	ALT	360					(386	- +1)
				VI -15			SITE	-1		2ND APP	SITE		-1			
				3RD REPLOT		DF	3204	RG	14280	3RD APP	EL		387		(QE	- SI)
				REPLOT GRID			6119	3961	ALT	355					(386	- -1)
				VI -20			SITE	-2		TRUE	SITE		-2	(QE - SI)		
				4TH REPLOT		DF	3204	RG	14300	TRUE	EL		388	(386 -	-2)	

REPLOT GRID 6118 3959 ALT 352

GFT DF CORR L3 | FINAL DF 3220

+ DFT ~ 1ST APP EL L13 | -TRUE TOT DF CORR L16

TRUE TOT DF CORR L16 | TRUE TOT DF CORR 3204

Btry	DTG	Tgt	Replot Grid	Replot Alt
1/A	270026ZFEB13	AL7231	6118 3959	352

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Legend:

ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CHG – charge
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
QE – quadrant elevation
REC – record
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure D-3. Example Completed Record of Fire for Replot with Fuze PD.

REPLOT WITH TIME FUZE

D-6. When a target is attacked with a mechanical time fuze, the observer adjusts the height of burst to 20 meters above the target. The final fuze setting provides an accurate representation of the target location and the altitude of a point 20 meters above the target. Consequently, when the time gauge line is placed over the final time, the range and 100/R (read under the MHL) and the elevation and drift correction (read under the elevation gauge line as a function of elevation) are true. The replot grid and altitude can then be determined (See figure D-4.)

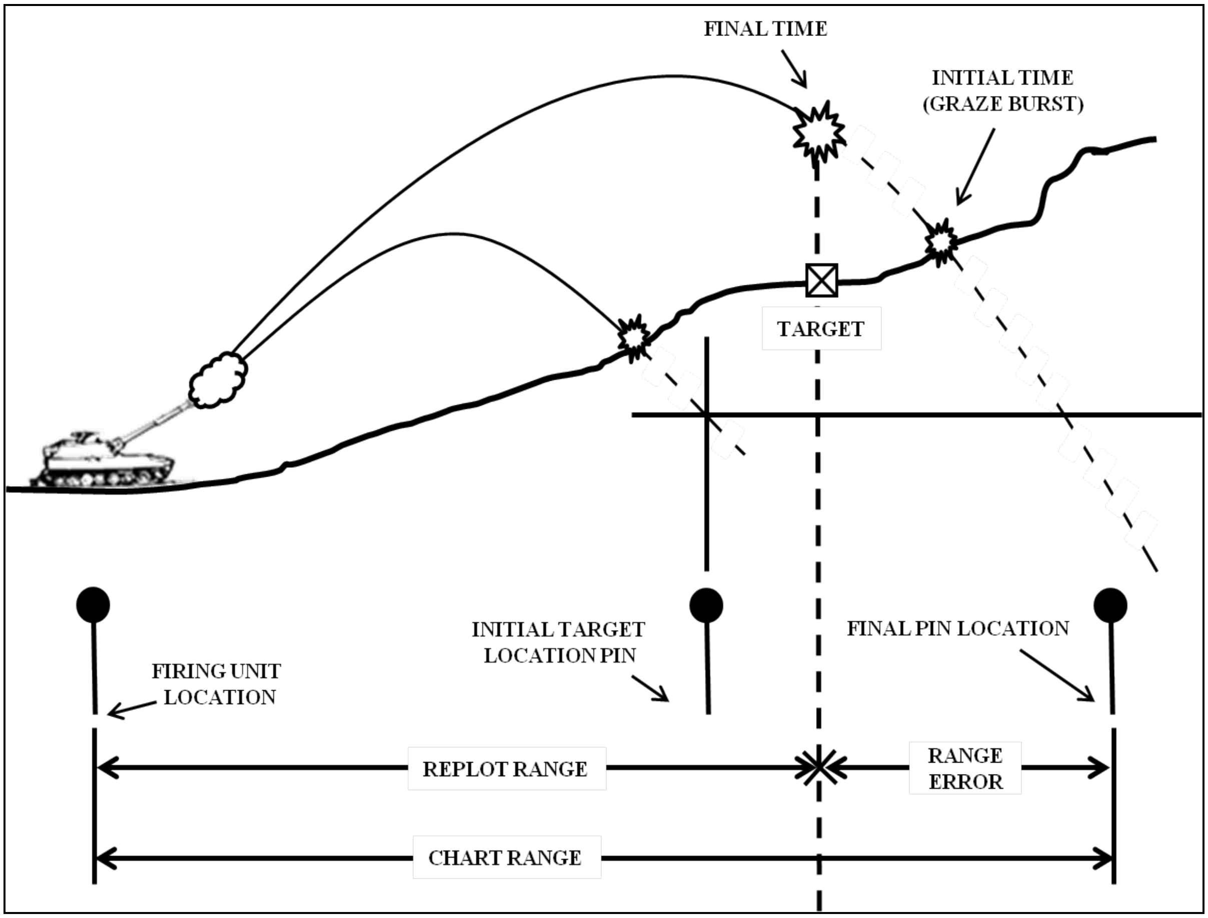


Figure D-4. Time Replot.

TIME REFINEMENT

D-7. To accurately replot targets when firing fuze time, determine refinement data to correct for inaccurate HOB.

D-8. During the adjustment phase of the mission, the observer usually adjusts the trajectory to within 50 meters of the target before requesting FFE rounds. Upon completion of the FFE phase, the observer sends refinement data to the FDC. Elements of refinement may include deviation, range, and/or HOB. These refinement data place the mean point of the FFE bursts over the actual target location, thereby allowing the FDC to compute accurate data to the target if future fires are required. Application of refinement is a requirement for replot of targets, which allows for transfer and massing of fires.

D-9. Fuze time procedures are slightly different. During the time adjustment phase of the mission, the FDC applies ▲FS to the fuze setting to correct for the difference in the height of burst above the target.

Therefore, when he requests fire for effect, we assume the observer has adjusted the height of burst to 20 meters. Therefore, it can be assumed that the final time fuze setting is accurate. Consequently, when the time gauge line (TGL) is over the fire-for-effect time, the range read underneath the manufacturer's hairline is assumed to be the correct range and the elevation read under the elevation gauge line (EGL) is assumed to be the correct elevation. Therefore, no successive approximation is required. To obtain replot data, the Computer places the TGL over the FFE time, reads 100/R and the range under the MHL, and reads the elevation under the EGL.

D-10. The procedures for determining replot deflection, grid and altitude with a time fuze when the observer has sent no target location refinements are found in table D-3 and table D-4.

Table D-3. Determining Replot Deflection Without Target Refinements.

STEP	***ACTION***
1	The Computer places the TGL over the final time
2	The Computer determines replot range and 100/R under the MHL and true elevation under EGL.
3	The Computer places the MHL over the elevation determined in step 2, and determines drift.
4	The computer determines the true total deflection correction by adding the drift from step 3 to the GFT deflection correction. **DRIFT + GFT DF CORR = TRUE DF CORR.**
5	The computer determines the replot deflection by subtracting the true total deflection correction from the final deflection fired. **FINAL DF FIRED – TRUE DF CORR = REPLOT DF**
Legend: CORR – correction DF – deflection EGL – elevation gauge line GFT – graphical firing table MHL – manufacturer's hair line TGL time gauge line	

Table D-4. Determining Replot Grid and Altitude Without Target Refinements.

STEP	***ACTION***
1	The Computer determines replot range and deflection as described in Table D-3, steps 1 through 5.
2	Using the replot range and deflection, the HCO polar plats the target and determines the replot grid.
3	The Computer determines true elevation by placing the MHL on the replot range and determines elevation from the EGL. The Computer then algebraically subtracts true elevation from the final quadrant elevation to determine true total site. **FINAL QE – TRUE EL = TRUE TOTAL SITE**
4	The Computer determines true ground site by algebraically subtracting the value of 20/R (from replot range 100/R) from the true total site determined in step 3. **TRUE TOTAL SITE – 20/R = TRUE GROUND SITE**
5	Using the GST, the VCO determines the VI using the true ground site and replot range as entry arguments.
6	The VCO algebraically adds the VI to the firing unit altitude to determine the replot altitude. **VI + FIRING UNIT ALTITUDE = REPLOT ALTITUDE**
Legend: EGL – elevation gauge line GST – graphical site table HCO – horizontal control operator MHL – manufacturer's hair line QE – quadrant elevation VCO – vertical control operator VI – vertical interval	

D-11. The procedures for determining replot grid, altitude, and refinement data when the observer has sent target location refinements are outlined in table D-5 on page D-7. Separate procedures for refinement data determination are required for refinements **with** or **without** HOB corrections.

D-12. For refinements without a HOB correction, deviation and/or range only, the refinement data include a correction for range and/or deviation corrections, but no correction for HOB. It must be assumed that the observer adjusted the HOB to 20 meters. The HCO plots the corrections on the firing chart and determines new chart 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 phase of the mission) 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 and quadrant elevation to fire, replot range and altitude are determined.

D-13. For refinements that include a HOB correction, FDC personnel initially ignore the HOB correction. If the HOB correction were considered in determining a new fuze setting, and error would be introduced in to the replot location by the ▲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 and determine the refined deflection, quadrant elevation, and fuze setting described above. It is assumed that these data will produce a mean burst location of range correct, line, and HOB of 30 meters. The computer now applies the HOB 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 refined quadrant elevation for a 20 m HOB. With the fuze setting and quadrant elevation to fire, replot range and altitude are determined.

Table D-5. Determining Replot Grid, Altitude, and Refinement Data (Time Fuze) with Target Refinements.

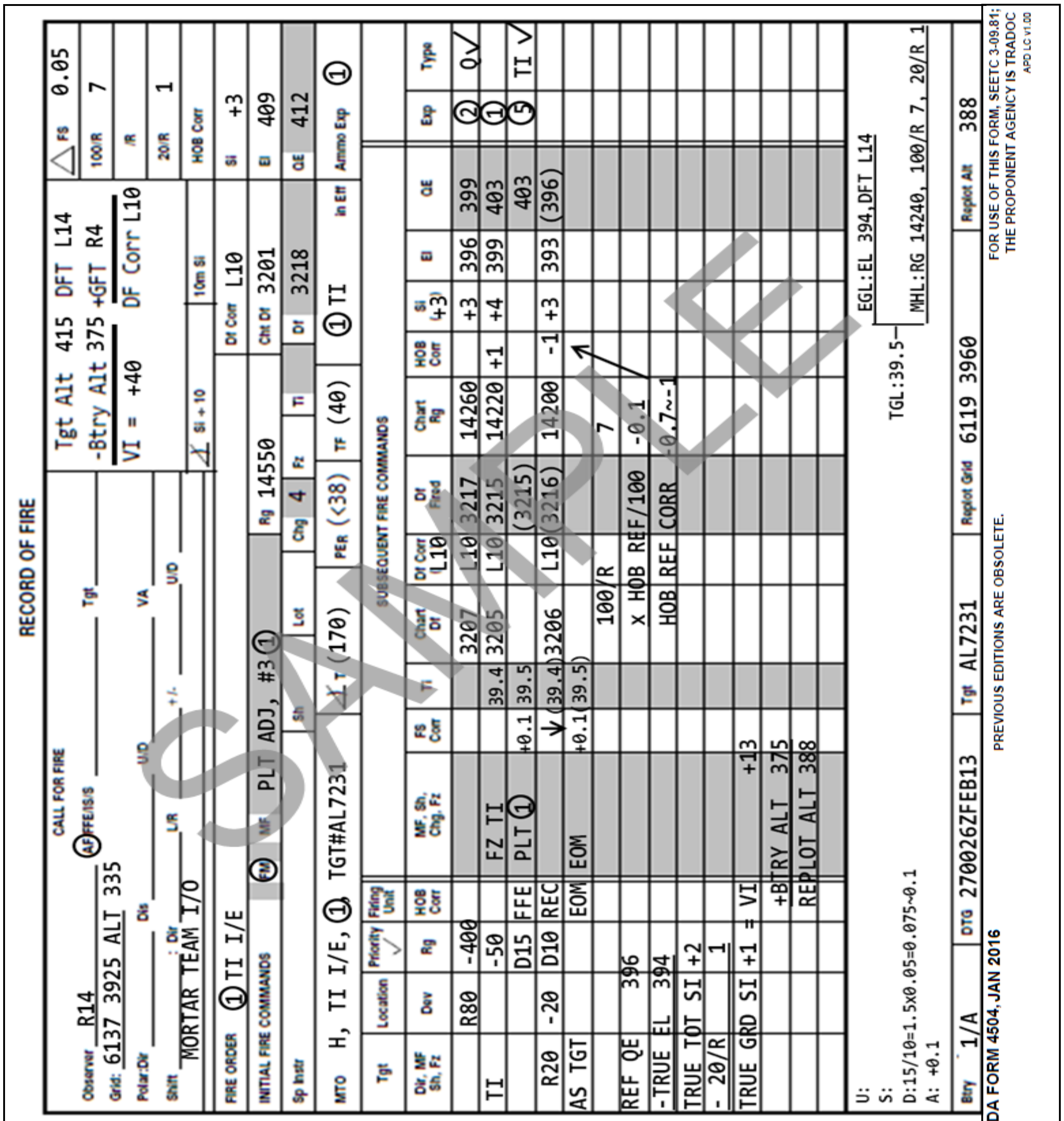
STEP	***ACTION***
1	The HCO plots any deviation and/or range correction and determines new chart data. The new chart deflection is the REPLOT DF.
2	The Computer determines a new deflection to fire and new elevation based off the new chart data and records the data on the record line in the subsequent fire commands block.
3	The Computer determines refinement data. Two different procedures are required for refinements with or without HOB correction.
3a	DETERMINING REFINEMENT DATA WITHOUT A HOB CORRECTION. To determine the refinement time, the computer algebraically applies the total fuze correction from the time adjustment phase of the mission to the new time determined. **TOTAL FZ CORR + NEW TIME = REFINEMENT TI.** The refinement deflection is the algebraic sum of new chart deflection plus the total deflection correction used during the mission. **NEW CHART DF + TOTAL DF CORR = REFINEMENT DF.** The refinement quadrant elevation is the algebraic sum of the new elevation and the total site fired. **NEW EL + TOTAL SITE = REFINEMENT QE.**

Table D-5. Determining Replot Grid, Altitude, and Refinement Data (Time Fuze) with Target Refinements (continued).

STEP	*ACTION*
3b	DETERMINING REFINEMENT DATA WITH A HOB CORRECTION. To determine the refinement time, the computer algebraically applies the total fuze correction from the time adjustment phase of the mission to the new time determined. **TOTAL FZ CORR + NEW TIME = REFINEMENT TI.** The refinement deflection is the algebraic sum of new chart deflection plus the total deflection correction used during the mission. **NEW CHART DF + TOTAL DF CORR = REFINEMENT DF.** Use the value of 100/R determined initially, and multiply this value by the HOB refinement divided by 100. Express the result to the nearest 1 mil. **100/R x (HOB REFINEMENT ÷ 100) = HOB REFINEMENT CORR.** Algebraically add the HOB refinement correction determined to the total site used during the time adjustment phase of the mission. **HOB REFINEMENT CORR + TOTAL SITE = NEW TOTAL SITE.** Algebraically apply the new total site and new elevation determined in step 2 to determine the refinement quadrant elevation. **NEW TOTAL SITE + NEW EL = REFINEMENT QE.**
4	The Computer places the TGL over the REFINEMENT TIME.
5	The Computer determines REPLOT RANGE and 100/R under the MHL and true elevation under the EGL. This is recorded in the lower computational space.
7	The computer announces the REPLOT RANGE to the HCO. Using the REPLOT RANGE and REPLOT DF (step 1), the HCO plots the target, determines and announces REPLOT GRID.
8	The Computer then algebraically subtracts true elevation from the REFINEMENT QUADRANT ELEVATION to determine true total site. **REFINEMENT QE – TRUE EL = TRUE TOTAL SITE**
9	The Computer determines true ground site by algebraically subtracting the value of 20/R (from replot range 100/R determined in step 5) from the true total site determined in step 3. **TRUE TOTAL SITE – 20/R = TRUE GROUND SITE**
10	Using the GST, the VCO determines the VI using the true ground site and REPLOT RANGE.
11	The VCO algebraically adds the VI to the battery altitude to determine the REPLOT ALTITUDE.
Legend: CORR – correction DF – deflection EGL – elevation gauge line EL – elevation FZ – fuze GST – graphical site table HCO – horizontal control operator HOB – height of burst MHL – manufacturer's hair line QE – quadrant elevation TGL – time gauge line TI – time VCO – vertical control operator	

D-14. See figure D-5 (page D-9) for an example of a completed ROF for replot procedures using fuze time. The example uses the following GFT Setting:

GFT 1/A, Chg 4, Lot A/H, Rg 14500, El 410, Ti 40.7 (M767)
Tot Df Corr L10, GFT Df Corr R4



RECORD OF FIRE

CALL FOR FIRE

Observer R14 (AF) FFE/IS/S Tgt

Grid: 6137 3925 ALT 335

Polar:Dir Dis U/D VA

Shift : Dir L/R +/- U/D

MORTAR TEAM I/O

Tgt Alt 415 DFT L14

-Btry Alt 375 +GFT R4

VI = +40 DF Corr L10

Si + 10 | 10m Si

△ FS	0.05
100/R	7
/R	
20/R	1
HOB Corr	

FIRE ORDER (1) TI I/E | Df Corr L10 | Si +3

INITIAL FIRE COMMANDS (FM) MF PLT ADJ, #3 (1) | Rg 14550 | Cht Df 3201 | El 409

Sp Instr | Sh | Lot | Chg 4 | Fz | Ti | Df 3218 | QE 412

MTO H, TI I/E, (1), TGT#AL7231 | ∡T (170) | PER (<38) | TF (40) | (1) TI | In Eff | Ammo Exp (1)

SUBSEQUENT FIRE COMMANDS

Tgt Dir, MF Sh, Fz	Location Dev	Priority Rg	Firing Unit HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart Df	Df Corr (L10)	Df Fired	Chart Rg	HOB Corr	Si (+3)	El	QE	Exp	Type
	R80	-400					3207	L10	3217	14260		+3	396	399	(2)	Q✓
TI		-50		FZ TI		39.4	3205	L10	3215	14220	+1	+4	399	403	(1)	
		D15	FFE	PLT (1)	+0.1	39.5			(3215)					403	(5)	TI ✓
R20	-20	D10	REC		↓	(39.4)	3206	L10	(3216)	14200	-1	+3	393	(396)		
AS TGT			EOM	EOM	+0.1	(39.5)										
							100/R			7						
REF QE	396						x HOB REF/100			-0.1						
-TRUE EL	394						HOB REF CORR			-0.7~-1						
TRUE TOT SI	+2															
- 20/R	1															
TRUE GRD SI	+1 = VI			+13												
				+BTRY ALT 375												
				REPLOT ALT 388												

U:
S:
D:15/10=1.5x0.05=0.075~0.1
A: +0.1

TGL:39.5 — EGL:EL 394,DFT L14 / MHL:RG 14240, 100/R 7, 20/R 1

Btry 1/A | DTG 270026ZFEB13 | Tgt AL7231 | Replot Grid 6119 3960 | Replot Alt 388

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Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CHG – charge
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EGL – elevation gauge line
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L/R – left/right
MF – method of fire
MHL – manufacturer's hair line
MTO – message to observer
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
REC – record
REF – refinement
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGL – time gauge line
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure D-5. Example of a Completed ROF for Replot With Fuze Time (Deviation, Range, and HOB Refinement).

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Appendix E

Automated FDC

While the means of technical fire direction is different, the basic operation of an automated FDC is similar to that of a manual FDC. The principles of mission processing data flow and independent checks remain constant in the automated FDC.

PERSONNEL

E-1. Duties of the **FDO and Chief Fire Control Sergeant** are the same as in a manual FDC. The equivalent USMC billet description is Operations Chief.

E-2. **Fire Direction Specialist.** The Senior Fire Direction Specialist (Computer) operates the automated system that is the primary means of determining firing data. He is also responsible for the transmission of digital fire commands to the howitzer sections if the primary automated system is digitally linked to the howitzers. The equivalent USMC billet description is Operations Assistant.

E-3. **Fire Direction Specialist** (USMC–Fire Control Man).

- **Recorder.** The recorder maintains the record of fire. The recorder is also responsible for the transmission of voice fire commands and pertinent reports to the howitzers section if required.
- **HCO.** The HCO operates the second automated system, providing the second independent check to the primary automated system operated by the computer. The HCO is commonly referred to as the Secondary Box Operator in the automated FDC.
- **VCO.** The VCO maintains a firing chart and follows each mission. The firing chart can be utilized as a tertiary check to the automated system should the need arise or as a primary means of data computation should automated systems fail.

FIRE ORDER

E-4. The FDO considers the same factors when determining a fire order in an automated or manual FDC, and the order and elements of the fire order remain the same. The biggest difference between the fire order for an automated FDC and for a manual FDC is the SOP. On the basis of the computer's ability to determine individual piece firing data and the automated programs, certain elements would be standardized differently.

E-5. **Adjusting Element/Method of Fire of the Adjusting Element.** On the basis of the computer's ability to compute firing data based on individual piece locations, muzzle velocities, and aimpoints, the use of base piece is not necessary. However, a base piece should be selected for ease of transition from automated to manual procedures. Depending on the automated system's programming, it may automatically select an adjusting piece in sequential order, or the operator may have to input an adjusting piece. Method of fire of the adjusting element would be included in the SOP, which may or may not be a programmed automated system default.

E-6. **Basis for Corrections.** The SOP for this element should reflect the primary means of computing firing data.

E-7. **Distribution.** In a manual FDC, the normal sheaf is parallel. In an automated FDC, the normal or default sheaf will be the default sheaf programmed into the automated system.

E-8. **Ammunition Lot and Charge.** The SOP for this element will allow the automated system to select the lot and charge to fire on the basis of its programmed selection routines. Safety constraints, availability of registration corrections, and muzzle velocity information, are additional considerations when determining the SOP.

E-9. **Target Number.** The SOP for this element is normally the next available, as in manual gunnery. The computer may or may not be programmed to automatically assign a target number.

FIRE COMMANDS

E-10. Fire commands for automated gunnery are exactly the same as for manual gunnery. Depending on the automated systems in use, fire commands may be transmitted by voice or digitally to the howitzer(s).

CREW DUTIES FOR THE AUTOMATED FDC

E-11. The procedures in Table E-1 should be used to facilitate mission processing and ensure accuracy and responsiveness. The focus of mission processing is on a clear, consistent flow of information. This will facilitate the many concurrent actions required to process a mission in a timely and accurate fashion. Concurrent actions by FDC personnel are denoted as sub-steps in table E-1. See figure E-1 (on page E-4) for a completed record of fire for automated mission processing.

Table E-1. Automated Mission Processing.

STEP	***ACTION***
1	**RTO** receives and records the Call for Fire (CFF), authenticates if necessary, and announces ***"Fire Mission"*** to the FDC. All FDC personnel announce ***"Fire Mission".***
2	**RTO** announces the CFF to the FDC in the three transmission format. The **Recorder** reads back each transmission and records information on the record of fire (ROF), ensuring all personnel within the FDC can hear the information.
2a	**Computer and HCO** input the target location into the automated system. The **VCO** records target location and plots target on the chart, determines chart range and deflection.
2b	**FDO** plots the target on the situation map and verifies it is safe and does not violate any fire support coordination measures and extracts target altitude (if necessary). **Recorder** reads back the announced target altitude and records it on the ROF. **Computer and HCO** input the target altitude into the automated system. The **VCO** records target altitude and determines site. **FDO** decides how to attack the target and issues the fire order (FO) to the FDC. **Recorder** reads back the announced FO and records it on the ROF.
3	**Computer and HCO** input the relevant FO information into the automated system (**Chief** monitors) in order to analyze the firing solution. The **Recorder** records initial fire commands on record of fire up to and including fuze. This is based on the CFF and FO.
3a	**RTO** composes and transmits Message to Observer (MTO) according to the CFF and FO (**FDO** monitors). **Recorder** records MTO on the record of fire.
4	Upon inputting analyzing the input data, the **Computer and HCO** ensure both sets of independent data from two separate automated systems correspond with each other.
4a	**Computer** announces range, for example, ***"Range, 5890."***
4b	**HCO** announces ***"Check"* or *"Hold"*** (± 0 meters).
4c	If ***"Check"*** is announced, **Computer** can proceed to deflection check. If ***"Hold"*** is announced, **Chief** verifies automated systems and determines the issue effecting the determination of range.
4d	**Computer** announces deflection, for example, ***"Deflection 3286."***
4e	**HCO** announces ***"Check"*** or ***"Hold"*** (± 0 mils). (±1 mil, Primary to Backup AFATDS/ ±3 mils Primary AFATDS to Centaur)

Table E-1. Automated Mission Processing (continued).

STEP	***ACTION***
4f	If ***"Check"*** is announced, **Computer** can proceed to quadrant elevation check. If ***"Hold"*** is announced, **Chief** verifies automated systems and determines the issue effecting the determination of deflection.
4g	**Computer** announces quadrant elevation, for example, ***"Quadrant 286."***
4h	**HCO** announces ***"Check"*** or ***"Hold"*** (± 0 mils).
4i	If ***"Check"*** is announced, **Computer** can proceed to fire command verification. If ***"Hold"*** is announced, **Chief** verifies automated systems and determines the issue effecting the determination of quadrant.
5	Computer verifies fire commands with FDO or Chief: Ensures fire commands accurately reflect the FO. If element of the fire command reflects the FO, then ***"Check"*** is announced. If element of the fire command does not reflect the FO, then ***"Hold"*** is announced. Ensures the data are safe according to the safety T (if applicable) If data is safe, announce ***"Safe."*** If data is unsafe, announce ***"Unsafe"*** and state the reason why; for example, ***"Unsafe, violates min QE."***
5a	**Recorder** records the remaining fire commands on the record of fire during the verification process (**Chief** inspects).
6	If fire commands accurately reflect the FO, and the data are safe, **Computer** digitally transmits fire commands to howitzer(s). If in degraded (voice) operations, the Recorder will transmit the voice fire commands to the howitzer(s).
7	**Recorder** polices the ROF.
7a	**VCO** orients target grid on firing charts, determine Angle T (if able) and awaits any subsequent corrections from the observer.
Legend: AFATDS – Advanced Field Artillery Tactical Data System CFF – call for fire FDC – fire direction center FO – fire order HCO – horizontal control operator MTO – message to observer QE – quadrant elevation ROF – record of fire RTO – radio telephone operator VCO – vertical control operator	

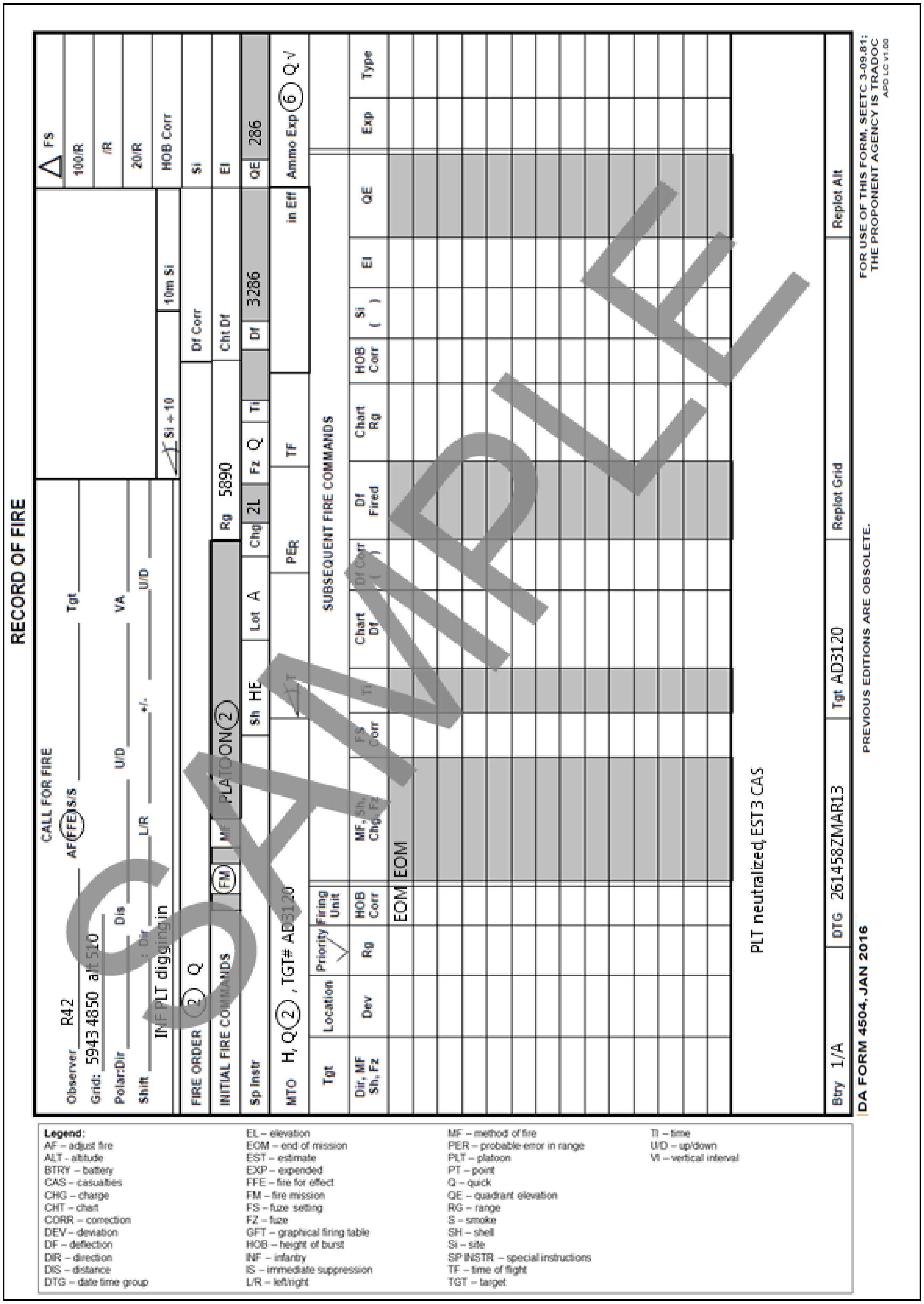

Figure E-1. Sample Record of Fire for Automated Fire Mission Processing.

ESTABLISH A MANUAL BACKUP FOR AUTOMATED OPERATIONS

E-12. **Concept.** The manual backup should be set up to allow the automated FDC to continue operations should one or more automated systems fail. **Manual backup should be established as a form of “position improvement” and should not impede setup or processing with automated means**. The manual backup also serves as a basis of a rapid independent check to the automated solution. The basis for the manual backup is that a piece will be designated as the base piece. The location of this piece is plotted on the firing chart. GFT settings are derived by using this howitzer and reflect all measured nonstandard conditions effecting the firing solution. Once the FDC converts from automated to manual operations, all adjustments are conducted with the base piece. All ranges are measured from base piece to the center of the target and all data computed reflects base piece muzzle velocity and location. When the observer requests fire for effect, the adjusted data from base piece is converted to data for the **remaining pieces by applying special corrections, or terrain gun position corrections (TGPCs).** These corrections take into account the differences in piece locations, propellant temperatures, and the differences in shooting strength for each individual howitzer. TGPCs can be determined by using automated means or the Ml7/M19 plotting board.

E-13. **Establishment of the Manual Backup.** The manual backup is established in five steps as follows:

- Select a base piece.
- Construct a surveyed firing chart.
- Determine and apply GFT setting(s).
- Determine and apply TGPCs.

E-14. Table E-2 elaborates on these steps.

Table E-2. Establishing a Manual Backup.

STEP	*ACTION*
1	**SELECT A BASE PIECE.** For ease in the computation of special corrections or accuracy when firing only base piece data (parallel sheaf), the base piece should be a howitzer close to the center of battery (COB). Ideally the base piece would have the most average shooting strength of all howitzers in the firing unit. The howitzer nearest the COB is determined by examining the automated system COB and individual howitzer grid coordinates. Compare the COB grid with each howitzer gird, and select the howitzer whose grid is closest to the center of battery. This howitzer is the base piece, and its location is plotted on the firing chart.
2	**CONSTRUCT A SURVEYED FIRING CHART.** Using the grid determined in step 1, construct a surveyed firing chart. The procedures for the construction of a surveyed firing chart can be found in Chapter 6.
3	**DETERMINE AND APPLY GFT SETTING(S).** GFT settings are determined for the shell-charge combinations that the unit may be called upon to fire. An accurate GFT setting can be derived by using automated means, without the requirement for registrations or lengthy manual computations, provided the unit is accounting for all non-standard conditions. To determine the GFT setting, use steps 3a through 3d.
3a	Enter the base piece grid and altitude into the automated database as an observer.
3b	Select an azimuth (most commonly the azimuth of lay) and range to the desired grid for the registration point (most commonly the center of the zone of action).

Table E-2. Establishing a Manual Backup (continued).

STEP	*ACTION*
3c	Using the observer constructed in step 3a, process a polar mission using the azimuth and range determined in step 3b (the target altitude should be the same as base piece altitude) for the entire firing unit utilizing **CONVERGED SHEAF** (using converged sheaf will assist in the concurrent determination of TGPCs). 1. Determine data for desired shell and charge using fuze PD (if shell is compatible with fuze PD). a. Under the fire commands for the base piece extract DF Fired. b. Under the fire commands for the base piece, extract QE. Due to the VI of 0 computed between the registration point and base piece, this is the **adjusted elevation**. 2. Determine data for desired shell and charge using fuze time. Under the fire commands for the base piece, extract TI fuze setting. This is the **adjusted fuze setting**.
3d	Determine the GFT deflection correction. 1. Determine total deflection correction by using the following formula: **DF FIRED (step 3c) – CHART DF (TO REGISTRATION PT) = TOTAL DEFLECTION CORRECTION.** 2. Determine GFT deflection correction by using the following formula: **TOTAL DEFLECTION CORRECTION – DRIFT AT ADJUSTED ELEVATION = GFT DEFLECTION CORRECTION.** **NOTE:** For additional information on the determination and application of GFT settings, see Chapter 10.
3e	Computed GFT settings are then applied to their respective GFTs.
4	**DETERMINE AND APPLY TGPCs.** TGPCs are determined for each howitzer in the firing unit from the fire commands computed in step 3. This is done by comparing the base piece data to the data of the remaining howitzers in the firing unit. TGPCs consist of individual howitzer deflection correction, quadrant elevation correction and time correction. Use the following formulas to determine TGPCs: Determine deflection correction for each howitzer, use the first, fuze PD, fire commands: **HOWITZER DF – BASE PIECE DF = DF CORRECTION.** Determine quadrant elevation correction for each howitzer, use the first, fuze PD, fire commands: **HOWITZER QE – BASE PIECE QE = QE CORRECTION ~ NEAREST 1 MIL.** Determine time correction for each howitzer, use the second, fuze time, fire commands: **HOWITZER TI – BASE PIECE TI = TI CORRECTION.**
5	Individual howitzer TGPCs are then announced to their respective howitzers.
Legend: COB – center of battery DF – deflection GFT – graphical firing table PD – point detonating QE – quadrant elevation TGPC – terrain gun position correction TI – time VI – vertical interval	

CONVERT A MISSION IN PROGRESS FROM AUTOMATED TO MANUAL PROCESSING

E-15. **General.** Should automated means fail, a battery must continue to process fire missions. With a manual backup established, the FDC continues operations with minimal delay.

E-16. **Procedure.** If during the processing of a fire mission the computer fails, the mission is switched to manual processing. If the observer's total corrections are applied to the firing chart, a significant difference in point of impact in the target area may be noticed because of the difference in automated accuracy. To make the transition as smooth as possible, the steps in table E-3 (on page E-7) are used.

Table E-3. Switching from Automated to Manual Mission Processing.

STEP	***ACTION***
1	Alert the observer of the change to from automated to manual computations. This should make him aware of a possible unexpected change in the location of the impact of the next round. Also he should be aware of the computational aspects of manual gunnery, especially the delay inherent in computation of special sheafs and the possibility of parallel sheaf fire for effect.
2	The VCO uses the GST to determine the site for the fire mission. The range used to compute site is the range from the base piece determined by the automated system.
3	The computer directs the HCO to polar plot the location of the aimpoint of the last correction. To determine the polar plot location, follow steps 3a through 3e.
3a	The computer algebraically subtracts the site from the last quadrant elevation computed by the automated system to determine the last elevation computed. **LAST QE COMPUTED – SITE = LAST EL COMPUTED.**
3b	The computer places the EGL of the GFT over the elevation scale at the elevation determined in step 3a. The computer determines range from the range scale under the MHL. **This range is the polar plot range.**
3c	The computer determines the polar plot deflection by determining drift corresponding to the elevation in step 3b. This drift is added to the GFT deflection correction to determine the total deflection correction for this mission. The computer subtracts the total deflection correction determined from the last deflection computed by the automated system. **The difference is the polar plot deflection.** **LAST DF COMPUTED – TOTAL DF CORR = POLAR PLOT DF.**
3d	The computer announces **POLAR PLOT DEFLECTION** determined in step 3c. The HCO orients the RDP along the announced deflection and reads back the deflection from the RDP. The computer then announces **POLAR PLOT RANGE** determined in step 3b. The HCO places a plotting pin in the chart along the range arm of the RDP at the announced range and reads back the range from the RDP.
3e	The HCO places a target grid on the target and orients it to the OT direction.
4	The computer records the site computed in step 2 and the total deflection correction computed in step 3c on the ROF for the mission. The computer determines 100/R for the range determined in step 2.
5	The FDC processes the subsequent corrections. Subsequent corrections are computed in the same manner described in Chapter 9 except that the adjusting howitzer is changed to the base piece.
Legend: CORR – correction DF – deflection EGL – elevation gauge line EL – elevation FDC – fire direction center GFT – graphical firing table GST – graphical site table HCO – horizontal control operator MHL – manufacturer's hair line OT – observer-target QE – quadrant elevation RDP – range deflection protractor VCO – vertical control operator	

RANGE K AND FUZE K

E-17. The proportion of correction to range and fuze setting that result from a registration or the solution of a subsequent met application is referred to as range K or fuze K. Once determined, range K and fuze K may be used to apply the determined corrections at lesser or greater ranges than the corrections were determined at. This procedure allows the application of a "GFT setting" to a TFT when the application of a physical GFT setting to a GFT is not available.

E-18. Range K can be determined and applied by using the technique described in table E-4 on page E-8.

Table E-4. Determining Range K.

STEP	***ACTION***
1	Determine the range corresponding to the adjusted elevation.
2	Divide the range corresponding to the adjusted by the chart range. This is expressed to the ten thousandth (0.0001) as range K. **RANGE ~ ADJ EL ÷ CHART RANGE = RANGE K** Once range K is determined, it can be applied to other missions to determine firing data.
3	To apply range K, multiply the chart range to that target by range k. The result is expressed to the nearest 10 meters and is the corrected range for entry into Table F of the TFT. **CHART RANGE x RANGE K = ENTRY RG ~ 10 METERS**
4	Enter Table F with the corrected range expressed to the nearest 10 meters. From Column 2 extract elevation. From Column 3 extract the corresponding fuze setting. **THIS IS NOT THE FUZE SETTING TO FIRE.**
Legend: ADJ – adjusted EL – elevation RG – range TFT – tabular firing table	

Appendix F

Determining Data

The purpose of this appendix is to assist in determining data with a GFT.

BASIC HE DATA (155AM3 HEM107 GFT)

F-1. The procedures for using the 155AM3HEM107 GFT are discussed in table F-1.

Table F-1. Determining Basic HE Data with the 155AM3 HE M107 GFT.

TO DETERMINE	***IS A FUNCTION OF***	***WITHOUT A GFT SETTING APPLIED***	***WITH A GFT SETTING APPLIED***
DRIFT	ELEVATION	Place MHL over range; read up to drift scale	Place MHL over range; determine elevation under Elevation Gauge Line (EGL); place MHL over that elevation; read up to the drift scale under MHL.
100/R	RANGE	Place MHL over range; read up to 100/R scale.	Place MHL over range; read up to 100/R scale.
ELEVATION	RANGE	Place MHL over range; read down to ELEV scale.	Place MHL over range; determine elevation under EGL.
MECHANICAL TIME SUPER QUICK/ELECTRONIC TIME FUZE SETTING	ELEVATION	Place MHL over range; read down to TF/FS MTSQ/ET scale.	**When registered with MTSQ or ET fuze:** Place MHL over range; determine MTSQ/ET fuze setting under Time Gauge Line. **When not registered with MTSQ or ET fuze:** Place MHL over range; determine elevation under EGL; place MHL over that elevation; read down to TF/FS MTSQ/ET scale under MHL.

Table F-1. Determining Basic HE Data with the 155AM3 HE M107 GFT (continued).

TO DETERMINE	*IS A FUNCTION OF*	*WITHOUT A GFT SETTING APPLIED*	*WITH A GFT SETTING APPLIED*
M564 FUZE SETTING	ELEVATION	Place MHL over range; read down to M564 FS scale.	**When registered with M564 fuze:** Place MHL over range; determine M564 fuze setting under TGL. **When not registered with M564 fuze:** Place MHL over range; determine elevation under EGL; place MHL over that elevation; read down to M564 scale under MHL.
VARIABLE TIME FUZE SETTING	ELEVATION	Place MHL over range; read down to TF/FS MTSQ/ET scale.	Place MHL over range; determine elevation under EGL; place MHL over that elevation; read down to TF/FS MTSQ/ET scale under MHL.
▲FS/▲10MHOB	FUZE SETTING	Place MHL over range; read down to ▲FS/▲10MHOB scale.	Place MHL over MTSQ/ET or M564 FS; read down to ▲FS/▲10MHOB scale under MHL.
TIME OF FLIGHT	ELEVATION	Place MHL over range; read down to TF/FS MTSQ/ET scale.	Place MHL over range; determine elevation under EGL; place MHL over that elevation; read down to TF/FS MTSQ/ET scale under MHL.

NOTES:

1. Determine **drift, 100/R, and elevation** to the nearest 1 ɱ.
2. Determine **MTSQ/ET and M564 FS** to the nearest 0.1 fuze setting increment.
3. Determine **VT FS** to nearest 0.1 fuze setting increment; then vanish the tenths (12.9 = 12.0). Fuze M732A2 is graduated only in even, whole seconds. The only fuze settings that may be physically set on the M732A2 fuze is even, whole second. Therefore, the TOF must be expressed down the next **even** whole second (13.2 = 12.0)
4. Determine **▲FS/▲10MHOB** to the nearest listed value.
5. Determine **time of flight** to nearest second.

Legend: EGL – elevation gauge line FS – fuze setting HOB – height of burst M – meter MHL – manufacturer's hair line MTSQ – mechanical time super quick TF – time fuze TGL – time gauge line

DETERMINE FIRING DATA FROM AN HA GFT

F-2. Table F-2 (page F-3) shows the procedures used to determine firing data from a high-angle GFT.

Table F-2. Determine Basic HE Data with the 155AM3 HE M107 High Angle GFT.

TO DETERMINE	***IS A FUNCTION OF***	***WITHOUT A GFT SETTING APPLIED***	***WITH A GFT SETTING APPLIED***
100/R	RANGE	Place MHL over range; read up to 100/R scale.	Place Range Gauge Line (RGL) over range; determine 100/R under range gauge line.
ELEVATION	RANGE	Place MHL over range; read down to ELEV scale.	Place RGL over range; determine elevation under MHL.
10-MIL SITE FACTOR	RANGE	Place MHL over range; read down to 10₥SI scale.	Place RGL over range; determine 10-Mil Site Factor under MHL.
DRIFT	ELEVATION	Place MHL over range; read down to DRIFT scale.	Place RGL over range; determine drift under MHL.
TIME OF FLIGHT	ELEVATION	Place MHL over range; read down to TF scale.	Place RGL over range; determine TF under MHL.
NOTES: 1. Determine **drift, 100/R, and elevation** to the nearest 1 ₥. 3. Determine **10-Mil Site Factor** is determined to the nearest 0.1 ₥. 4. Determine **VT FS** to nearest 0.1 fuze setting increment from TF scale; then vanish the tenths (12.9 = 12.0). Fuze M732A2 is graduated only in even, whole seconds. The only fuze settings that may be physically set on the M732A2 fuze is even, whole second. Therefore, the TOF must be expressed down the next even whole second (13.2 = 12.0) 5. Determine **time of flight** to nearest second. 6. **Firing time fuze is impractical in high angle fire due to large probable errors in height of burst**.			
Legend: FS – fuze setting ₥ - mil MHL – manufacturer’s hair line RGL – range gauge line SI – site TF – time fuze VT – variable time			

DPICM, M825/A1, AND M449/A1 DATA (155AM3 HE M107 GFT)

F-3. The procedures for using the 155AM3HEM107 GFT to determine DPICM, M825/A1, or M449/A1 data are discussed in table F-3.

Table F-3. Determining M483A1or M825/A1 Data with the 155AM3 HE M107 GFT.

TO DETERMINE	***IS A FUNCTION OF***	***WITHOUT A GFT SETTING APPLIED***	***WITH A GFT SETTING APPLIED***
NOTE: Data is determined from the appropriate nonstandard projectile scale.			
DRIFT	M107 QUADRANT ELEVATION	Place MHL over range; determine M107 elevation under MHL; compute HE QE; place MHL over HE QE; read to nonstandard projectile DEFL CORR scale under MHL.	Place MHL over range; determine M107 elevation under EGL; compute HE GRAZE QE; place MHL over HE QE; read nonstandard projectile DEFL CORR scale under MHL.
QUADRANT ELEVATION	M107 QUADRANT ELEVATION	Place MHL over range; determine M107 elevation under MHL; compute HE QE; place MHL over HE QE; read to nonstandard projectile QE scale under MHL.	Place MHL over range; determine M107 elevation under EGL; compute HE QE; place MHL over HE QE; read to nonstandard projectile QE scale under MHL.

Table F-3. Determining M483A1or M825/A1 Data with the 155AM3 HE M107 GFT (continued).

TO DETERMINE	***IS A FUNCTION OF***	***WITHOUT A GFT SETTING APPLIED***	***WITH A GFT SETTING APPLIED***
M577/M762 FUZE SETTING	M107 FUZE SETTING	Place MHL over range; determine MTSQ/ET fuze setting under MHL; compute HE FS; place MHL over HE FS; read to nonstandard projectile FSM577/M762 scale under MHL.	Place MHL over range; determine MTSQ/ET fuze setting under TGL; compute HE FS; place MHL over HE FS; read to nonstandard projectile FSM577/M762 scale under MHL.
NOTES: 1. The preferred method of determining data is with the GFT, but corrections to M107 graze burst data may also be determined from the addendum FT 155 ADD-R-3 (M483A1), FT 155 ADD-T-2 (M825/A1). 2. **HOB corrections require the use of the addendum**. 3. Determine drift the first time the observer requests a nonstandard projectile. a. For FFE missions, determine nonstandard projectile drift initially. b. For AF missions, determine nonstandard projectile drift when the observer requests a nonstandard projectile, add the GFT Df Corr and determine the total nonstandard Df Corr.			
Legend: AF – adjust fire CORR – correction EGL – elevation gauge line FFE – fire for effect FS – fuze setting HE – high explosive HOB – height of burst M – meter MHL – manufacturer's hair line MTSQ – mechanical time super quick TF – time fuze TGL – time gauge line			

ADAM AND RAAMS DATA (155AN2 M483A1 GFT)

F-4. The procedures for using the 155AN2M483A1 GFT to determine ADAM and RAAMS are discussed in table F-4.

Table F-4. Determining ADAM and RAAMS Data With 155AN2 M483A1 GFT.

PROJECTILE	***TO DETERMINE***	***PROCEDURE WITH A DPICM GFT SETTING APPLIED TO THE 155AN2M483A1 GFT, DETERMINED FROM A DPICM (SR) M483A1 REGISTRATION OR A MET+VE SOLUTION***
RAAMS M718-L M741-S	RAAMS TIME	Place MHL over range; determine M483A1 FS under TI gauge line; place MHL over that FS; read to RAAMS FS scale under the MHL.
RAAMS	RAAMS DRIFT	Place MHL over range; determine M483A1 graze elevation under EGL; place MHL over that elevation; read up to M483A1 DEFL CORR/DRIFT scale under the MHL.
RAAMS	RAAMS QE	Place MHL over Range; determine M483A1 graze elevation under EGL; compute DPICM graze QE; place MHL over DPICM graze QE; read to RAAMS QE scale under the MHL.
ADAM M692-L M731-S	ADAM TIME	Place MHL over range; determine M483A1 FS under TGL; place MHL over that FS; read to ADAM FS scale under the MHL.
ADAM	ADAM DRIFT	Place MHL over range; determine M483A1 graze elevation under EGL; place MHL over that elevation; read up to M483A1 DEFL CORR/DRIFT scale under the MHL.
ADAM	ADAM QE	Place MHL over Range; determine M483A1 graze elevation under EGL; compute DPICM graze QE; place MHL over DPICM graze QE; read to ADAM QE scale under the MHL.
NOTES: 1. Base Scales on AN-2 GFT are for DPICM graze burst data in the self-registration mode. The preferred method of determining data is with a GFT, but corrections to DPICM graze burst data can also be determined from the appropriate addendum. **HOB corrections require the use of an addendum.** A. FT 155-ADD-L-2: corrections to HE M483A1 for ADAM data. B. FT 155-ADD-N-2: corrections to HE M483A1 for RAAMS data. C. FT 155-ADD-Q-1: corrections to HE M483A1 for M825/A1 data. 2. All scales printed on AN-2 GFT are only valid for members of the M795 projectile family. 3. Only one DEFL CORR/DRIFT scale. Drift is a function of DPICM elevation.		

CONSTRUCT A GFT SETTING FROM AN HE REGISTRATION ON AN ILLUMINATING GFT

F-5. Table F-5 shows the procedure for constructing a GFT setting from an HE registration on an illum GFT.

Table F-5. Construct GFT Setting on Illuminating GFT (HE Registration).

STEP	*ACTION*
1	Place MHL over the HE adjusted elevation on the HE GFT.
2	Under the MHL, determine the HE range corresponding to the HE adjusted elevation from the range scale.
3	Place the MHL of the illum GFT over the adjusted HE range determined in step 2.
4	On the illum GFT, draw a 1-inch line (length) parallel to MHL at the chart range from the HE GFT setting. Label this line “RG”.
Legend: HE – high explosive GFT – graphical firing table MHL – manufacturer’s hair line RG – range	

DETERMINE FIRING DATA FROM AN ILLUMINATING GFT

F-6. Table F-6 shows the procedures for determining firing data from an illuminating GFT.

Table F-6. Determining Firing Data by Using an Illum GFT.

TO DETERMINE	*IS A FUNCTION OF*	*WITHOUT A GFT SETTING APPLIED*	*WITH A GFT SETTING APPLIED*
100/R	RANGE	Place MHL over range; read up to 100/R scale under the MHL.	Place RGL over range; read up to 100/R scale under the RGL
RANGE TO IMPACT	QUADRANT ELEVATION	Place MHL over range; determine QE from the appropriate HOB scale under MHL; place MHL over QE on the ELEVATION TO IMPACT scale; read up to RANGE scale under the MHL.	Place RGL over range; determine QE from the appropriate HOB scale under MHL; place MHL over QE on the ELEVATION TO IMPACT scale; read up to RANGE scale under the MHL.
QUADRANT ELEVATION	RANGE	Place MHL over range; read down to appropriate HOB scale under the MHL.	Place RGL over range; read down to appropriate HOB scale under the MHL.
FUZE SETTING	QUADRANT ELEVATION	Place MHL over range; read down to appropriate HOB scale under the MHL.	Place RGL over range; read down to appropriate HOB scale under the MHL.
TIME OF FLIGHT	ELEVATION	Place MHL over range; read down to TF scale.	Place RGL over range; determine TF under MHL.
NOTES: 1. Determine **100/R and quadrant** elevation to the nearest 1 mil. 2. Determine **FS** to nearest 0.1 fuze setting increment in relation to the red arcs along the appropriate HOB scale.			
Legend: FS – fuze setting HOB – height of burst M – meter MHL – manufacturer’s hair line QE – quadrant elevation RGL – range gauge line TF – time fuze			

EXAMPLES

F-7. Table F-7 shows the procedures for determining firing data from a low-angle HE GFT (GFT setting applied) for an HE adjust fire mission with fuze VT in effect. Figure F-1 on page F-7 shows an example of a completed record of fire using a GFT setting. The GFT setting determined from the registration is:

GFT 1/A, Chg 4, Lot A/H, Rg 14500, El 410, Ti 40.7
Tot Df Corr L10, GFT Df Corr R4

F-8. Apply the GFT setting to the appropriate GFT. The HCO announces the following chart data:

ONE ALPHA RANGE 15220, DEFLECTION 3214.
The VCO announces SITE -6.

Table F-7. HE Adjust-Fire Mission with Fuze VT I/E.

STEP	***ACTION***
1	Place MHL over range 15220.
2	Under the EGL, determine the elevation scale to the nearest mil **(436).**
3	To determine drift, move the MHL over elevation 436 and read drift from the drift scale under the MHL to the nearest mil **(L16).**
4	To determine 100/R, place the MHL over range 15220 and read the 100/R from the 100/R scale under the MHL to the nearest mil **(7).**
5	To determine TOF, place MHL over range elevation 436 and determine TOF from the TF/FS MTSQ/ET scale to the nearest tenth of a second (0.1). Express the TOF determined to the nearest whole second **(43.1 ~ 43).**
6	Upon announcement of FFE, determine VT FS by placing the MHL on range 15320, and determine elevation under the EGL. Place the MHL on the elevation 460 and determine TOF from the TF/FS MTSQ/ET scale to the nearest tenth of a second (0.1). Express the TOF to the lower whole second by vanishing the tenths of seconds and applying a .0 to determine VT FS **(44.9 ~ 44.0).**
Legend: EGL – elevation gauge line FS – fuze setting MHL – manufacturer's hair line MTSQ – mechanical time super quick TF – time fuze TOF – time of flight VT – variable time	

RECORD OF FIRE

CALL FOR FIRE

Observer: R14 (AF) FFE/IS/S Tgt ______

Grid: 613 392 ALT 295

Polar:Dir ______ Dis ______ U/D ______ VA ______

Shift: ______ Dir: ______ L/R ______ +/- ______ U/D ______

MORTAR TEAM I/O

TGT ALT 295	DRIFT L16	ΔFS	
-BRTY ALT 375	+GFT R4	100/R	7
VI -80	DF Corr L12	/R	
		20/R	1
∡Si ÷ 10	10m Si	HOB Corr	

FIRE ORDER (2) VT I/E — Df Corr L12 — Si -6

INITIAL FIRE COMMANDS (FM) MF PLT ADJ, # 3 (1) — Rg 15220 — Cht Df 3214 — El 442

Sp Instr — Sh — Lot — Chg 4 — Fz — Ti — DF 3226 — QE 436

MTO H, VT I/E (2), TGT# AL7281 — ∡T (170) — PE_R (<38) — TF (43) — (2) VT in EFF — Ammo Exp (1)

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L12)	Df Fired	Chart Rg	HOB Corr	Si (-6)	El	QE	Exp	Type
5300	R80	+200					3207	L12	3219	15390		-6	464	458	(2)	
		-100					3205	L12	3217	15280		-6	457	451	(3)	Q ✓
		+50	FFE	PLT (2) FZ VT		44.0	3206	L12	3218	15320		-6	460	402	(8)	VT ✓
			EOM	EOM												

MORTAR TEAM DEST, EST 4 CAS

Btry 1/A	DTG 131226ZMAR13	Tgt AL7281	Replot Grid	Replot Alt

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APD LC v1.00

Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CHG – charge
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
QE – quadrant elevation
REC – record
REF – refinement
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure F-1. Example Record of Fire for Adjust-Fire Mission with Fuze VT I/E Using a GFT Setting.

F-9. Table F-8 shows the procedures for determining firing data from a low-angle HE M107 GFT (GFT setting applied) for an HE adjust-fire mission with shell DPICM in effect. Figure F-2 on page F-9 shows an example of a completed record of fire using a GFT setting. The GFT setting determined from the registration is:

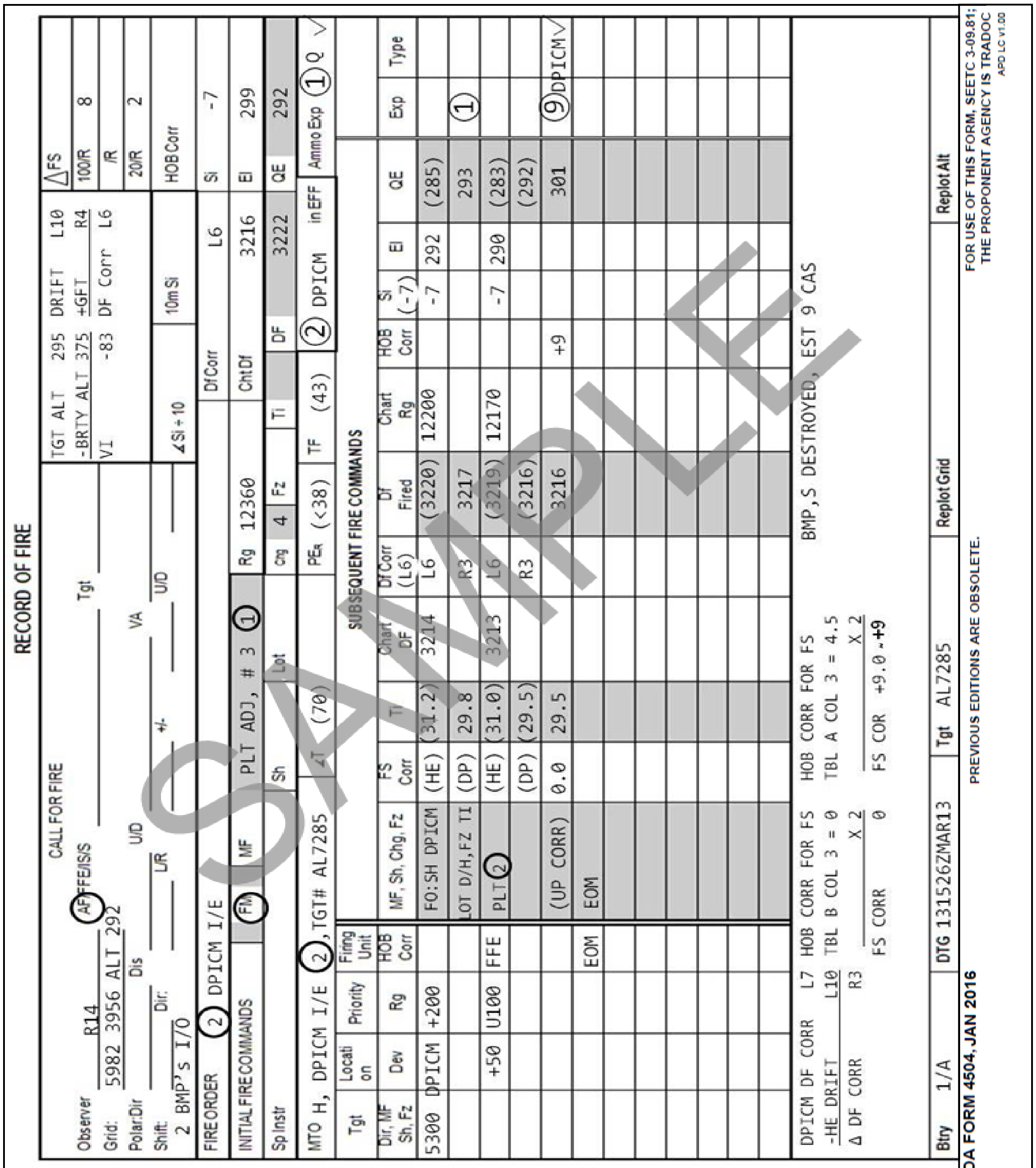
GFT 1/A, Chg 4, Lot A/H, Rg 14500, El 410, Ti 40.7
Tot Df Corr L10, GFT Df Corr R4

F-10. Apply the GFT setting to the appropriate GFT. The HCO announces the following chart data after shell DPICM is requested by the observer:

ONE ALPHA, RANGE 12200, DEFLECTION 3214.
The VCO announces SITE -7.

Table F-8. HE Adjust-Fire Mission with Shell DPICM I/E.

STEP	***ACTION***
1	Place MHL over range 12200.
2	Under the EGL, determine the HE elevation scale to the nearest mil (292).
3	Under the TGL, determine time fuze setting under TF/FS MTSQ/ET scale to the nearest tenth **(31.2).**
4	Determine HE QE by algebraically applying site (-7) to HE elevation (292) **(292 + -7 = 285).**
5	Place MHL over the time fuze setting determined (step 3) and determine the DPICM fuze setting from the M483A1 FS M577/M762 scale under the MHL to the nearest tenth **(29.8).**
6	Place the MHL over the HE QE determined (step 4) on the elevation scale.
7	Under the MHL, determine the DPICM deflection correction from the M483A1 DEFL CORR scale (L7). Determine the difference between the HE drift and DPICM deflection correction in the lower computational space. **DPICM DEFLECTION CORRECTION L7** **- HE DRIFT L10** **DIFFERENCE IN DEFLECTION CORRECTION R3** Apply the computed difference in deflection correction to the HE deflection to fire to determine the DPICM deflection to fire. **HE DEFLECTION TO FIRE 3214** **+ DIFFERENCE IN DEFLECTION CORRECTION R3** **DPICM DEFLECTION TO FIRE 3211**
8	Under the MHL, determine the DPICM quadrant elevation from the M483A1 QE scale **(293).**
Legend: DPICM – dual-purpose improved conventional munition EGL – elevation gauge line FS – fuze setting HE – high explosive MHL – manufacturer's hair line MTSQ – mechanical time super quick QE – quadrant elevation TGL – time gauge line TOF – time of flight VT – variable time	


RECORD OF FIRE

CALL FOR FIRE

Observer R14 (AF) FFE/IS/S — Tgt

Grid: 5982 3956 ALT 292

Polar: Dir ___ Dis ___ U/D ___ VA ___

Shift: 2 BMP's I/O Dir: ___ L/R ___ +/- ___ U/D ___

TGT ALT 295 DRIFT L10
-BRTY ALT 375 +GFT R4
VI -83 DF Corr L6

∡Si ÷ 10 — 10m Si — HOB Corr

ΔFS: 100/R 8; /R; 20/R 2

FIRE ORDER (2) DPICM I/E — DfCorr L6 — Si -7

INITIAL FIRE COMMANDS (FM) MF PLT ADJ, # 3 (1) — Rg 12360 — ChtDf 3216 — El 299

Sp Instr — Sh — Lot — Chg 4 — Fz — Ti — DF 3222 — QE 292

MTO H, DPICM I/E (2), TGT# AL7285 — ∡T (70) — PEr (<38) — TF (43) — (2) DPICM in EFF — Ammo Exp (1) Q ✓

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	DfCorr (L6)	Df Fired	Chart Rg	HOB Corr	Si (-7)	El	QE	Exp	Type
5300	DPICM	+200		FO:SH DPICM	(HE)	(31.2)	3214	L6	(3220)	12200		-7	292	(285)		
				LOT D/H,FZ TI	(DP)	29.8		R3	3217					293	(1)	
	+50	U100	FFE	PLT (2)	(HE)	(31.0)	3213	L6	(3219)	12170		-7	290	(283)		
					(DP)	(29.5)		R3	(3216)					(292)		
				(UP CORR)	0.0	29.5			3216		+9			301	(9) DPICM ✓	
			EOM	EOM												

DPICM DF CORR L7
-HE DRIFT L10
Δ DF CORR R3

HOB CORR FOR FS
TBL B COL 3 = 0
X 2
FS CORR 0

HOB CORR FOR FS
TBL A COL 3 = 4.5
X 2
FS COR +9.0 → +9

BMP,S DESTROYED, EST 9 CAS

Btry 1/A — DTG 131526ZMAR13 — Tgt AL7285 — Replot Grid — Replot Alt

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SAMPLE

Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CHG – charge
COL – column
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DPICM – dual purpose improved conventional munition
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FO – fire order
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TBL – table
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure F-2. Example of Completed Record of Fire for an AF Mission with Shell DPICM I/E.

F-11. Table F-9 shows the procedures for determining firing data from a high-angle GFT (GFT setting applied). Figure F-3 on page F-11 shows and example of a completed record of fire using a high-angle GFT setting. The GFT setting determined from the registration is:

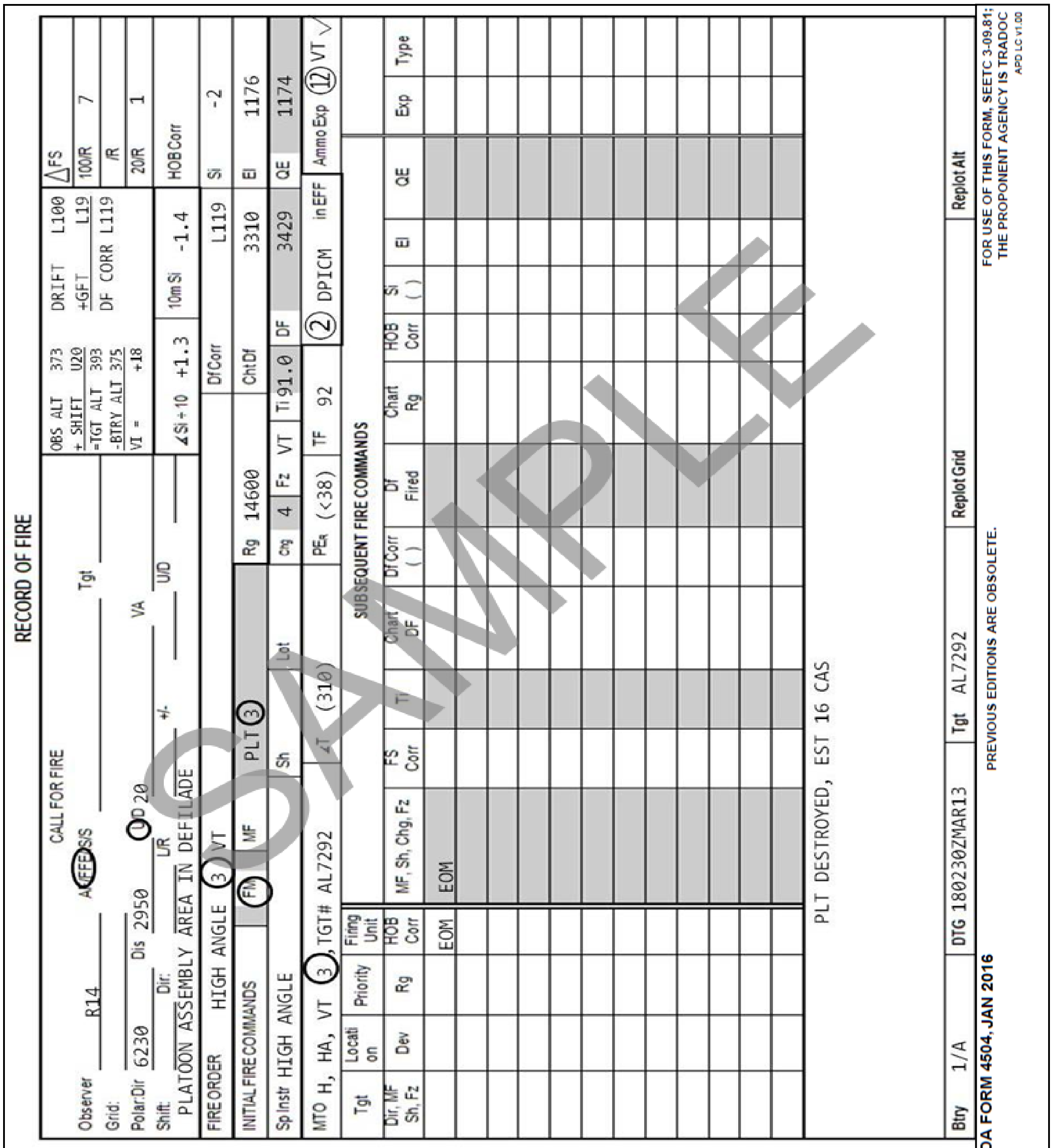
GFT 1/A, Chg 4, Lot A/H, Rg 14500, El 1180
Tot Df Corr L121 GFT Df Corr L19

F-12. Apply the GFT setting to the appropriate GFT. The HCO announces the following chart data:

ONE ALPHA, RANGE 14600, DEFLECTION 3310.
The VCO announces ANGLE OF SITE +1.3

Table F-9. HE High-Angle FFE Mission with Fuze VT Using the High-Angle GFT (GFT Setting Applied).

STEP	***ACTION***
1	Place the RGL over the announced range **(14600).**
2	Under the MHL, determine elevation from the ELEV scale for the appropriate charge to the nearest mil **(1176).**
3	Under the MHL, determine the 10 mil site factor (if VI is a positive value) from the 10₥SI scale for the appropriate charge to the nearest tenth of a mil, **this value is extracted as a NEGATIVE value (-1.4).**
4	Under the MHL, determine drift from the DRIFT scale for the appropriate charge to the nearest mil **(L100).**
5	Under the MHL, determine TOF from the TF scale for the appropriate charge to the nearest tenth of a second **(91.6).**
5a	To determine VT fuze setting, express the TOF (step 5) down to the whole second and apply a .0 **(91.0).**
5b	To determine TOF, express the TOF (step 5) to the nearest whole second **(92).** This will be announced to the observer.
7	Under the RGL, determine 100/R from the 100/R scale **(7).**
NOTE: During high-angle fire missions, drift is determined for each correction and applied to the GFT deflection correction to determine a new deflection correction to apply for every new subsequent correction.	
Legend: GFT – graphical firing table HOB – height of burst M – meter MHL – manufacturer's hair line RGL – range gauge line TF – time fuze TOF – time of flight VI – vertical interval	



Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CAS – casualties
CHG – charge
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
I/O – in the open
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure F-3. Example of Completed Record of Fire for a High-Angle FFE Mission with Fuze VT (GFT Setting Applied).

F-13. Table F-10 shows the procedure for determining firing data from an illum GFT with a GFT setting applied. Figure F-4 on page F-13 shows an example of a completed record of fire using an HE GFT setting on the Illumination GFT. The GFT setting determined from the registration is:

GFT 1/A, Chg 4, Lot A/H, Rg 14500, El 410, Ti 40.7
Tot Df Corr L10, GFT Df Corr R4

F-14. Apply the GFT setting to the appropriate illum GFT. The HCO announces the following chart data:

ONE ALPHA, RANGE 11000, DEFLECTION 3210.

NOTE: Use the 550 HOB scale to determine firing data.

Table F-10. Illumination AF Mission Using the Illumination GFT (GFT Setting Applied).

STEP	***ACTION***
1	Place the RGL over the announced range **(11000).**
2	Determine HOB by modifying the optimum HOB. The VI, expressed to the nearest 50 meters, is applied to the optimum HOB and recorded in the upper computational space. This value determines the HOB scale to be used on the GFT.
3	Under the MHL, determine the quadrant elevation from the QE scale of the appropriate HOB Scale (550) **(311).**
4	Under the MHL, determine the time fuze setting between the red arcs of the appropriate HOB scale (550) **(25.1).**
5	Under the RGL, determine 100/R from the 100/R scale **(9).**
NOTES: 1. If firing a 2 or 4 gun illumination pattern, complete steps 1-4 for each aimpoint's set of chart data determined by the HCO. 2. The chart deflection will be used as the deflection to fire.	
Legend: GFT – graphical firing table HOB – height of burst MHL – manufacturer's hair line QE – quadrant elevation RGL – range gauge line	

RECORD OF FIRE

SAMPLE

CALL FOR FIRE			
Observer: R14	AF(FFE) S/S (FFE circled)	Tgt	
Grid: 697 348 ALT 395			
Polar:Dir	Dis	U/D	VA
Shift: Dir:	L/R	+/-	U/D
SUSPECTED ENEMY MOVEMENT, ILLUM			

TGT ALT 345	OPT HOB 600	ΔFS
-BRTY ALT 375	+VI -50	100/R 9
VI= -35 ≈ -50	HOB 550	500/R 45
		20/R
∠Si ÷ 10	10m Si	HOB Corr

FIRE ORDER	#2, AMC, (1) LOT I/H		Df Corr	Si
INITIAL FIRE COMMANDS	(FM) MF	#2, (1)	Rg 11000	Cht Df 3310	El
Sp Instr AMC	Sh ILLUM	Lot I/L	Chg 4, Fz TI, Ti 25.1	DF 3210	QE 311
MTO H, (1), TGT# AL7297	∠T (150)	PER (<38)	TF (25)	in EFF	Ammo Exp (1) ILLUM ✓

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS													
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
			EOM	EOM												

NO ENEMY DETECTED

Btry 1/A	DTG 180442ZMAR13	Tgt AL7297	Replot Grid	Replot Alt

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Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CHG – charge
CORR – correction
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
ILLUM – illumination
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
OPT – optimum
PER – probable error in range
PLT – platoon
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure F-4. Example of Completed Record of Fire for an AF Illumination Mission (GFT Setting Applied).

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Appendix G

Special Situations

This appendix is a supplement to Chapter 13, which details the more common "special situations" missions.

FINAL PROTECTIVE FIRES

G-1. A final protective fire (FPF) is an immediately available prearranged barrier of fire designed to protect friendly troops and installations by impeding enemy movements across defensive lines or areas. The normal use of an FPF is to establish prearranged close-in defensive fires, which include other artillery fires, minefield, obstacles, final protective machine gun lines and small-arms fire, and final protective fire of mortars. Each battery is assigned one FPF and normally is laid on that FPF when not firing other missions. The FPF may be fired on prearranged signal or on call from the supported unit. The firing of an FPF may be repeated on call as often as necessary. When time and ammunition permit, the FPF can be adjusted or check rounds fired. A battery FPF may be fired either individually or in coordination with those of other batteries.

G-2. **Width of FPF.** The width (or length) of the FPF that can be covered by a single battery without shifting its fire should not exceed the width of an open sheaf for the battery concerned. When necessary, the width (length) of the FPF may be increased by agreement between the commanders of the artillery and the supported unit. However, the effectiveness of fire will be decreased.

G-3. **Preparation of Data.** The actual map location of the FPF is reported by the supported unit through the various fire support channels. The FPF is assigned to an artillery unit, which is responsible for computing the firing data. Since the FPF usually is located within a very short distance of positions occupied by friendly troops, precise computational procedures must be employed and all available corrections must be applied. Special corrections in the form of calibration corrections and position corrections, obtained by use of the M17 plotting board, are determined and applied as individual piece corrections. When the axis of the FPF is other than perpendicular to the direction of fire, additional computations must be made to bring each burst to a desired point on the FPF line.

G-4. **Call for Fire.** The call for fire for final protective fires is as outlined in ATP 3-09.30, Chapter 7.

COMPUTATIONAL PROCEDURES

G-5. There are two techniques for determining FPF data: observer-adjusted FPF and nonadjusted FPF. Both techniques will result in the determination of firing data that are announced to the howitzers and that are used to lay the howitzers when they are not involved in other fire missions.

G-6. **Observer Adjusted FPF.** The observer will adjust the burst of each round to its desired location on the FPF sheaf. He starts with the flank round that impacts to the location of the desired sheaf and continues the adjustment until all howitzers have been adjusted. (See table G-1)

Note: The use of fuze delay is recommended when adjusting rounds for an FPF.

Table G-1. Computational Procedure for Observer-Adjusted FPF.

STEP	*ACTION*
1	A battery one volley at 5-second intervals if fired initially to the center range and deflection with TGPC applied. This allows the observer to determine the flank piece and begin adjustment. Data fired are to the initial grid transmitted by the observer.

Table G-1. Computational Procedure for Observer-Adjusted FPF (continued).

STEP	*ACTION*
2	The observer selects the flank howitzer closest to the desired FPF line and using appropriate (danger close, if necessary) adjustment procedures, the observer adjusts the howitzer onto the FPF line. Once the first howitzer is adjusted, the observer transmits to the next weapon **NUMBER (such-and-such), REPEAT**.
3	Initial firing data for the second howitzer are the adjusted firing data from the first howitzer. The observer then adjusts the second howitzer onto the FPF line. The initial firing data for each succeeding howitzer are the adjusted firing data from the previous howitzer. This procedure continues until all howitzers are adjusted.
4	End of mission is announced to the howitzers.
5	The adjusted FPF data are announced to the howitzers, and the howitzers are laid on these data when not involved in other missions.
	Note: The TGPC in effect at the time the FPF was adjusted must be set off on the howitzers each time they are laid on the adjusted FPF data.
Legend: FPF – final protective fire TGPC – terrain gun position correction	

G-7. **Nonadjusted FPF.** When the situation does not permit the adjustment of each burst to its location on the FPF sheaf, the FDC determines firing data by using standard FFE techniques. In the call for fire, the observer should include the altitude of FPF and the length, if different from that of an open sheaf. The FDC will compute special corrections with the M17 for a linear sheaf and determine the FPF firing data. The FPF firing data will be announced to the howitzers and, as in observer adjusted FPFs, the howitzers will lay on the FPF data when not involved in other fire missions.

LASER ADJUST MISSIONS

G-8. An observer equipped with a laser can determine accurate target locations if the laser is accurately located. If the observer has directional control and his accurate location has been recorded at the FDC, he should request first-round fire for effect. If the observer does not feel he can achieve first-round fire for effect on the target, he should request an adjust-fire mission, The FDO may also decide to fire an adjustment if the FDC cannot account for some of the requirements for accurate fire. This may occur even if the observer requests first-round fire for effect.

G-9. Most laser missions, if not fire for effect initially, should require only one adjusting round. Fire for effect should be requested by the observer unless he determines the lasing of the burst is not satisfactory. Many variables could cause an unsatisfactory lase. For example, an observed burst partially obscured by trees or intermediate hill mass would yield inaccurate land distance to the burst. The **total deviation** between the target and the adjusting burst does not generally determine if fire for effect is requested. Rather, the observer need only determine if an accurate lase to the burst has been obtained.

G-10. The observer uses the polar method of target location to determine the target location. He transmits the target location in his call for fire. (See figure G-1.)

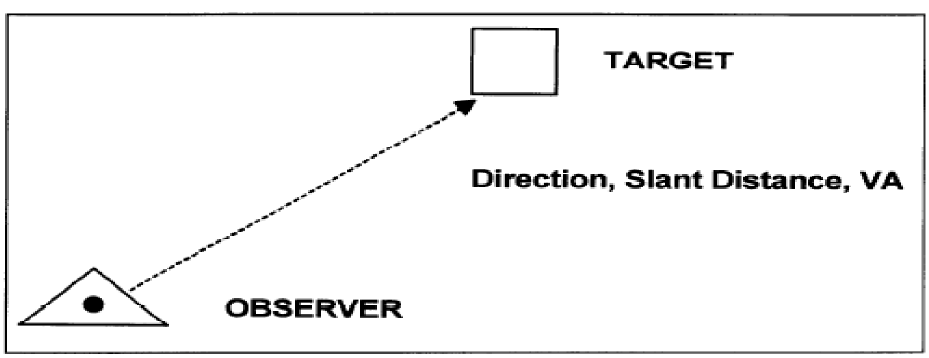


Figure G-1. Laser Polar Target Location.

G-11. The adjusting round is fired and the observer reports the direction, slant distance, and VA to the burst. (See figure G-2.)

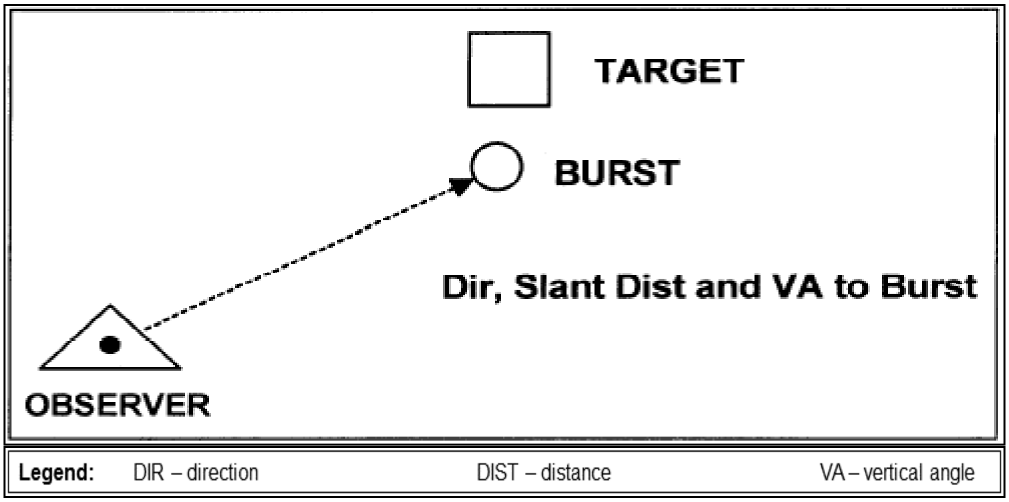


Figure G-2. Lase of Burst.

G-12. The FDC determines the fire for effect aimpoint from the total corrections necessary to engage the target. (See figures G-3 and G-4.)

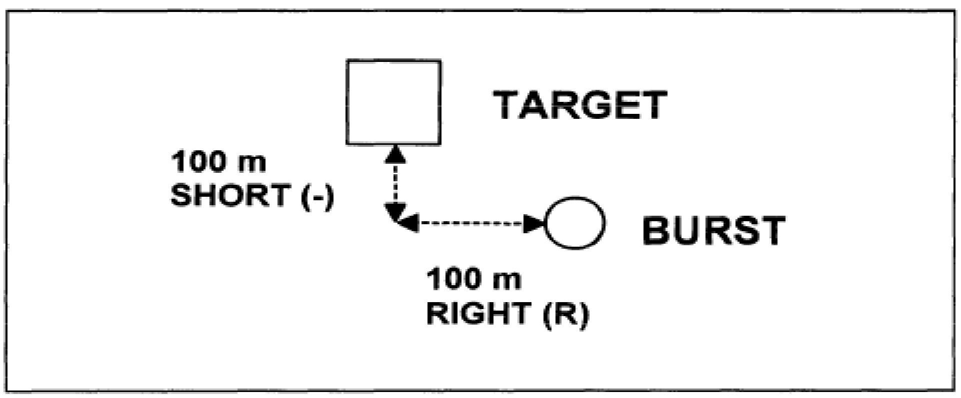


Figure G-3. Burst Spotting.

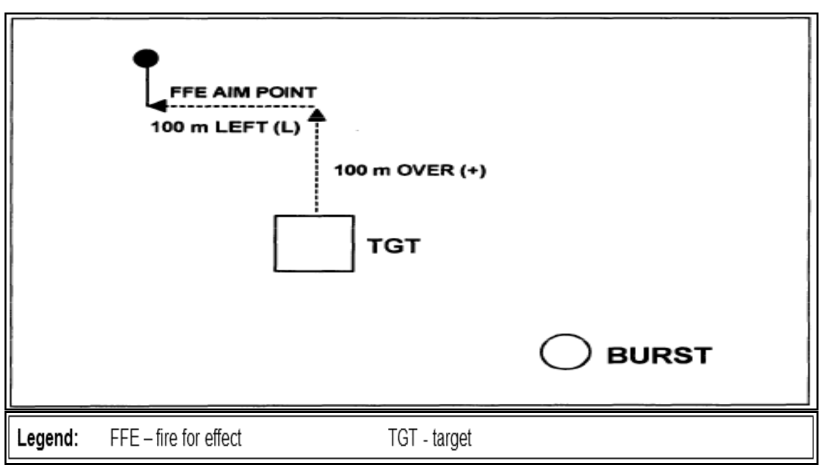


Figure G-4. FFE Aimpoint.

G-13. If additional adjustment is required, continue to plot the burst locations and compare each to the initial target location. Apply each correction determined to the previous aimpoint location **not** the initial target location.

G-14. The M17 plotting board may also be used to determine corrections (see Chapter 12).

LASER ADJUST-FIRE MISSION

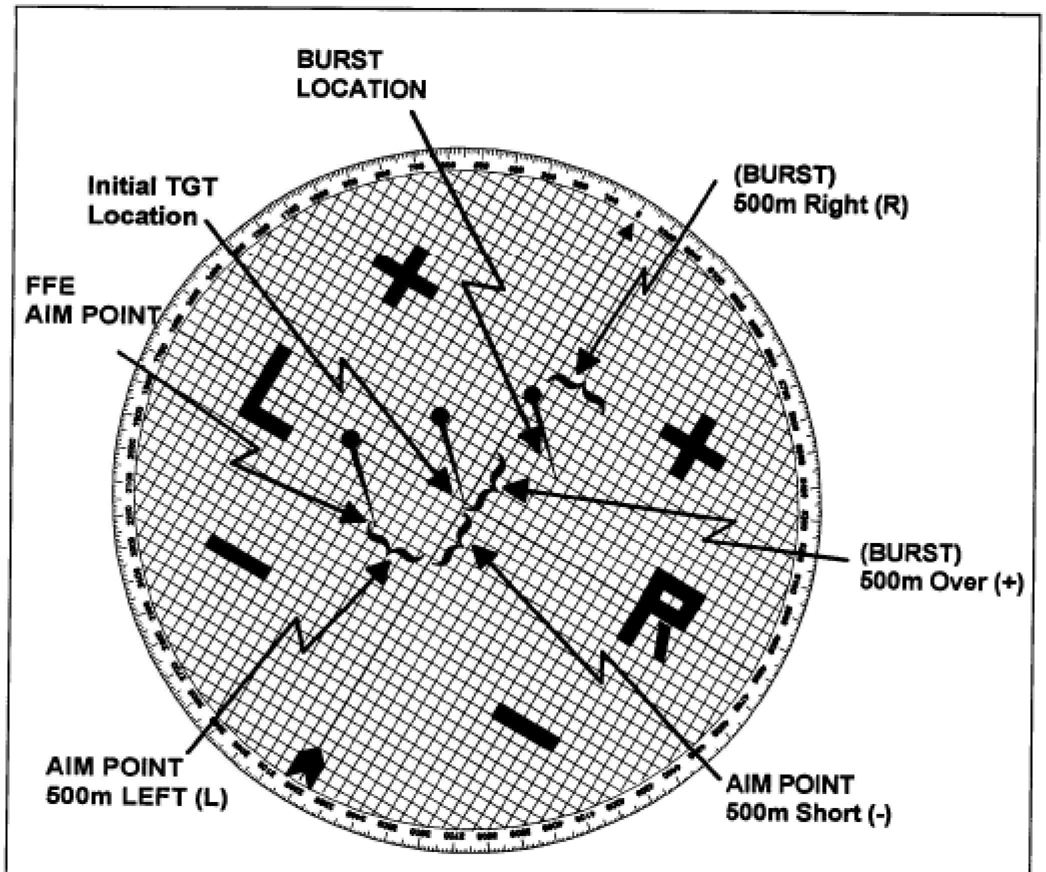
G-15. Table G-2 shows the procedures for a laser adjust-fire mission.

Table G-2. Procedures for Laser Adjust-Fire Mission.

STEP	*ACTION*
1	The HCO plots the target location from the observer's location by using the direction and slant distance received in the fire request. (Direction will be received to the nearest 1 mil; slant distance, nearest 10 meters.)
2	The HCO determines and announces the initial chart data.
3	The VCO converts the VA received in the fire request into a vertical interval.
4	The VCO determines the target altitude by applying the VI (step 3) to the altitude and determines and announces site.
5	The computer determines the initial fire commands in compliance with the fire order.
6	The HCO positions the target grid over the initial target location.
7	The HCO orients the target grid by using the initial OT direction.
	Note: After the observer spots and lases the initial round, he will transmit the burst direction, distance and VA to the FDC.
8	The HCO plots the burst location by using the direction and slant distance as received from the observer.
9	The HCO determines the difference between the initial target location (step 1) and the burst location (step 7) to the nearest 10 meters LEFT (L)/RIGHT I and OVER (+)/SHORT (-).
10	The HCO places a pin in the opposite direction and magnitude (from the initial target location) of the burst. (LEFT [L] spotting becomes a RIGHT [R] correction, over [+] spotting becomes a drop [-] correction.) This is the FFE aimpoint. (See figure G-5 on page G-5.)
11	The HCO determines chart data to the FFE aimpoint (step 10).
12	The VCO converts the burst VA to a burst vertical interval.
13	The VCO determines the burst altitude by applying the burst VI (step 12) to the observer's altitude.
14	The VCO determines the vertical correction by subtracting the initial target altitude (step 4) from the burst altitude (step 12).
15	The VCO applies the vertical correction to the VI (step 3) and uses this value to recompute and announce site.
16	The computer determines corrections for the adjustment of fuze time by using standard procedures.
17	The computer determines FFE fire commands in compliance with the fire order.
Legend: FDC – fire direction center FFE – fire for effect HCO – horizontal control operator OT – observer-target VA – vertical angle VCO – vertical control operator VI – vertical interval	

RADAR ADJUST-FIRE MISSIONS

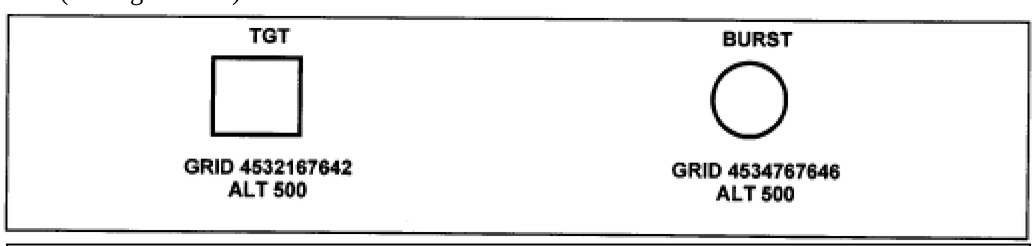
G-16. The FA radars are used as counter battery radars. They have survey capability, which allows them to determine accurate locations of enemy firing bursts. If used in the friendly mode, the radars are capable of determining burst locations of rounds fired by friendly units.



Legend: FFE – fire for effect	TGT - target

Figure G-5. Laser Polar Mission Processing.

G-17. The initial target location for a radar adjust-fire mission can be determined by radar in the case of enemy firing units or by another observer. Once the initial target location is established and the initial round is fired, the radar will trace the round and report the spotting of the burst by grid coordinates and altitude. (See figure G-6.)



Legend: ALT - altitude	TGT - target

Figure G-6. Radar Spotting.

G-18. The FDC then determines the corrections needed to move the burst to the target and determines the FFE aimpoint. (See figure G-7 on page G-6.)

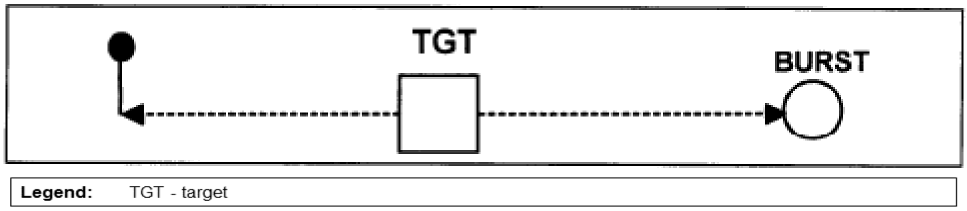


Figure G-7. FFE Aimpoint.

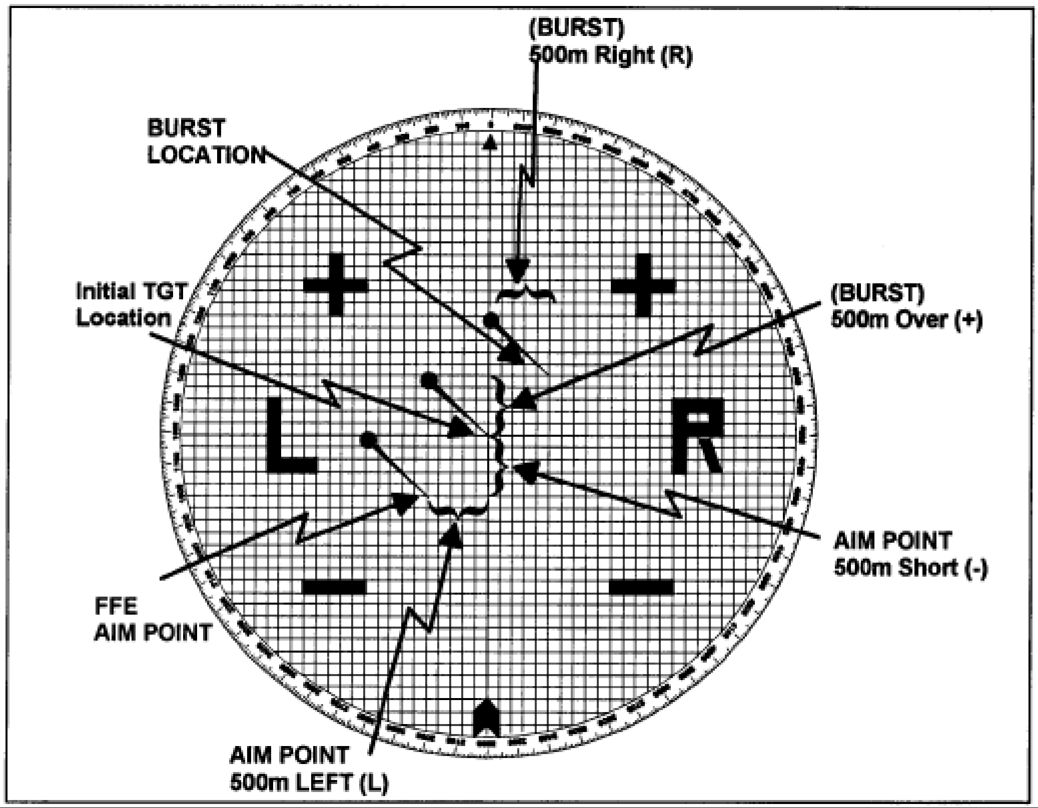
G-19. Once the FFE aimpoint location is established, FFE fire commands can be determined.

G-20. If additional adjustment is required, continue to plot the burst locations and compare each to the initial target location. **Apply** each correction determined to the previous aimpoint location, **not** the initial target location. When orienting the target grid for direction, **any** direction will produce the desired results. Each burst location will be reported by using grid coordinates. The target grid is used only to determine the magnitude of the correction needed and the direction of the corrections relative to the orientation (direction) of the target grid that has been chosen.

G-21. Another way to determine the corrections would be to mathematically determine the difference between the grid coordinates of the target location and burst location (table G-3). The corrections would be applied by using a target grid oriented to grid north (0000). Continued adjustment would be performed by determining the difference between each burst location and the initial target location. Each correction would be applied to the previous aimpoint.

Table G-3. Determining Difference Between Grid Coordinates of Target Location and Burst Location.

STEP	***ACTION***
1	The HCO plots the target location on the firing chart by using the grid as received in the fire request.
2	The HCO determines and announces the initial chart data.
3	The VCO determines and announces site that is based on the target altitude.
4	The computer determines the initial fire commands in compliance with the fire order.
5	The HCO positions the target grid over the initial target location.
6	The HCO orients the target grid to north.
	Note: After the radar spots the first round, the burst location will be transmitted to the FDC. (See figure G-8 on page G-7)
7	The HCO plots the subsequent grid (burst location) as received from the radar.
8	The HCO determines the difference between the initial target location (step 1) and the burst location (step 4) to the nearest 10 meters, LEFT (L)/RIGHT I and OVER (+)/SHORT (-).
9	The HCO places a pin in the opposite direction and magnitude (from the initial target location) of the burst. (LEFT [L] spotting becomes a RIGHT [R] correction, over [+] spotting becomes a drop [-] correction.) This is the FFE aimpoint.
10	The HCO determines chart data to the FFE aimpoint (step 9).
11	The VCO determines the vertical correction by subtracting the initial target altitude from the burst altitude.
12	The VCO applies the vertical correction to the VI and uses this value to recompute and announce site.
13	The computer determines FFE fire commands in compliance with the fire order.
Legend: FDC – fire direction center FFE – fire for effect HCO – horizontal control operator OT – observer-target VA – vertical angle VCO – vertical control operator VI – vertical interval	



Legend: FFE – fire for effect TGT - target

Figure G-8. Radar Mission Processing.

DESTRUCTION MISSION

G-22. **General.** The purpose of the destruction mission is, as the name implies, to destroy the target. This requires a target hit. The mission is conducted with a single gun and closely parallels precision registration procedures. Given the dispersion suffered by indirect fire weapons and the requirement for a target hit, the great expenditure of ammunition required becomes apparent. This requirement for ammunition and the ensuing possible disclosure of the firing unit make a destruction mission a less desirable method of engaging targets. Whenever possible, other methods or other means of attack should be considered.

G-23. **Conduct of the Destruction Mission.** The destruction mission follows the same procedures as a precision registration until the observer establishes a 25-meter bracket. Once it is established, the observer will split the 25-meter bracket by adding or dropping 10 meters and will continue to fire additional rounds. After every third round, additional corrections are announced if necessary. The observer may make corrections after each round. This will continue until the target is destroyed or the observer or FDO chooses to end the mission. At intervals, the observer may request a change of fuze from delay or concrete-piercing to fuze quick to clear rubble and debris around the target.

SWEEP AND ZONE

G-24. Sweep and zone fires provide a method for the attack of large or irregularly shaped targets. The advantage of sweep and zone fires is the ease with which they may be computed in comparison to attacking the target by using special corrections. The disadvantages are the great quantity of ammunition that must be expended and the time required to do so. The resulting loss of surprise and potential for disclosing the firing unit location make sweep and zone fires a less appealing alternative. The FDO should weigh these considerations before attacking targets by using sweep and zone techniques. Possible alternatives are the use of special corrections or dividing the target among a number of firing units.

COMPUTATION OF SWEEP

G-25. Sweep fires are used to cover a wide target with fire. (Wide target is described as a target whose long axis lies perpendicular or nearly perpendicular to the GTL.) Sweep fire is similar to traversing fire applied with direct fire weapons. The purpose of the sweep is to cause the guns to fire a number of deflections (at the same quadrant elevation) to place a number of sheafs side by side over the target.

G-26. Chart data are computed as with any area target.

G-27. The number of deflections to fire is determined on the basis of the width of the target and by the sheaf front.

G-28. **Determination of sheaf front.** The sheaf front is the lateral distance between the center of the flank bursts, plus one effective burst width. The size of the sheaf front depends on the type of sheaf fired and the burst width of the projectile. For an open sheaf, the sheaf front is computed as number of bursts multiplied by the burst width for the projectile. The sheaf front for a circular sheaf is the distance across the center of the circle from burst to burst plus one burst width. If special corrections or TGPCs are being used, the size of the sheaf front will correspond with the sheaf front used to determine those corrections. Converged sheaf should not be used as the concentration of fire on a single point. This is contrary to the purpose for sweep fire. The front for a converged sheaf is one burst width. (See table G-4.)

Table G-4. Sheaf Fronts.

Caliber	*Burst width*	*Open*	*100 m circular*	*Converged*
105 mm (4 guns)	35 m	140 m	135 m	35 m
155 mm (4 guns)	50 m	200 m	150 m	50 m
Legend: m – meters mm – millimeters				

G-29. **Determination of the number of deflections to fire**. To determine the number of deflections to fire, divide the target width by the sheaf front. If the result is an even number, the result must be expressed **UP** to the next higher odd number. Because fire commands will be sent to the guns with the center data and special instructions addressing the size and number of shifts, a center sheaf and equal number of sheafs on either side require that an odd number of deflections be fired.

$$\frac{\text{TARGET WIDTH}}{\text{SHEAF FRONT}} = \text{NUMBER OF DEFLECTIONS}$$

G-30. The number of mils by which the guns must change the center deflection in order to fire the sheafs is the deflection shift. The deflection shift is computed as the sheaf front divided by chart range in thousands.

$$\frac{\text{SHEAF FRONT}}{\text{CHART RANGE IN 1000s}} = \text{SWEEP IN MILS}$$

G-31. Fire commands are transmitted as with any area fire mission. The time, deflection and quadrant to the center are announced. The special instruction **SWEEP, (the value of the deflection shift) MILS, (the number of deflections) DEFLECTIONS** is announced. The number of rounds announced in the method of fire for effect is the number of rounds to be fired **at each deflection.**

COMPUTATION OF ZONE

G-32. Zone fires are used to cover a deep target with fire. (Deep target is described as a target whose long axis lies parallel or nearly parallel to the GTL.) Zone fire is similar to searching fire applied with direct fire weapons. The purpose of the zone is to cause the guns to fire a number of quadrants (at the same deflection) to place a number of sheafs "stacked" over the target.

G-33. Chart data are computed as with any area target.

G-34. The number of quadrants to fire is determined by dividing the depth of the target by the sheaf depth.

G-35. **Determination of sheaf depth**. The sheaf depth is the distance between the center of the foremost and rearmost burst. The size of the sheaf depth depends on the type of sheaf fired and the burst width of the projectile. For an open sheaf, the sheaf depth is computed as the burst width for the projectile. The sheaf depth for a circular sheaf is the distance across the center of the circle from burst to burst plus one burst width. If special corrections or TGPCs are being used, the size of the sheaf depth will correspond with the sheaf depth used to determine those corrections. Converged sheaf should not be used as the concentration of fire on a single point. This is contrary to the purpose of zone fire. The depth for a converged sheaf is one burst width. (See table G-5.)

1-2

Table G-5. Sheaf Depths.

Caliber	***Open***	***100 m circular***	***Converged***
105 mm (4 guns)	140 m	135 m	35 m
155 mm (4 guns)	200 m	150 m	50 m
Legend: m – meters mm – millimeters			

G-36. **Determination of the number of quadrants to fire**. To determine the number of quadrants to fire, divide the target depth by the sheaf depth. If the result is an even number, the result must be expressed UP to the next higher odd number. (Because fire commands will be sent to the guns with the center data and special instructions addressing the size and number of shifts, a center sheaf and equal number of sheafs on either side require that an odd number of quadrants be fired.)

$$\frac{TARGET\ WIDTH}{SHEAF\ DEPTH} = NUMBER\ OF\ QUADRANTS$$

G-37. The number of mils by which the howitzers must change the center quadrant to fire the sheafs is the quadrant shift. The quadrant shift is computed by comparing the elevation corresponding to the range to the center of the target to the elevation corresponding to the center range plus the sheaf depth. The difference is the quadrant shift.

$$ELEVATION \sim (CHART\ RANGE + SHEAF\ DEPTH) \\ - ELEVATION \sim CHART\ RANGE = ZONE$$

G-38. Fire commands are transmitted as with any area fire mission is announced. The time, deflection, and quadrant to the center are announced. The special instruction **ZONE, (the value of the quadrant shift) MILS, (the number of quadrants) QUADRANTS** is announced. The number of rounds announced in the method of fire for fire for effect is the number of rounds to be fired **at each quadrant.**

Note**:** Zone fires are less effective when fired with HE/Ti. Since an FS correction is not applied, the chance of graze or high airburst increases as the zone moves from the center. VT is the preferred airburst fuze for shell HE.

Sweep and Zone Fires Combined

G-39. Sweep and zone fires are used to attack targets that are both wider and deeper than the sheaf covers. The procedures used are the same as when firing sweep or zone fires individually. The special instructions announced in the fire commands are **SWEEP, (the value of the deflection shift) MILS, (the number of deflections) DEFLECTIONS, ZONE, (the value of the quadrant shift) MILS, (the number of quadrants) QUADRANTS.** (See table G-6 on page G-10.)

Table G-6. Determining Combination of Sweep and Zone Fires.

STEP	***ACTION***
1	The FDO analyzes the target description and determines that it would be best engaged by using sweep and/or zone fires and issues the fire order. If sweep fire is announced in the fire order, go to step 2. If zone fire is announced in the fire order, refer to step 6.
2	Determine the sheaf width by using Table 1 on the basis of the sheaf type announced in the fire order and the weapon caliber.
3	Determine the number of deflections to fire by dividing the target width announced by the observer by the sheaf width (step 2). If the result is an even number, express it up to the next higher odd number.
4	Determine the deflection shift by dividing the sheaf width (step 2) by the chart range (in thousands) as announced by the HCO. Express the result to the nearest whole mil. $\frac{SHEAF\ WIDTH}{CHART\ RANGE\ (IN\ THOUSANDS)} = DF\ SHIFT$
5	If zone fire was not announced in the fire order, special instructions for the sweep are announced SWEEP, (the value of the deflection shift [step 4]) MILS, (the number of deflections [step 3]) DEFLECTIONS. Go to step 11. If zone fire was announced in fire order, refer to step 6.
6	Determine the sheaf depth by using Table 2. Use the sheaf type announced in the fire order and the weapon caliber to enter the table.
	Note: After the radar spots the first round, the burst location will be transmitted to the FDC. (See Figure G-8 on page G-8)
7	Determine the number of quadrants to fire by dividing the target depth by the sheaf depth (step 6). If the result is an even number, express it up to the next higher odd number. $\frac{TARGET\ DEPTH}{SHEAF\ DEPTH} = NUMBER\ OF\ QUADRANTS$
8	Determine the quadrant shift by subtracting the elevation corresponding to the chart range from the elevation corresponding to the chart and sheaf depth.
9	If sweep fire is not announced in the fire order, special instructions for the zone are ZONE, (the value of the quadrant shift [step 8]) MILS, (the number of quadrants [step 7]) QUADRANT. Refer to step 11. If sweep fire was also announced in the fire order, refer to step 10.
10	Special instructions for sweep and zone are SWEEP, (the value of the deflection shift [step 4]) MILS, (the number of deflections [step 3]) DEFLECTIONS, ZONE, (the value of the quadrant shift [step 8]) MILS, (the number of quadrants [step 7]) QUADRANTS.
11	The computer announces the remainder of the fire commands. The initial data are based on the chart range and deflection determined and announced by the HCO.
Legend: FDO – fire direction officer HCO – horizontal control operator	

AERIAL OBSERVERS

G-40. **Problems Requiring FDC Assistance.** Aerial observers may encounter three problems that require special assistance from the fire direction center:

G-41. The aerial observer (AO) has no fixed direction to the target. Normally, he is moving in relation to the target area. Hence, FDC personnel must be prepared for unusual and changing observer directions or spotting lines. Each adjustment may have a different observer direction (that is, different magnetic or cardinal direction).

G-42. While in the air, the AO may lose his perception of distance and direction. He may request ranging rounds (two rounds impacting 400 meters apart) to help visualize distance and direction in the target area. The observer and FDC personnel must realize that ranging rounds fired along the GTL may disclose to the enemy the general location of the firing unit.

G-43. The AO must minimize the time he is exposed to enemy detection. In forward areas, the pilot must fly close to the earth and behind cover as much as possible. Therefore, the AO and his pilot require from the FDC very accurate time of flight, **SHOT,** and **SPLASH** so that the pilot can unmask the aircraft 2 to 3 seconds before the round impacts.

OBSERVER DIRECTION AND/OR SPOTTING LINE.

G-44. **Using GTL adjustment.** If the AO knows the location of the firing unit with respect to the target, he may choose to adjust along the GTL. When the AO announces **DIRECTION, GUN-TARGET LINE,** the HCO plots the target and centers the target grid over the plot with the 0-3200 line (the center arrow) parallel to the GTL.

G-45. **Using a shift from a known point along the GTL.** The AO may announce **DIRECTION, GUN-TARGET LINE** for a shift from a known point. In this instance, the HCO plots the known point, centers the target grid, and orients it parallel to the gun-target line. He then plots the observer's shift and determines chart data. He then rotates the target grid around the new pinhole so that the arrow is parallel to the GTL.

G-46. **Using helicopter instrument readings for direction.** When the AO's aircraft is moving in relation to the target area, the AO may use an aircraft instrument reading for his observer direction. As this direction is expressed in degrees, FDC personnel must convert the reading to mils by using the following formula:

DIRECTION IN DEGREES X 17.8 = DIRECTION IN MILS

G-47. For example, if the direction is 250°, the direction in mils is 4,450 (250° x 17.8 mils= 4,450 mils).

Note: In preparing for AO missions, the VCO (recorder) should mark a target grid in degrees or prepare a conversion chart for quick conversion from degrees to mils.

G-48. **Using a cardinal direction.** The AO may choose to adjust along a cardinal direction (one of the eight principal points of the compass) (see figure G-9 on page G-12). When the observer announces a cardinal direction, the HCO converts the direction to mils and orients the target grid to that direction. For example, FDC personnel would convert direction southwest (SW) to direction 4,000 mils. The observer may also shift from a known point by using a cardinal direction. The preferred method for transmitting direction to the FDC is to transmit in degrees if possible.

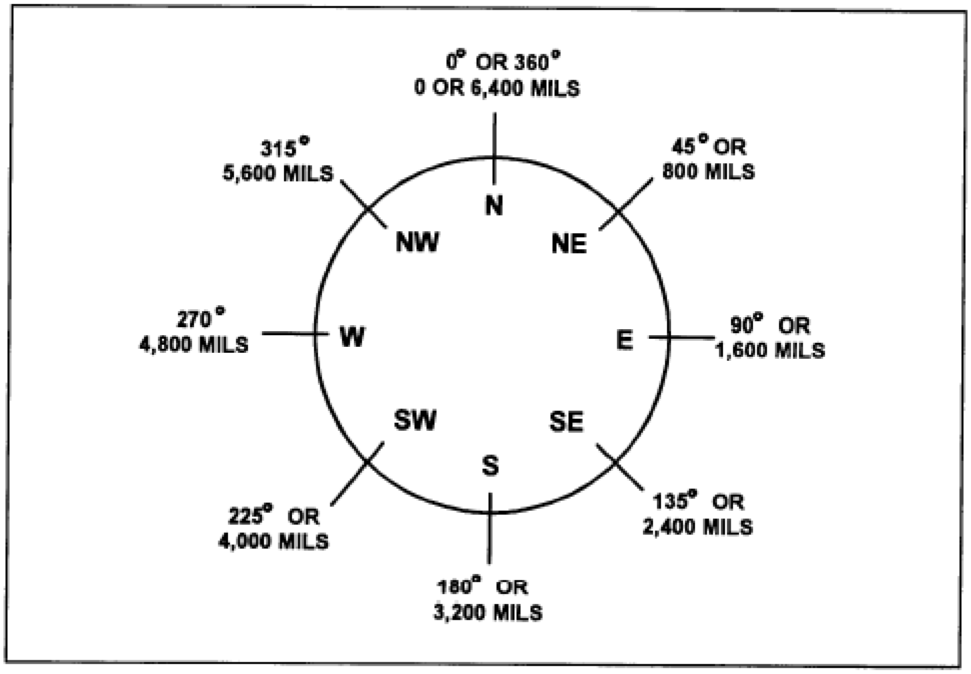


Figure G-9. Cardinal Directions.

G-49. **Using a spotting line.** The AO may adjust along a spotting line formed by natural or man-made terrain features, such as roads, railroads, canals, or ridge lines. Before flight, if possible, the AO selects the line, determines the direction, and notifies the fire direction center. While in flight, he may select a line that is more readily identifiable and convenient. The AO may describe the feature in detail and have FDC personnel use a protractor to determine the direction from a map. The HCO orients the target grid over the target location on this new direction.

RANGING ROUNDS

G-50. In his call for fire, the AO may announce **REQUEST RANGING ROUNDS.** This indicates that he wants to see a volley of two rounds that impact 400 meters apart at relatively the same time. Ranging rounds (figure G-10 on page G-13) are fired only as a last resort, since they reveal the general location of the firing position. These rounds are fired along the GTL. The HCO determines initial chart data, and the computer determines initial firing data for the adjusting howitzer. The computer then adds 400 meters to the announced chart range. Using the new range and the initial chart deflection, the computer determines firing data for the second howitzer to fire in the volley (usually the other piece in the center platoon). Ranging rounds are fired at the same time by firing **AT MY COMMAND.** The AO observes the impact of the round and determines the corrections necessary to hit the target. He bases his corrections on the round that impact nearest the target. He bases his corrections on the round that impact nearest the target. He must specify to the FDC from which round he is adjusting, and the HCO plots the shift accordingly (figure G-11 on page G-13).

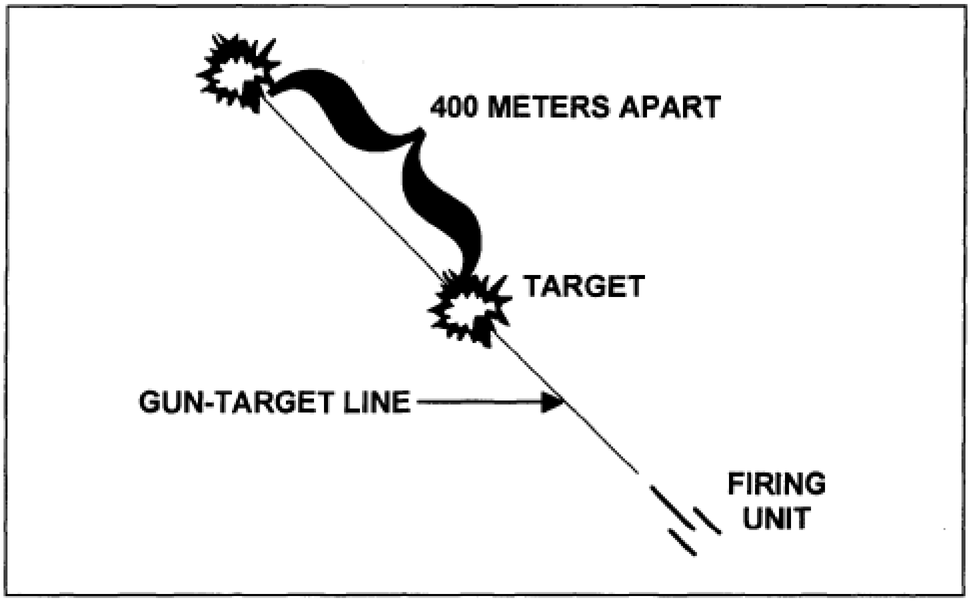


Figure G-10. Ranging Rounds.

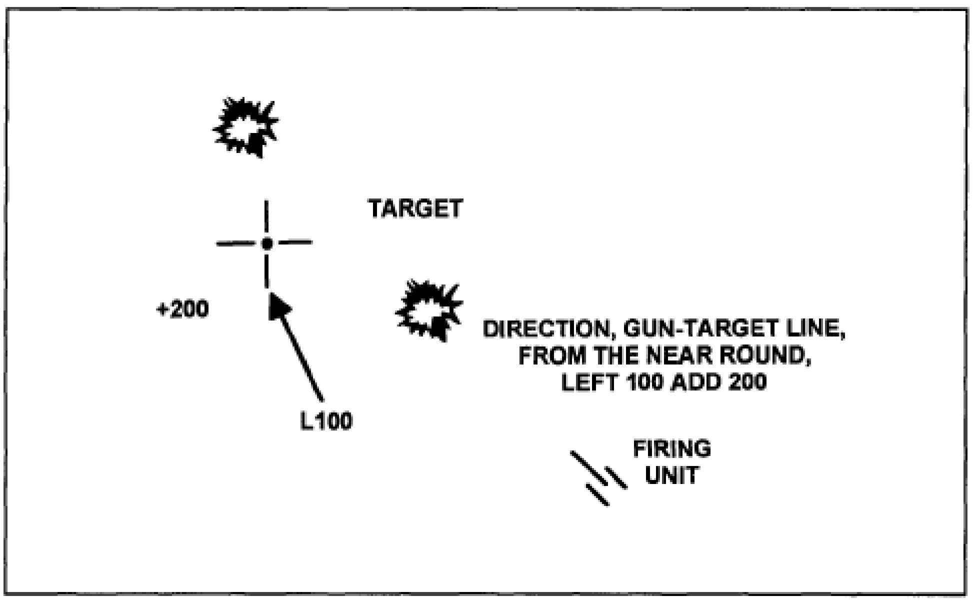


Figure G-11. Adjusting From Ranging Round.

TIME OF FLIGHT, SHOT, AND SPLASH

G-51. In the message to observer, the FDC must specify the time of flight. On all volleys, the FDC must promptly announce **SHOT** and **SPLASH.** The FDC should report changes in the time of flight as the mission progresses.

UNTRAINED OBSERVERS

G-52. Calls for fire from untrained personnel acting as ground observers require close attention and initiative from every member of the fire direction center. The FDC personnel must be prepared to assist the untrained observer in his call for fire and adjustment of artillery.

G-53. FDC personnel must take the initiative if the observer is hesitant or confused in his request for fire support. They must ask leading questions, such as the following:

- Where is the target?
  - What are the grid coordinates of the target?
  - Where is the target in relation to a readily identifiable natural or man-made feature?
  - Where are you? How far is the target from you and in what direction is it?
- What is the target?
  - Is the target personnel, vehicles, installations, or equipment?
  - What is the size of the enemy force?
  - What is the enemy force doing at present?
  - If the enemy force is moving, in what direction is it moving? How fast is the force moving?
- How close is the target to you? If the target is within 600 meters or closer to other friendly troops, the observer may need to "creep" the rounds to the target.
- What is your direction to the target?
  - What is the azimuth to the target in degrees or mils?
  - What is the cardinal direction to the target (N, NE, E, SE, S, SW, W, NW)?
  - Is the direction along a natural or man-made feature?
- What effect do you need on target?
  - Is the target shooting at you?
  - Is it necessary to obscure vision of the target?
  - Do we need to neutralize or destroy the target?

G-54. The FDC personnel must explain to the observer what artillery fire he is getting. If necessary, the FDC members must educate or inform the observer as follows:

- You will see one round that will look like a cloud of dust. You will get more rounds when you move the burst within 50 meters of the target.
- The round is now on the way and will impact in (so many) seconds.

G-55. The FDC personnel must help the observer in making corrections. They must help the observer move the rounds to the target and must be prepared for unusual shifts. To obtain corrections, they should ask leading questions such as the following:

- Where did the round land in relation to the target?
  - Did it land left or right? How far?
  - Did it land over or short? How far? Ask for distances in meters or in the number of football field lengths.
- Did the round land closer than the previous round?

Note**:** The FDO should consider using shell WP to help the observer locate initial rounds.

G-56. The FDC personnel must use sound judgment. They must decide whether to require the observer to authenticate. They must watch for possible observer misorientation. Also, FDC personnel must help the observer determine when satisfactory effects on the target have been achieved. In all cases, the FDC personnel must take the initiative.

EXAMPLE PROBLEMS

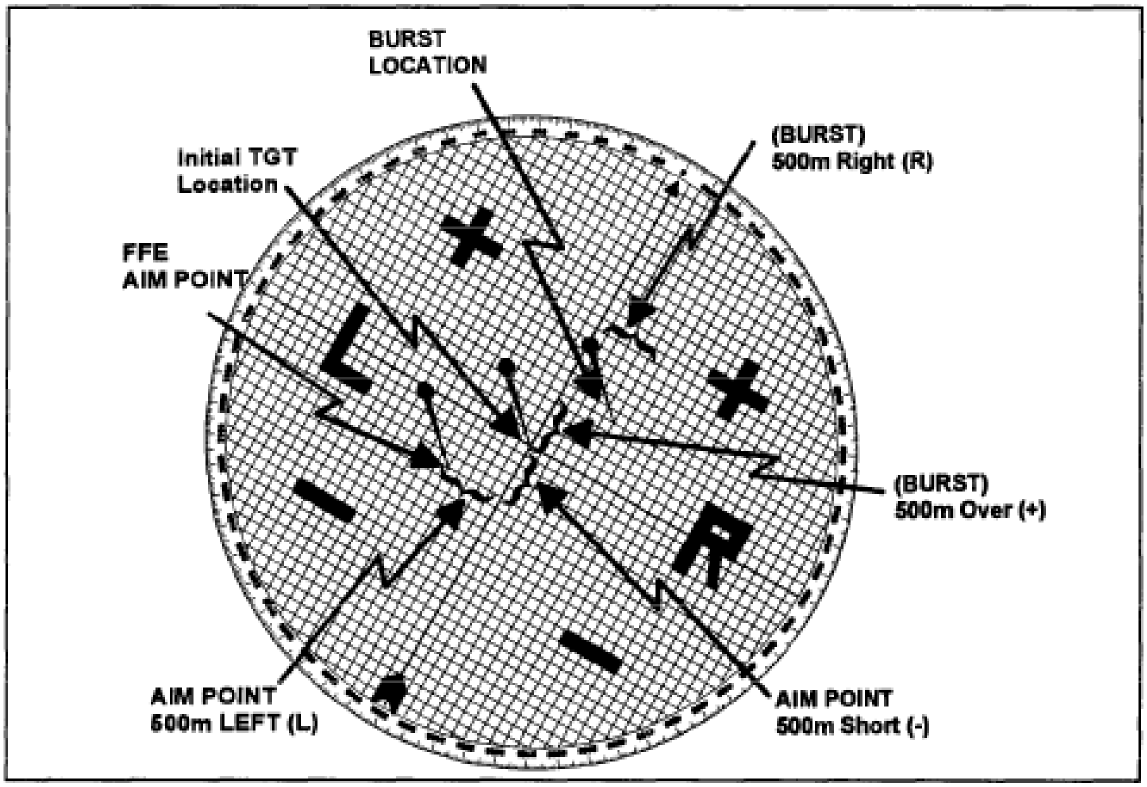
G-57. **Process a Laser Adjust-Fire Mission.** The observer transmits the following call for fire:

H57 THIS IS C19, AF POLAR, OVER.
DIRECTION 4950, DISTANCE 6990, VA PLUS 5, OVER.
BMP WITH DISMOUNTED INFANTRY, ICM IN EFFECT, OVER.

G-58. The procedures for processing a laser adjust-fire mission are discussed in table G-7.

Table G-7. Processing a Laser Adjust-Fire Mission.

STEP	*ACTION*
1	The HCO plots the target location from the observer's location by using the direction (4950) and slant distance (6990) received in the fire request. (Direction will be received to the nearest 1 mil, and slant distance to the nearest 10 meters.)
2	The HCO determines and announces the initial chart data. **(Range 12760, deflection 3053)**
3	The VCO converts the vertical angle received in the fire request into a vertical interval. **(VI = +34)**
4	The VCO determines the target altitude by applying the VI (step 3) to the observer's altitude and determines and announces site. **(+34 + 1103 = 1137 and site = +3)**
5	The computer determines the initial fire commands in compliance with the fire order. (Check and announce **FIRE MISSION, PLATOON ADJUST #3 1 ROUND, LOT A/H, CHARGE 4, DEFLECTION 3064, QUADRANT ELEVATION 313).**
6	The HCO positions the target grid over the initial target location.
7	The HCO orients the target grid by using the initial OT direction. **(4950)** After the observer spots and lases the initial round, he will transmit the burst direction, distance and vertical angle to the FDC. **(BURST DIRECTION 5028, DISTANCE 6500, VERTICAL ANGLE +10)**
8	The HCO plots the burst location by using the direction and slant distance as received from the observer. (See figure G-12 on page G-16.)
9	The HCO determines the difference between the initial target location (step 1) and the burst location (step 8) to the nearest 10 meters LEFT (L)/RIGHT I and OVER (+)/SHORT (-). **(R500, -500)**
10	The HCO places a pin in the opposite direction and magnitude (from the initial target location) of the burst. (LEFT (L) spotting becomes a RIGHT I correction, OVER (+) spotting becomes a DROP (-) correction). This is the FFE aimpoint **(L500, +500).**
11	The HCO determines chart data to the FFE aimpoint (step 10). **(Range = 13600, DF = 3102**)
12	The VCO converts the burst vertical angle to a burst vertical interval (from the observer's position). **(+64)**
13	The VCO determines the burst altitude by applying the burst VI (step 12) to the observer's altitude. **(+64 + 1103 = 1167)**
14	The VCO determines the vertical correction by subtracting the initial target altitude (step 4) from the burst altitude (Step 13). **(1167 – 1137 = 30)**
15	The VCO applies the vertical correction to the VI (step 3) and uses this value to recompute and announce site. **(30 + (34) = 64 and site = +5)**
16	The computer determines corrections for the adjustment of fuze time using standard procedures. (See figure G-13 on page G-17.)
17	The computer determines FFE fire commands in compliance with the fire order. (See figure G-13 on page G-17.)
Legend: FDC – fire direction center FFE – fire for effect HCO – horizontal control operator OT – observer-target VA – vertical angle VCO – vertical control operator VI – vertical interval	



Legend: FFE – fire for effect TGT - target

Figure G-12. Laser Polar Mission Processing.

RECORD OF FIRE

CALL FOR FIRE

Observer C19 (AF) FFE/IS/S Tgt

Grid:

Polar:Dir 4950 Dis 6990 U/D VA +5

Shift: Dir: L/R +/- U/D

BMP W/ DISM INF, ICM I/E

OBS ALT 1103 +VI 34 TGT ALT 1137 -PLT ALT 1105 VI +32	DRIFT L11 +GFT 0 DF CORR L11	△FS 100/R 8 /R 20/R 2
∠Si ÷ 10	10m Si	HOB Corr

FIRE ORDER (2) TI I/E			Df Corr L11	Si +3
INITIAL FIRE COMMANDS	(FM) MF	PLT ADJ #3 (1)	Rg 12760 / Cht Df 3053	El 310
Sp Instr	Sh / Lot A/H	Chg 4 / Fz	Ti / DF 3064	QE 313
MTO H, TI I/E 2 AB1050	∠T (0010)	PE_R (<38) / TF (33)	(2) TI in EFF	Ammo Exp (1) Q ✓

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L11)	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
DIR 5028	DIST	6500	VA +10	PLT (2) FZ TI		36.4	3102	L11	3113	13600	+2	+7	351	358	(8)	TI ✓
FFE																
			EOM	EOM												

BMP DEST EST 15 CAS

Btry 1/A	DTG 061300ZJUN13	Tgt AB1050	Replot Grid	Replot Alt

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Legend:

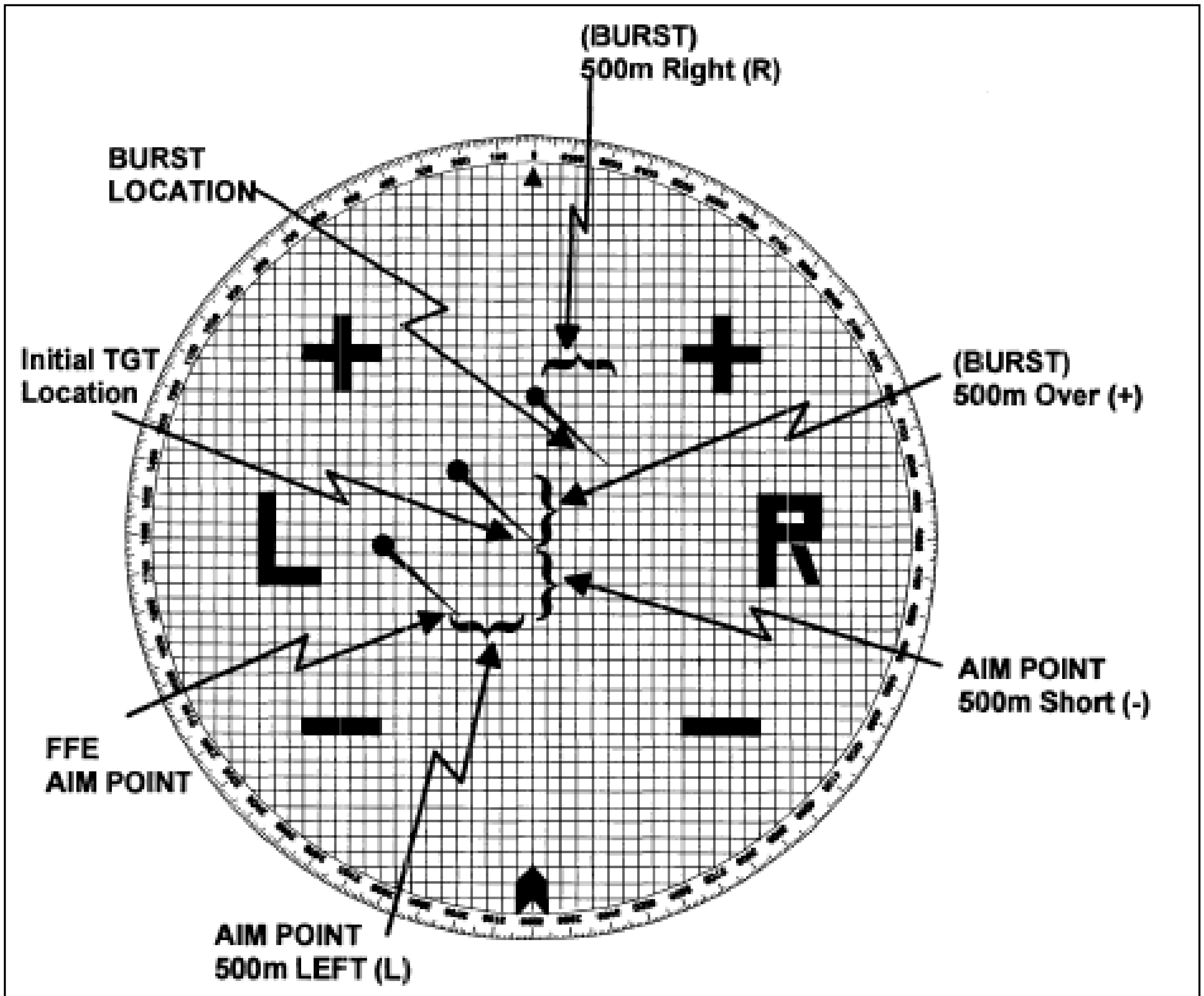
- ADJ – adjust
- AF – adjust fire
- ALT – altitude
- BTRY – battery
- CHG – charge
- CORR – correction
- DEST – destroyed
- DEV – deviation
- DF – deflection
- DIR – direction
- DIS – distance
- DISM – dismount
- DTG – date time group
- EFF – effect
- EL – elevation
- EOM – end of mission
- EST – estimate
- EXP – expended
- FFE – fire for effect
- FM – fire mission
- FS – fuze setting
- FZ – fuze
- GFT – graphical firing table
- HE – high explosive
- HOB – height of burst
- I/E – in effect
- ICM – improved conventional munition
- INF – infantry
- IS – immediate suppression
- L/R – left/right
- MF – method of fire
- MTO – message to observer
- OPT – optimum
- PER – probable error in range
- PLT – platoon
- Q – quick
- QE – quadrant elevation
- RG – range
- S – smoke
- SH – shell
- Si – site
- SP INSTR – special instructions
- TF – time of flight
- TGT – target
- TI – time
- U/D – up/down
- VA – vertical angle
- VI – vertical interval

Figure G-13. ROF (Laser Adjust-Fire Mission).

G-59. **Process a Radar Adjust-Fire Mission.** The procedures for processing a radar adjust-fire mission are discussed in table G-8.

Table G-8. Processing a Radar Adjust-Fire Mission.

STEP	***ACTION***
1	The HCO plots the target location on the firing chart by using the grid as received in the fire request. **(412 260)**
2	The HCO computer determines and announces initial chart data. **(Range 11630, DF 3602)**
3	The VCO determines and announces site on the basis of the target altitude. **(+11)**
4	The computer determines the initial fire commands in compliance with the fire order. (Circle and announce **FIRE MISSION, PLATOON ADJUST #3 1 ROUND, CHARGE 4, DEFLECTION 3611, QUADRANT ELEVATION 270)**
5	The HCO positions the target grid over the target location (step 1).
6	The HCO orients the target grid to grid north. After the radar spots the first round, the burst location will be transmitted to the FDC (see figure G-14 on page G-19).
7	The HCO plots the subsequent grid (burst location) as received from the radar.
8	The HCO determines the difference between the initial target location (step 1) and the burst location (step 3) to the nearest 10 meters, LEFT (L)/RIGHT I and OVER (+)/SHORT(-). **(R500, +500)**
9	The HCO places a pin in the opposite direction and magnitude (from the initial target location) of the burst. (LEFT [L] spotting becomes a RIGHT [R] correction, OVER [+] spotting becomes a DROP [-] correction.)(**L500, -500)**
10	The HCO determines chart data to the FFE aimpoint location (step 9). **(Range 12280, DF 3638)**
11	The VCO determines the vertical correction by subtracting the initial target altitude (step 1) from the burst altitude (step 7). **(1190 -1180 = +10)**
12	The VCO applies the vertical correction to the VI and uses the result to recompute and announce site. **(+10 + 118 = 128 and site= +12)**
13	The computer determines corrections for the adjustment of fuze time using standard procedures. (See figure G-15 on page G-20.)
14	The computer determines FFE fire commands in compliance with the fire order. (See figure G-15 on page G-20.)
Legend: FDC – fire direction center FFE – fire for effect HCO – horizontal control operator OT – observer-target VA – vertical angle VCO – vertical control operator VI – vertical interval	



Legend: FFE – fire for effect TGT - target

Figure G-14. Radar Mission Processing.

RECORD OF FIRE

CALL FOR FIRE

Observer G88 (AF)/FFE/IS/S Tgt
Grid: 412 260
Polar:Dir 4950 Dis 6990 U/D VA +5
Shift: Dir: L/R +/- U/D
PLT IN TREELINE, Q I/E

TGT ALT 1180
-PLT ALT 1062
VI +118

DRIFT L9
+GFT 0
DF CORR L9

∆FS
100/R 9
/R
20/R 2

∡Si ÷ 10 | 10m Si | HOB Corr

FIRE ORDER (4) I/E | Df Corr L9 | Si +11

INITIAL FIRE COMMANDS (FM) MF PLT ADJ #3 (1) | Rg 11630 | Cht Df 3602 | El 259

Sp Instr | Sh | Lot | Chg 4 | Fz | Ti | DF 3611 | QE 270

MTO H, 2 I/E, AB1051 | ∡T (0320) | PE_R (<38) | TF (29) | (4) in EFF | Ammo Exp (1)

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS														
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L9)	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE		Exp	Type
GRID 4186	2650	ALT 1190	DIR 4100	PLT (4)		36.4	3638	L9	3647	12280		+12	287	299		(17)	Q ✓
			EOM	EOM													

BURST ALT 1197
-INIT TGT ALT 1180
VERT CORR +17

PLT DEST EST 8 CAS

Btry 1/A | DTG 061300ZJUN13 | Tgt AB1051 | Replot Grid | Replot Alt

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Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CAS – casualties
CHG – charge
CORR – correction
DEST – destroyed
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
INIT – initial
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
RG – range
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VERT – vertical
VI – vertical interval

Figure G-15. Record of Fire (Radar Adjust-Fire Mission).

G-60. **Process a Destruction Mission.** The observer transmits the following call for fire:

> **H57 THIS IS T03, ADJUST FIRE, OVER.**
> **GRID 375 257, OVER**
> **CONCRETE BUNKER, DESTRUCTION, CP IN EFFECT, OVER.**

G-61. The following GFT setting is available:

GFT 1/A, Chg 4, Lot A/H, Rg 13020, El 335, Ti 34.6 (M582)
Total Df Corr = L6   GFT Df Corr = R6

G-62. The procedures for processing a destruction mission are discussed in table G-9. Figure G-16 on page G-22 shows a ROF for a destruction mission.

Table G-9. Processing a Destruction Mission.

STEP	***ACTION***
1	The RTO authenticates the call for fire.
2	The chart operators plot the target and determine chart data. (**Range 13200, DF 3488)**
3	The VCO determines site. **(+6)**
4	The RTO sends the MTO to the observer**. H, 1 ROUND, AB1052, RANGE PROBABLE ERROR GREATER THAN 25.**
	NOTE: Because range probable error exceeds 25 meters, the observer need only split the 100-meter bracket.
5	The computer announces initial fire commands: **FIRE MISSION, NUMBER 3 1 ROUND, LOT A/H, CHARGE 4, DEFLECTION 3494, QUADRANT ELEVATION 350, 1 ROUND CP IN EFFECT.**
6	The observer sends the following corrections: R30, +400 -200 +100 2 RDS, -50 1 RD, +50 Fuze CP, L20, -20
7	Upon receiving the refinement, the HCO plots the correction and determines chart range and deflection. **(Range 13440, DF 3487)**
8	The computer applies a 1 percent increase in air density (determined at the initial chart range) to the chart range (13440 + 60 = 10500) to correct for the firing of the concrete-piercing fuze. The commands **FUZE CP, QUADRANT ELEVATION 366** are sent to the howitzers.
9	The observer requests the next two rounds at the same data.
10	The observer requests the refinement **RIGHT 10, MINUS 10**. The FDC complies.
11	The observer requests **REPEAT**.
12	A target hit is achieved, and the observer requests end of mission and provides surveillance. The computer sends the command **END OF MISSION**.
Legend: CP – concrete penetrating DF – deflection FDC – fire direction center HCO – horizontal control operator RTO – radio telephone operator VCO – vertical control operator	

RECORD OF FIRE

CALL FOR FIRE

Observer: T13 | (AF) FFE/IS/S | Tgt

Grid: 375 257

Polar: Dir | Dis | U/D | VA

Shift: Dir: | L/R | +/- | U/D

CONCRETE BUNKER, DESTRUCTION, CP I/E

TGT ALT 1130 -PLT ALT 1062 VI +68	DRIFT L12 +GFT R6 DF CORR L6		△FS 100/R 8 /R 20/R 2
∡Si ÷ 10	10m Si		HOB Corr
FIRE ORDER (1) I/E	Df Corr L6		Si +6
INITIAL FIRE COMMANDS (FM) MF #3 (1)	Rg 13200	Cht Df 3488	El 344
Sp Instr / Sh / Lot	Chg 4 / Fz / Ti	DF 3494	QE 350
MTO H, (1) I/E, AB1052 / ∠T (0090)	PE_R >25 / TF (37)	(1) CP in EFF	Ammo Exp (1)

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L6)	Df Fired	Chart Rg	HOB Corr	Si (+6)	El	QE	Exp	Type
4600	R30	+400					3484	L6	3490	13590		+6	365	371	(2)	
		-200					3486	L6	3492	13390		+6	354	360	(3)	
		+100					3485	L6	3491	13470		+6	359	365	(4)	
(2)		-50		(2)			3486	L6	3492	13390		+6	354	360	(6)	
(1)		+50		(1)			3487	L6	3493	13450		+6	357	363	(7)	Q ✓
CP	L20	-20		FZ CP			3487	L6	(3493)	13440/13500		+6	360	366	(1)	
			RPT						(3493)						(2)	
			RPT						(3493)						(3)	
	R10	-10					3486	L6	3492	13440/13500		+6	360	366	(4)	
			RPT						(3492)						(5)	CP ✓
			EOM	EOM												

GFT 1/A CHG 4 LOT A/H RG 13020 EL 335 TI 34.6 (M582)
TOT DF CORR L6 GFT DF CORR R6

BUNKER DESTROYED EST 10 CAS

CORR FOR 1% INCREASE IN DENSITY @ RG 13200 = +59.9 ~ +60

Btry 1/A	DTG 061300ZJUN13	Tgt AB1052	Replot Grid	Replot Alt

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SAMPLE

Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
BTRY – battery
CAS – casualties
CHG – charge
CORR – correction
CP – concrete penetrating
DEST – destroyed
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
Q – quick
QE – quadrant elevation
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval

Figure G-16. Record of Fire (Destruction Mission).

G-63. **Process a Sweep and Zone Fire Mission.** The observer transmits the following all for fire:

H57 THIS IS T03, FIRE FOR EFFECT, OVER.
GRID 359 284, OVER
BATTALION ASSEMBLY AREA, LENGTH 600, WIDTH 300, ALTITUDE 0800, ICM, OVER.

G-64. The following GFT setting is available:

GFT 1/A, Chg 4, Lot A/H, Rg 11440, El 261, Ti 28.4 (M482)
Tot Df Corr L1
GFT Df Corr R8

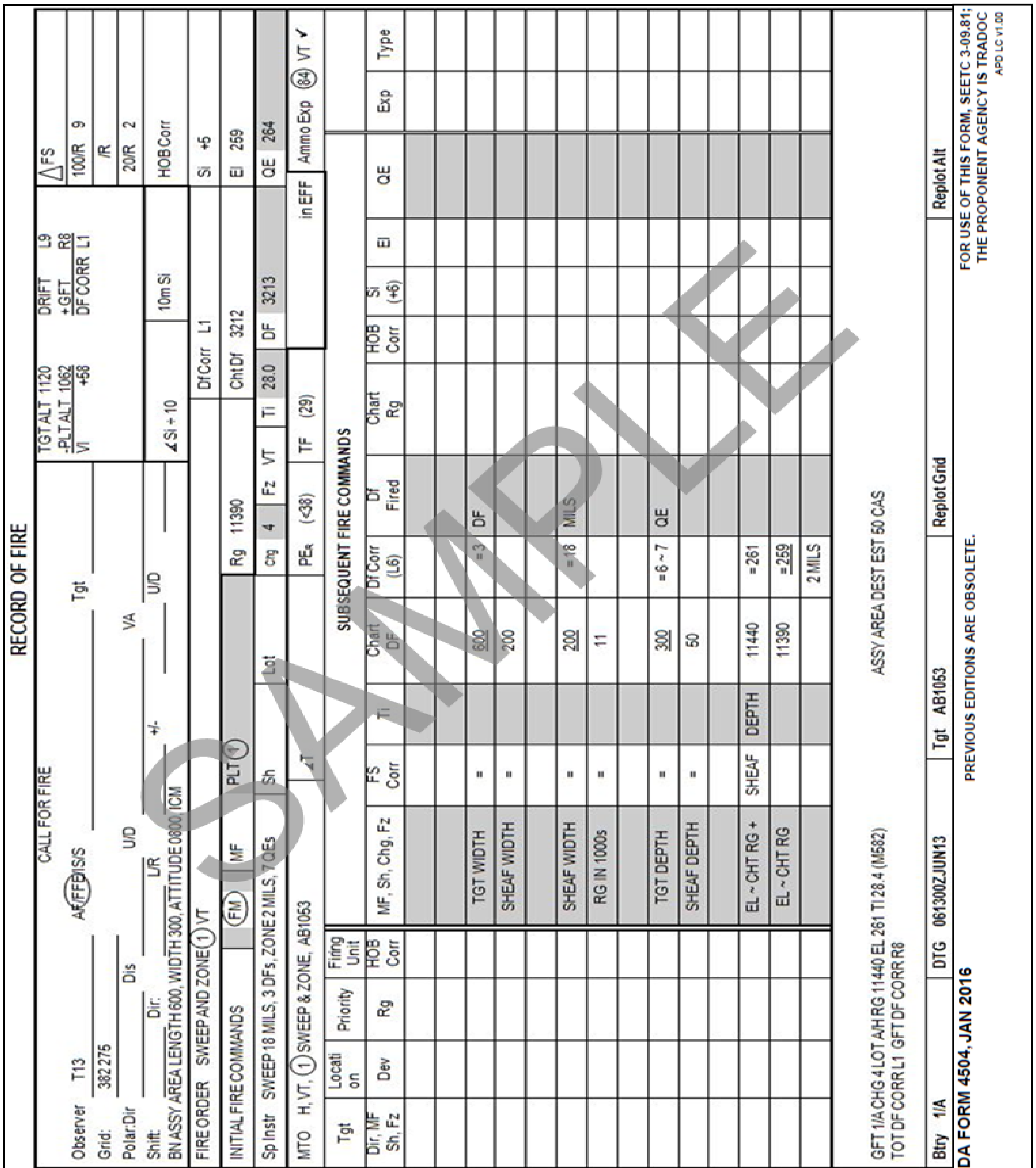
G-65. The procedures for processing a sweep and zone fire mission are discussed in table G-10. Figure G-17 on page G-25 shows a ROF for a sweep and zone fire mission.

Table G-10. Processing a Sweep and Zone Fire Mission.

STEP	***ACTION***
1	The FDO examines the plot of the target. By comparing the deflection and the attitude from the call for fire, he determines the long axis of the target is almost perpendicular to the GT line. (The deflection is converted to an azimuth on the basis of the azimuth of lay.) **COMMON DF 3200** **- CHART DF -3212** **-12** **+ AZ OF LAY 5650** **GT AZ 5638** The angle formed by the intersection of the attitude (0800) and the GT azimuth is 2412 (0800 + 6400 = 7200, 7200 – 4788 = 2412). The FDO decides to fire a sweep and zone.
2	The FDO issues the fire order: **SWEEP AND ZONE, ONE ROUND, VT**.
3	The RTO sends the **MTO H, VT, ONE ROUND, SWEEP AND ZONE, AB1053**
4	The fire direction chief determines the number of deflections to fire: **TGT WIDTH ÷ SHEAF WIDTH = NUMBER OF DEFLECTIONS** **600 ÷ 200 = 3**
5	The operations chief determines the deflection shift: $\frac{\mathit{SHEAF\ WIDTH}}{\mathit{CHART\ RANGE\ IN\ 1000s}} = \mathit{DF\ SHIFT}$ $\frac{200}{11.39} = 18$
6	The fire direction chief determines the number of quadrants to fire: **TGT DEPTH ÷ SHEAF DEPTH = NUMBER OF QUADRANTS** **300 ÷ 50 = 6** The fire direction chief expresses the result to the next higher odd number. (7)
7	The fire direction chief determines the quadrant shift: **EL AT CHART RG + SHEAF DEPTH OR** **EL ~ RG (11390 + 50) 11440 261** **EL AT CHART RG (11390) -259** **ZONE 2**
8	The computer announces initial fire commands **FIRE MISSION, PLATOON 1**.

Table G-10. Processing a Sweep and Zone Fire Mission (continued).

STEP	*ACTION*
9	The fire direction chief directs the computer to announce **SWEEP, 18 MILS, 3 DEFLECTIONS, ZONE, 2 MILS, 7 QUADRANTS.**
10	The computer determines the remainder of the fire commands: **CHARGE 4, FUZE VT, TIME 28.0, DEFLECTION (drift L9 + GFT df corr R8 + cht DF 3212) 3213, QUADRANT ELEVATION (si (+5) + el 259) 264.**
11	The number of rounds that will be expended is: **NUMBER OF Qes 7** **X NUMBER OF DFs 3** **NUMBER OF SHEAFS 21** **X RDS PER SHEAF 4** **RDS FIRED 84**
Legend: DF – deflection EL – elevation FDO – fire direction officer GFT – graphical firing table GT – gun-target MTO – message to observer QE – quadrant elevation RTO – radio telephone operator TGT – target VT – variable time	



RECORD OF FIRE

CALL FOR FIRE

Observer T13 AF/FFE/IS/S Tgt
Grid: 382275 Dis VA
Polar:Dir U/D
Shift: Dir: L/R U/D +/- VA U/D
BN ASSY AREA LENGTH 600, WIDTH 300, ATTITUDE 0800, ICM

TGT ALT 1120 -PLT ALT 1062 VI +58
DRIFT L9 +GFT R8 DF CORR L1
ΔFS 100/R 9 /R 20/R 2
∠Si ÷ 10 | 10m Si | HOB Corr

FIRE ORDER SWEEP AND ZONE (1) VT | Df Corr L1 | Si +5
INITIAL FIRE COMMANDS (FM) MF PLT (1) | Rg 11390 | Cht Df 3212 | El 259
Sp Instr SWEEP 18 MILS, 3 DFs, ZONE 2 MILS, 7 QEs | Sh | Lot | chg 4 | Fz | VT | Ti 28.0 | DF 3213 | QE 264
MTO H, VT, (1) SWEEP & ZONE, AB1053 | ∠T | PE_R (<38) | TF (29) | in EFF | Ammo Exp (84) VT ✓

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh, Chg, Fz	FS Corr	Ti	Chart DF	Df Corr (L6)	Df Fired	Chart Rg	HOB Corr	Si (+6)	El	QE	Exp	Type
				TGT WIDTH	=		600	÷3	DF							
				SHEAF WIDTH	=		200									
				SHEAF WIDTH	=		200	÷18	MILS							
				RG IN 1000s	=		11									
				TGT DEPTH	=		300	÷6 ~ 7	QE							
				SHEAF DEPTH	=		50									
				EL ~ CHT RG +	SHEAF	DEPTH	11440	=261								
				EL ~ CHT RG			11390	=259								
								2 MILS								

GFT 1/A CHG 4 LOT A/H RG 11440 EL 261 TI 28.4 (M582)
TOT DF CORR L1 GFT DF CORR R8
ASSY AREA DEST EST 50 CAS

Btry 1/A | DTG 061300ZJUN13 | Tgt AB1053 | Replot Grid | Replot Alt

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Legend:
ADJ – adjust
AF – adjust fire
ALT – altitude
ASSY – assembly
BTRY – battery
CAS – casualties
CHG – charge
CORR – correction
DEST – destroyed
DEV – deviation
DF – deflection
DIR – direction
DIS – distance
DTG – date time group
EFF – effect
EL – elevation
EOM – end of mission
EST – estimate
EXP – expended
FFE – fire for effect
FM – fire mission
FS – fuze setting
FZ – fuze
GFT – graphical firing table
HE – high explosive
HOB – height of burst
I/E – in effect
ICM – improved conventional munition
IS – immediate suppression
L/R – left/right
MF – method of fire
MTO – message to observer
PER – probable error in range
PLT – platoon
QE – quadrant elevation
RG – range
RPT – repeat
S – smoke
SH – shell
Si – site
SP INSTR – special instructions
TF – time of flight
TGT – target
TI – time
U/D – up/down
VA – vertical angle
VI – vertical interval
VT – variable time

Figure G-17. Record of Fire (Sweep and Zone Fire Mission).

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Appendix H

Smoke Tables

This Appendix contains the tables for firing smoke missions.

For all Smoke Missions:

H-1. Enter table H-1 (on page H-2) and select the appropriate Smoke Table.

H-2. Enter table H-2 (on page H-3) and extract the Weather Type.

H-3. Enter figure H-1(on page H-3) and extract the Pasquill Category.

H-4. For HC and WP (not M825) enter table H-3 (on page H-4) and extract the Mean Wind speed (WS).

H-5. Refer to the appropriate Smoke Worksheet and process the fire mission:

- M825
- M116/M84 HC
- M110/M60 WP

Table H-1. Smoke Table.

WEAPON CALIBER	PROJECTILE	SCREEN REQUIREMENT	RELATIVE HUMIDITY (PERCENT)	TABLE
M825 TABLES				
155mm	M825	NEAR INFRARED	80	I-5
			50	I-6
			20	I-7
		VISIBLE	80	I-8
			50	I-9
			20	I-10
HC TABLES				
155mm	M116	NEAR INFRARED	80	I-11
			50	I-12
			20	I-13
		VISIBLE	80	I-14
			50	I-15
			20	I-16
105mm	M84	VISIBLE	80	I-17
			50	I-18
			20	I-19
WP TABLES				
155mm	M110	NEAR INFRARED	80	I-20
			50	I-21
			20	I-22
		VISIBLE	80	I-23
			50	I-24
			20	I-25
105mm	M60	VISIBLE	80	I-26
			50	I-27
			20	I-28
Legend: HC – hexachloroethane mm – millimeter WP – white phosphorus				

Table H-2. Weather Type.

	COOL	*WARM*	*HOT*
FAHRENHEIT (F)	<50^0 F	50^0< F <75^0	>75^0 F
CELSIUS	<10^0 C	10^0< C <24^0	>24^0 C
KELVIN (K) (MET)	<283.2^0 K	283.2^0< K <297.2^0	>297.2^0 K
%STANDARD (MET)	<98.3%	98.3< % <103.1	>103.1%

H-6. Figure H-1 depicts the decision tree for determining the Pasquill weather categories.

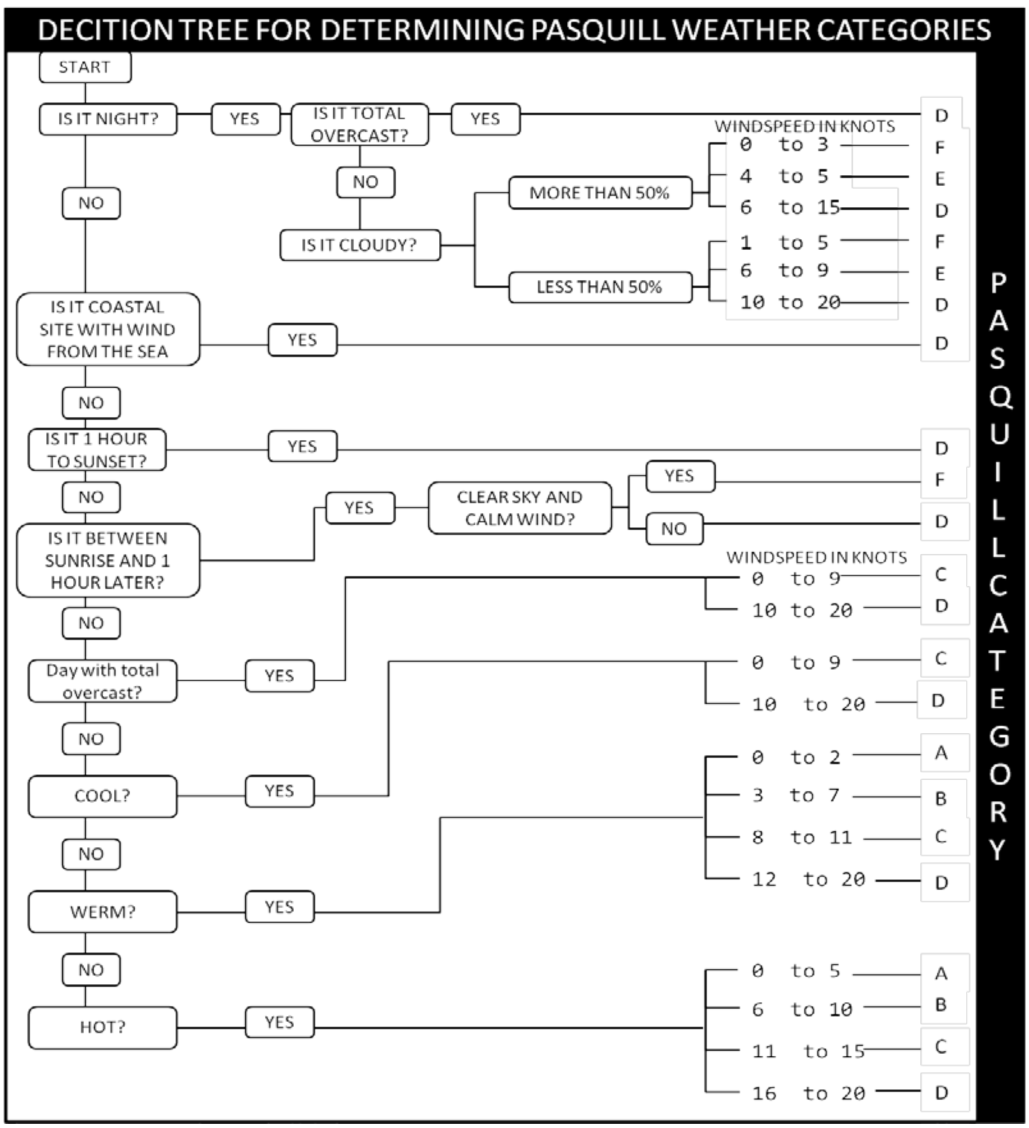

Figure H-1 Decision Tree to Determine a Pasquill Weather Category.

Table H-3. Mean Windspeed for Pasquill Category (WS).

PASQUILL CATEGORY	*WINDSPEED RANGE (IN KNOTS, Line 00)*	*MEAN WINDSPEED (WS) IN METERS PER SECOND*
A	2-5	2
B	3-6 6-10	2 4
C	0-8 9-10 11-15	2 5 7
D	6-10 11-15 16	4 6 8
E	4-5 6-9	2 4
F	1-3 4-5	1 2

H-7. See tables H-4 through H-9 (on pages H-5 through H-10) for M825 smoke tables.

Table H-4. M825 Munition Expenditure Table (Near Infrared, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5	5/3	5/2	7	7/5	8/3	9	9/7	10/4	11	11/9	12/5	15	15/13	16/7	5
B	3-6	5	5/3	5/2	7	7/5	7/3	8	8/6	9/4	10	10/8	11/5	14	14/12	16/7	5
	6-10	5	5/3	6/2	7	7/5	8/3	9	9/7	10/4	11	11/9	12/5	15	15/13	16/7	5
C	0-8	4	4/3	4/2	5	5/4	6/3	7	6/7	8/4	8	8/7	10/5	12	12/11	14/7	5
	9-10	4	4/3	5/2	6	6/5	7/3	8	8/7	9/4	10	10/9	11/5	14	14/13	15/7	5
	11-15	4/2	4/2	5/2	6/2	6/2	7/2	9/2	9/2	9/2	11/2	11/2	11/2	15/2	15/2	16/2	1.5
D	6-10	4	4/3	4/2	6	6/5	7/3	8	8/7	9/4	9	9/8	11/5	13	13/12	15/7	5
	12	4/2	4/2	5/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/2	11/2	14/2	14/2	15/2	1.5
	16	4/2	4/2	5/2	6/2	6/2	7/2	9/2	9/2	9/2	11/2	11/2	11/2	15/2	15/2	16/2	1.5
E	4-5	2	2	3/2	3	3/2	3/2	4	4/3	6/3	5	5/4	8/4	8	8/7	11/6	5
	6-9	3	3/2	3/2	4	5/3	4/3	6	6/5	7/4	7	7/6	9/5	10	10/9	13/7	5
F	1-3	2	2	2	4	4/2	4/3	5	5/4	5/3	6	6/5	6/3	9	9/8	9/5	5
	4-5	2	2	2	3	4/2	3/2	3	3/2	5/3	6	6/5	7/4	8	8/7	9/5	5
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
B	3-6	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
	6-10	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
C	0-8	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	9-10	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	11-15	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/2	11/2	15/8	15/8	15/9	*	*	*	1
D	6-10	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/2	11/2	14/2	14/3	14/2	*	*	*	2
	12	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/2	11/2	14/2	14/2	14/2	*	*	*	1
	16	5/3	5/3	5/3	8/4	8/4	8/5	11/6	11/6	11/6	14/7	14/8	14/8	*	*	*	1
E	4-5	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
	6-9	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
F	1-3	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
	4-5	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
* EXCEEDS 16 ROUNDS																	
Legend: CAT – category INT – interval KN – knots MIN – minutes																	

Table H-5. M825 Munition Expenditure Table (Near Infrared, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5	5/3	6/2	8	8/6	8/3	10	10/8	10/4	12	12/10	12/5	16	16/14	*	5
B	3-6	5	5/3	6/2	7	7/5	8/3	9	9/7	10/4	11	11/9	12/5	15	15/13	16/7	5
	6-10	6	6/4	6/2	8	8/6	8/3	10	10/8	10/4	12	12/10	12/5	16	16/14	16/7	5
C	0-8	4	4/3	4/2	6	6/5	7/3	8	8/7	9/4	10	10/9	11/5	14	14/13	15/7	5
	9-10	5	5/4	5/2	7	7/6	7/3	9	9/8	9/4	11	11/10	11/5	15	15/14	16/8	5
	11-15	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	11/2	11/2	11/2	15/2	15/2	16/2	1.5
D	6-10	4	4/3	5/2	6	6/5	7/3	8	8/7	9/4	11	11/10	11/5	15	15/14	16/8	5
	12	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	11/2	11/2	11/2	15/2	15/2	16/2	1.5
	16	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	11/2	11/2	11/2	15/2	15/2	16/2	1.5
E	4-5	3	3/2	3/2	4	4/3	5/3	6	6/5	7/4	8	8/7	9/5	11	11/10	13/7	5
	6-9	3	3/2	4/2	5	5/4	6/3	7	7/6	8/4	9	9/8	10/5	13	13/12	14/7	5
F	1-3	2	2	3/2	4	4/3	5/3	4	4/3	6/3	6	6/5	8/4	8	8/7	12/6	5
	4-5	2	2	3/2	4	4/3	5/3	5	5/4	7/4	6	6/5	9/5	9	9/8	12/6	5
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
B	3-6	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
	6-10	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
C	0-8	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	9-10	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	11-15	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/2	11/2	15/8	15/8	15/9	*	*	*	1
D	6-10	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	12	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/2	11/2	14/2	14/2	14/2	*	*	*	1
	16	5/3	5/3	5/3	8/4	8/4	8/5	11/6	11/6	11/6	14/7	14/8	14/8	*	*	*	1
E	4-5	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
	6-9	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
F	1-3	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
	4-5	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
* EXCEEDS 16 ROUNDS																	
Legend: CAT – category INT – interval KN – knots MIN – minutes																	

Table H-6. M825 Munition Expenditure Table (Near Infrared, 20% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	6	6/4	6/2	8	8/6	8/3	10	10/8	10/4	12	12/10	12/5	16	16/14	*	5
B	3-6	5	5/3	6/2	7	7/5	8/3	10	10/8	10/4	12	12/10	12/5	16	16/14	*	5
	6-10	6	6/4	6/2	8	8/6	8/3	10	10/8	10/4	12	12/10	12/5	16	16/14	*	5
C	0-8	4	4/3	5/2	6	6/5	7/3	8	8/7	9/4	10	10/9	11/5	14	14/13	15/7	5
	9-10	5	5/4	5/2	7	7/6	7/3	9	9/8	9/4	11	11/10	11/5	15	15/14	16/8	5
	11-15	5/4	5/4	5/4	8/7	8/7	8/7	11/10	11/9	11/10	13/12	13/11	13/12	*	*	*	1.5
D	6-10	4	4/3	5/2	7	7/6	7/3	9	9/8	9/4	11	11/10	11/5	15	15/4	16/8	5
	12	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	11/12	11/2	11/2	15/2	15/2	16/2	1.5
	16	5/4	5/4	5/4	8/7	8/7	8/7	10/9	10/8	10/9	13/12	13/11	13/12	*	*	*	1.5
E	4-5	3	3/2	3/2	5	5/4	5/3	6	6/5	8/4	8	8/7	10/5	12	12/11	14/7	5
	6-9	3	3/2	4/2	5	5/4	6/3	7	7/6	8/4	9	9/8	10/5	13	13/12	14/7	5
F	1-3	2	2	3/2	4	4/3	5/3	5	5/4	7/4	7	7/6	9/5	9	9/8	13/7	5
	4-5	3	3/2	3/2	4	4/3	5/3	6	6/5	7/4	7	7/6	9/5	10	10/9	13/7	5
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
B	3-6	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
	6-10	6/2	6/2	6/2	9/2	9/2	9/2	12/2	12/3	12/2	15/2	15/3	15/2	*	*	*	2
C	0-8	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	9-10	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	11-15	6/3	6/3	6/3	9/5	9/5	9/5	12/6	12/7	12/7	15/8	15/8	15/9	*	*	*	1
D	6-10	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/3	11/2	14/2	14/3	14/2	*	*	*	2
	12	5/2	5/2	5/2	8/2	8/2	8/2	11/2	11/2	11/2	14/2	14/2	14/2	*	*	*	1
	16	5/3	5/3	5/3	8/4	8/4	8/5	11/6	11/6	11/6	14/7	14/8	14/8	*	*	*	1
E	4-5	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
	6-9	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
F	1-3	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
	4-5	4/2	4/2	4/2	7/2	7/2	7/2	10/2	10/3	10/2	13/2	13/3	13/2	*	*	*	2
* EXCEEDS 16 ROUNDS																	

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-7. M825 Munition Expenditure Table (Visible, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5	5/3	5/2	6	6/4	7/3	8	8/6	9/4	10	10/8	11/5	13	13/11	15/7	5
B	3-6	4	4/2	5/2	6	6/4	7/3	7	7/5	9/4	8	8/6	10/4	11	11/9	14/6	5
	6-10	5	5/3	5/2	7	7/5	7/3	8	8/6	9/4	10	10/8	11/5	13	13/11	15/7	5
C	0-8	3	3/2	4/2	4	4/3	5/2	5	5/4	7/3	6	6/5	9/4	9	9/8	12/6	5
	9-10	4	4/3	4/2	6	6/5	6/3	7	7/6	8/4	9	9/8	10/5	12	12/11	14/7	5
	11-15	4/2	4/2	4/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/3	11/2	13/2	13/4	15/3	2.5
D	6-10	3	3/2	4/2	5	5/4	6/3	6	6/5	8/4	8	8/7	10/5	10	10/9	13/6	5
	12	4/2	4/2	4/2	5/2	5/2	6/2	7/2	7/2	8/2	9/2	9/3	10/2	12/2	12/4	14/3	2.5
	16	4/2	4/2	4/2	6/2	6/2	7/2	8/2	8/2	9/2	9/2	9/3	11/2	13/2	13/4	15/3	2.5
E	4-5	2	2	2	3	3/2	3/2	4	4/3	5/3	6	6/5	6/3	8	8/7	8/4	5
	6-9	2	2	3/2	3	3/2	4/2	4	4/3	6/3	5	5/4	7/4	7	7/6	7/6	5
F	1-3	2	2	2	2	2	2	3	3/2	3/2	4	4/3	4/2	5	5/4	5/3	5
	4-5	2	2	2	2	2	2	3	3/2	3/2	4	4/3	4/2	6	6/5	6/3	5
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
B	3-6	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
	6-10	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
C	0-8	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	9-10	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	11-15	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
D	6-10	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	12	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
	16	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
E	4-5	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
	6-9	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
F	1-3	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
	4-5	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-8. M825 Munition Expenditure Table (Visible, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5	5/3	5/2	7	7/5	7/3	8	8/6	9/4	10	10/8	11/5	14	14/12	15/7	5
B	3-6	5	5/3	5/2	6	6/4	7/3	8	8/6	9/4	9	9/7	11/5	12	12/10	15/7	5
	6-10	5	5/3	5/2	7	7/5	7/3	9	9/7	10/4	10	10/8	12/5	14	14/12	16/7	5
C	0-8	3	3/2	4/2	5	5/4	6/3	6	6/5	7/3	7	7/6	9/4	10	10/9	13/6	5
	9-10	4	4/3	4/2	6	6/5	6/3	8	8/7	9/4	9	9/8	10/5	12	12/11	14/7	5
	11-15	4/2	4/2	5/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/3	11/2	14/2	14/4	15/3	2.5
D	6-10	4	4/3	4/2	5	5/4	6/3	7	7/6	8/4	8	8/7	10/5	11	11/10	14/7	5
	12	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	9/2	9	9/3	11/2	13/2	13/4	15/3	2.5
	16	4/2	4/2	5/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/3	11/2	14/2	14/4	15/3	2.5
E	4-5	2	2	2	3	3/2	4/2	3	3/2	5/3	6	6/5	7/4	8	8/7	9/5	5
	6-9	2	2	3/2	3	3/2	3/2	4	4/3	6/3	6	6/5	8/4	8	8/7	11/6	5
F	1-3	2	2	2	3	3/2	3/2	3	3/2	3/2	4	4/3	4/2	6	6/5	6/3	5
	4-5	2	2	2	3	3/2	3/2	4	4/3	4/2	5	5/4	5/3	7	7/6	7/4	5
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		250			500			750			1000			1500			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
B	3-6	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
	6-10	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
C	0-8	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	9-10	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	11-15	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
D	6-10	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	12	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
	16	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
E	4-5	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
	6-9	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
F	1-3	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
	4-5	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
Legend: CAT – category INT – interval KN – knots MIN – minutes																	

Table H-9. M825 Munition Expenditure Table (Visible, 20% Relative Humidity).

CROSSWIND																
SCREEN WIDTH (METERS)		250			500			750			1000			1500		
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5	5/3	5/2	7	7/5	8/3	9	9/7	10/4	11	11/9	12/5	15	15/13	16/7	5
B	3-6	5	5/3	5/2	7	7/5	7/3	8	8/6	9/4	10	10/8	11/5	13	13/11	15/7	5
	6-10	5	5/3	6/2	7	7/5	8/3	9	9/7	10/4	11	11/9	12/5	15	15/13	16/7	5
C	0-8	4	4/3	4/2	5	5/4	6/3	7	7/6	8/4	8	8/7	10/5	11	11/10	14/7	5
	9-10	4	4/3	5/2	6	6/5	7/3	8	8/7	9/4	10	10/9	11/5	14	14/13	15/7	5
	11-15	4/2	4/2	5/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/3	11/2	15/2	15/5	15/3	2.5
D	6-10	4	4/3	4/2	6	6/5	6/3	7	7/6	9/4	9	9/8	11/5	13	13/12	15/7	5
	12	4/2	4/2	5/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/3	11/2	14/2	14/4	15/3	2.5
	16	4/2	4/2	5/2	6/2	6/2	7/2	8/2	8/2	9/2	10/2	10/3	11/2	15/2	15/5	15/3	2.5
E	4-5	2	2	3/2	3	3/2	4/2	4	4/3	6/3	5	5/4	8/4	7	7/6	11/6	5
	6-9	3	3/2	3/2	4	4/3	5/3	5	5/4	7/4	7	7/6	9/5	10	10/9	13/7	5
F	1-3	2	2	2	3	3/2	3/2	4	4/3	4/2	6	6/5	6/3	8	8/7	8/4	5
	4-5	2	2	2	3	3/2	4/2	4	4/3	5/3	6	6/5	6/3	8	8/7	9/5	5
HEAD OR TAIL WIND																
SCREEN WIDTH (METERS)		250			500			750			1000			1500		
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN															FIRE INT (MIN)
A	2-5	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
B	3-6	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
	6-10	5/2	5/2	5/2	7/2	7/2	7/2	9/2	9/2	9/2	12/2	12/3	12/2	16/2	16/4	16/2	2
C	0-8	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	9-10	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	11-15	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
D	6-10	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/3	11/2	15/2	15/4	15/2	2
	12	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
	16	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	11/2	11/2	11/2	15/2	15/2	15/2	1.5
E	4-5	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
	6-9	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
F	1-3	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
	4-5	3/2	3/2	3/2	5/2	5/2	5/2	7/2	7/2	7/2	10/2	10/3	10/2	14/2	14/4	14/2	2
Legend: CAT – category INT – interval KN – knots MIN – minutes																

H-8. See tables H-10 through H-15 (on pages H-11 through H-16) for M116 smoke tables.

Table H-10. M116 HC Munition Expenditure Table (Near Infrared, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4/2			6/2			8/2			10/2			14/4			2
B	3-6	4/2			4/2	6/2	6/2	6/2	8/2	8/2	8/2	10/2	10/2	12/2			2
	6-10	2			4/2			6/2			6/4			8/4			
C	0-8	4/2			6/2			8/2	4	4	10/2			12/2			2
	9-10	2			4/2			4/2			4			6/4	6/4	6	
	11-15	2			4/2	4/2	4	4			4			6/4			
D	6-10	2			4/2			4/2			6/2			6/4			2
	12	2			2			4			4			4			
	16	2			2			4/2			4			4			
E	4-5	2			4/2			6/2			8/2			10/2			2
	6-9	2			4/2			4/2			6/2			6/2			
F	1-3	6/2			8/2			10/2			12/2			14/2			2
	4-5	2			4/2			6/2			8/2			10/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4			6			10			12			14			2
B	3-6	4			6			8			10			12			2
	6-10	4			6			8			10			12			
C	0-8	4			6			8			10			12			2
	9-10	4			6			8			10			10			
	11-15	4			6			8			10			14			
D	6-10	4			4			6			6			8			2
	12	2			4			6			8			10			
	16	4			6			8			10			12			
E	4-5	2			4			6			8			10			2
	6-9	2			4			4			6			6			
F	1-3	4			8			12			16			*			2
	4-5	2			4			6			8			10			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-11. M116 HC Munition Expenditure Table (Near Infrared, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4/2			4			8/4			10/4			12/6			2
B	3-6	2			4/2			6/4			8/4			10/4			2
	6-10	2			4/2	4	4	4			6/4	6	6	6			
C	0-8	4/2			6/2			8/2			8/4			10/4			2
	9-10	2			2			4			4			6/4	6	6	
	11-15	2			4/2	4/2	4	4			6			8/6	8/6	8	
D	6-10	2			4/2			4			4			6/4			2
	12	2			4/2	4	4	4			4			6/4	6/4	6	
	16	4/2	4/2	4	4			6/4	6/4	6	6			8/6	8/6	8	
E	4-5	2			4/2			6/2			8/2			10/2			2
	6-9	2			4/2			4/2			6/2			6/4			
F	1-3	6/2			8/2			10/2			12/2			14/2			2
	4-5	2			4/2			6/2			8/2			10/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4			6			10			12			14			2
B	3-6	4			6			8			10			12			2
	6-10	6/4			10/8			12			16			*			
C	0-8	4			6			8			10			12			2
	9-10	6			8			12			14			*			
	11-15	6			12			16			*			*			
D	6-10	4			6			6			8			10			2
	12	4			8			10			12			16			
	16	6			10			14			16			*			
E	4-5	4			6			8			10			12			2
	6-9	2			4			4			6			8			
F	1-3	6			10			14			*			*			2
	4-5	4			6			8			10			12			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-12. M116 HC Munition Expenditure Table (Near Infrared, 20% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4/2			6/2			8/2			10/2			14/4			2
B	3-6	4/2	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	10/2	10/2	12/2			2
	6-10	2			4/2			6/2	4	4	6/4			8/4			
C	0-8	4/2			6/2			8/2			10/2			12/2			2
	9-10	2			4/2			4/2			4			6/4			
	11-15	2			4/2	4/2	4	4			4			6/4	6/4	6	
D	6-10	2			4/2			4/2			6/2			6/2			2
	12	2			2			4			4			4			
	16	2			2			4/2			4			4			
E	4-5	2			4/2			6/2			8/2			6/4			2
	6-9	2			4/2			4/2			6/2			6/2			
F	1-3	6/2			8/2			10/2			12/2			14/2			2
	4-5	2			4/2			6/2			8/2			10/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4			6			10			12			14			2
B	3-6	4			6			8			10			12			2
	6-10	4			6			8			10			12			
C	0-8	4			6			8			10			12			2
	9-10	4			6			8			10			10			
	11-15	4			6			8			10			14			
D	6-10	4			4			6			6			8			2
	12	2			4			6			8			10			
	16	4			6			8			10			12			
E	4-5	2			4			6			8			10			2
	6-9	2			4			4			6			6			
F	1-3	4			8			12			16			*			2
	4-5	2			4			6			8			10			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-13. M116 HC Munition Expenditure Table (Visible, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4/2			6/2			8/2			10/2			14/2			2
B	3-6	2	4/2	4/2	4/2	6/2	6/2	6/2	8/2	8/2	8/2	10/2	10/2	12/2			2
	6-10	2	4/2	4/2	4/2			6/2			6/2	6/4	6/4	6/4			
C	0-8	4/2			6/2			8/2			10/2			12/2			2
	9-10	2			2	4/2	4/2	4/2			6/2			6/4			
	11-15	2			2			4/2	4/2	4	4			6/4			
D	6-10	2			4/2			4/2			6/2			6/2			2
	12	2			2			4/2			4			4			
	16	2			2			4/2			4			4			
E	4-5	2			4/2			6/2			8/2			10/2			2
	6-9	2			4/2			4/2			6/2			6/2			
F	1-3	6/2			8/2			10/2			12/2			14/2			2
	4-5	2			4/2			6/2			8/2			10/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4			6			8			12			14			2
B	3-6	2			6			8			10			12			2
	6-10	4			4			6			8			10			
C	0-8	4			6			8			10			12			2
	9-10	4			4			6			8			8			
	11-15	2			4			6			8			10			
D	6-10	2			4			6			6			8			2
	12	2			4			4			6			8			
	16	4			6			6			8			10			
E	4-5	2			4			6			8			10			2
	6-9	2			4			4			6			6			
F	1-3	4			8			12			16			*			2
	4-5	2			4			6			8			10			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-14. M116 HC Munition Expenditure Table (Visible, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4/2			6/2			8/4			10/4			12/4			2
B	3-6	2			4/2			6/2			8/4			10/4			2
	6-10	2			4/2	4/2	4	4			6/4			6/4			
C	0-8	4/2			6/2			8/2			10/2			12/2			2
	9-10	2			2			4/2	4	4	4	4	4	6/4			
	11-15	2			2			4/2	4	4	4/2			4			
D	6-10	2			4/2			4/2			6/2			6/4			2
	12	2			4/2			4/2	4/2	4	4/2	4	4	4			
	16	2			4/2	4/2	4	4/2	4	4	4			4			
E	4-5	2			4/2			6/2			8/2			10/2			2
	6-9	2			4/2			4/2			6/2			6/2			
F	1-3	6/2			8/2			10/2			12/2			14/2			2
	4-5	2			4/2			6/2			8/2			10/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4			6			10			12			14			2
B	3-6	4			6			8			10			12			2
	6-10	4			6			8			10			12			
C	0-8	4			6			8			10			12			2
	9-10	4			8			8			10			10			
	11-15	4			8/6			10			12			16			
D	6-10	2			4			6			6			8			2
	12	4			4			6			8			10			
	16	4			6			8			10			12			
E	4-5	4			6			8			10			12			2
	6-9	2			4			4			6			6			
F	1-3	6/2			10/2			14/2			*			*			2
	4-5	4			6			8			10			12			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-15. M116 HC Munition Expenditure Table (Visible, 20% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4/2			6/2			8/4			10/4			12/4			2
B	3-6	2			4			6/4			8/4			10/6			2
	6-10	2			4/2			4			6/4			6			
C	0-8	4/2			6/2			8/2			10/2			10/4			2
	9-10	2			2			4/2	4/2	4	4			6/4			
	11-15	2			2			4			4			6/4	6/4	6	
D	6-10	2			4/2			4/2			6/4			6/4			2
	12	2			2			4/2			4			4			
	16	2			2			4			4			6/4			
E	4-5	2			4/2			6/2			8/2			10/2			2
	6-9	2			4/2			6/2			6/2			6/4			
F	1-3	6/2			4/2			10/4			12/2			14/2	14/2	16/2	2
	4-5	2			4/2			6/2			8/2			10/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	6			6			10			12			14			2
B	3-6	4			6			8			10			12			2
	6-10	4			8			10			12			14			
C	0-8	4			6			8			10			12			2
	9-10	4			8			8			10			12			
	11-15	6			8			10			14			*			
D	6-10	4			6			8			10			12			2
	12	4			6			8			10			12			
	16	4			8			10			12			16			
E	4-5	4			6			8			10			12			2
	6-9	2			4			4			6			6			
F	1-3	6			10			14			*			*			2
	4-5	4			6			8			10			12			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

H-9. See tables H-16 through H-18 (on pages H-17 through H-19) for M84A1 smoke tables.

Table H-16. M84A1 HC Munition Expenditure Table (Visible, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	4			7			9			12			15			2
B	3-6	4			6			8			10			12			2
	6-10	46			11			15			*			*			
C	0-8	4/2			6/4			8/5			10/6			12/8			2
	9-10	6			10			15			*			*			
	11-15	8			15			*			*			*			
D	6-10	4			6			8			10			12			2
	12	5			9			13			*			*			
	16	8			14			*			*			*			
E	4-5	3/2			5/2			7/2			9/3			11/3			2
	6-9	3/2			4			5			6			7			
F	1-3	6/2			10/2			14/2			*			*			2
	4-5	3/2			5/2			7/2			9/2			11/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	11			*			*			*			*			2
B	3-6	10			*			*			*			*			2
	6-10	*			*			*			*			*			
C	0-8	6			11			16			*			*			2
	9-10	*			*			*			*			*			
	11-15	*			*			*			*			*			
D	6-10	10			*			*			*			*			2
	12	16			*			*			*			*			
	16	*			*			*			*			*			
E	4-5	3			5			5			9			11			2
	6-9	8			9			9			*			*			
F	1-3	6			10			10			*			*			2
	4-5	3			5			5			9			11			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-17. M84A1 HC Munition Expenditure Table (Visible, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	5			9			13			*			*			2
B	3-6	5			8			11			15			*			2
	6-10	8			15			*			*			*			
C	0-8	4			6			8			10			12			2
	9-10	8			15			*			*			*			
	11-15	12			*			*			*			*			
D	6-10	5			8			12			15			*			2
	12	8			14			*			*			*			
	16	11			*			*			*			*			
E	4-5	3/2			5/2			7/3			9/4			11/5			2
	6-9	3			5			7			8			10			
F	1-3	6/2			10/2			14/2			*			*			2
	4-5	3/2			5/2			7/2			9/2			12/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	16			*			*			*			*			2
B	3-6	14			*			*			*			*			2
	6-10	*			*			*			*			*			
C	0-8	9			*			*			*			*			2
	9-10	*			*			*			*			*			
	11-15	*			*			*			*			*			
D	6-10	14			*			*			*			*			2
	12	*			*			*			*			*			
	16	*			*			*			*			*			
E	4-5	4			7			10			13			16			2
	6-9	8			14			*			*			*			
F	1-3	6			10			14			*			*			2
	4-5	3			3			7			9			11			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-18. M84A1 HC Munition Expenditure Table (Visible, 20% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	6			10			15			*			*			2
B	3-6	5			9			13			*			*			2
	6-10	10			*			*			*			*			
C	0-8	4			6			9			11			14			2
	9-10	10			*			*			*			*			
	11-15	14			*			*			*			*			
D	6-10	6			10			14			*			*			2
	12	9			*			*			*			*			
	16	13			*			*			*			*			
E	4-5	3/2			5/3			7/4			9/5			11/6			2
	6-9	4			6			8			10			12			
F	1-3	6/2			10/2			14/2			*			*			2
	4-5	3/2			5/2			7/2			9/2			11/3			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		200			400			600			800			1000			
SCREEN TIME (MINUTES)		4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (MIN)
A	2-5	*			*			*			*			*			2
B	3-6	16			*			*			*			*			2
	6-10	*			*			*			*			*			
C	0-8	11			*			*			*			*			2
	9-10	*			*			*			*			*			
	11-15	*			*			*			*			*			
D	6-10	*			*			*			*			*			2
	12	*			*			*			*			*			
	16	*			*			*			*			*			
E	4-5	5			9			12			16			*			2
	6-9	9			*			*			*			*			
F	1-3	6			10			14			*			*			2
	4-5	3			5			7			9			11			

[1] 6 AND 8 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 4 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

H-10. See tables H-19 through H-24 (on pages H-20 through H-25) for M110 smoke tables.

Table H-19. M110 WP Munition Expenditure Table (Near Infrared, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	4			6			8			10/8			12/10			60
B	3-6	4			6/4			6/4			6			8/6			60
	6-10	4			6/4			8/4			8/6			8			40
C	0-8	4/2			4/2			6/4			6/4			8/6			40
	9-10	4/2			4/2			6/4			6/4			6			
	11-15	4/2			4			6/4			6/4			8/6			
D	6-10	4/2			4/2			4			4			6/4			40
	12	4/2			4/2			6/4			6/4			6			
	16	4/2			4/2			6/2			4			6			
E	4-5	2			2			4/2			4/2			4/2			40
	6-9	2			4/2			4/2			4/2			4			
F	1-3	2			2			2			4/2			4/2			40
	4-5	2			2			2			2			4/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	8			10			10			12			16			40
B	3-6	6			8			8			10			12			40
	6-10	6			8			8			10			12			
C	0-8	4			6			6			8			8			60
	9-10	6			6			6			8			8			40
	11-15	6			6			6			8			10			
D	6-10	4			6			6			6			8			40
	12	4			6			6			6			8			
	16	6			6			6			6			8			
E	4-5	4			4			4			4			4			60
	6-9	4			4			4			4			6			
F	1-3	4			4			4			4			4			60
	4-5	4			4			4			4			4			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-20. M110 WP Munition Expenditure Table (Near Infrared, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	8/4			10/8			14/12			*			*			40
B	3-6	6/4			8/6			10/8			12/10			16/14			40
	6-10	6/4			8/6			10/8			12/10			16/14			
C	0-8	4			6/4			8/6			8			12/10			40
	9-10	4			6/4			8/6			8			12/10			
	11-15	4			6/4			8/6			8			12/10			
D	6-10	4/2			4			6/4			6			8			40
	12	4/2			4			6/4			6			8			
	16	4/2			4			6/4			6			8			
E	4-5	2			2			4			4			6			40
	6-9	2			2			4			4			6			
F	1-3	2			2			2			2			4			40
	4-5	2			2			2			4			4			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	10			12			16			*			*			40
B	3-6	8			10			12			14			*			40
	6-10	8			10			12			14			*			
C	0-8	6			8			8			10			12			60
	9-10	6			8			10			10			14			40
	11-15	6			8			10			10			14			
D	6-10	4			6			8			8			10			40
	12	6			6			8			8			10			
	16	6			6			8			8			10			
E	4-5	4			4			6			6			6			60
	6-9	4			4			6			6			6			
F	1-3	4			4			4			4			6			60
	4-5	4			4			4			4			6			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-21. M110 WP Munition Expenditure Table (Near Infrared, 20% Relative Humidity).

CROSSWIND

SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	8/6			12/10			16/14			*			*			40
B	3-6	6/4			8			12/10			14/12			*			40
	6-10	6/4			8			12/10			14/12			*			
C	0-8	4			6			8			10/8			12			40
	9-10	4			6			8			10			14/12			
	11-15	4			6			8			10			14/12			
D	6-10	4			6/4			6			6			10			40
	12	4			6/4			6			6			10			
	16	4			6/4			6			8/6			10			
E	4-5	2			4			4			4			6			40
	6-9	2			4			4			6			6			
F	1-3	2			2			2			4			4			40
	4-5	2			2			2			4			4			

HEAD OR TAIL WIND

SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	10			14			*			*			*			40
B	3-6	8			12			14			*			*			40
	6-10	8			12			14			16			*			
C	0-8	6			8			10			12			16			60
	9-10	6			8			10			12			16			40
	11-15	6			8			10			12			16			
D	6-10	4			8			8			10			12			40
	12	6			8			8			10			12			
	16	6			8			8			10			12			
E	4-5	4			4			6			6			8			60
	6-9	4			6			6			6			8			
F	1-3	4			4			4			6			6			60
	4-5	4			4			4			6			6			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-22. M110 WP Munition Expenditure Table (Visible, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	4/2			4			6/4			6			8			60
B	3-6	4/2			4			4			6/4			6			60
	6-10	4/2			4			4			6/4			6			40
C	0-8	2			4/2			4			4			6/4			40
	9-10	4/2			4/2			4			4			6/4			
	11-15	4/2			4/2			4/2			4			4			
D	6-10	2			2			4/2			4/2			4			40
	12	2			4/2			4/2			4			4			
	16	2			4/2			4/2			4			6/4			
E	4-5	2			2			2			2			4/2			60
	6-9	2			2			4/2			4/2			4			
F	1-3	2			2			2			2			2			60
	4-5	2			2			2			2			4/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	6			8			8			8			10			60
B	3-6	6			6			6			8			8			60
	6-10	6			6			8			8			8			40
C	0-8	4			4			6			6			6			60
	9-10	4			4			6			6			6			40
	11-15	4			6			6			6			6			
D	6-10	4			4			6			6			6			40
	12	4			4			6			6			6			
	16	6			6			6			6			6			
E	4-5	4			4			4			4			4			60
	6-9	4			4			4			4			6			
F	1-3	2			4			4			4			4			60
	4-5	4			4			4			4			4			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-23. M110 WP Munition Expenditure Table (Visible, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	4/2			4			6			8/6			10/6			60
B	3-6	4/2			4			4			6/4			6			60
	6-10	4/2			4			6/4			6/4			8/6			40
C	0-8	2			4/2			4			4			6/4			40
	9-10	4/2			4/2			4			4			6/4			
	11-15	4/2			4/2			4			4			6/4			
D	6-10	2			4/2			4/2			4/2			4			40
	12	2			4/2			4/2			4			4			
	16	2			4/2			4/2			4			6/4			
E	4-5	2			2			2			2			4/2			60
	6-9	2			2			4/2			4/2			4			
F	1-3	2			2			2			2			2			60
	4-5	2			2			2			2			4/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	6			8			8			10			12			60
B	3-6	6			6			8			8			10			60
	6-10	6			6			8			8			10			40
C	0-8	4			6			6			6			8			60
	9-10	6			6			6			6			8			40
	11-15	6			6			6			6			8			
D	6-10	4			4			6			6			6			40
	12	4			6			6			6			8			
	16	4			6			6			6			8			
E	4-5	4			4			4			4			6			60
	6-9	4			4			4			4			6			
F	1-3	2			4			4			4			4			60
	4-5	4			4			4			4			4			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-24. M110 WP Munition Expenditure Table (Visible, 20% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	4			6			8/6			10/8			12			60
B	3-6	4/2			4			6/4			6			8			60
	6-10	4			6/4			6			8/6			10/8			40
C	0-8	2			4/2			4			6/4			6			40
	9-10	4/2			4			4			6/4			6			
	11-15	4/2			4			4			6/4			6			
D	6-10	2			4/2			4/2			4			6/4			40
	12	4/2			4/2			4			4			6/4			
	16	4/2			4/2			4			4			6/4			
E	4-5	2			2			2			2			4/2			60
	6-9	2			2			4/2			4/2			4			
F	1-3	2			2			2			2			2			60
	4-5	2			2			2			2			4/2			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	8			8			10			12			16			60
B	3-6	6			8			8			10			12			60
	6-10	6			8			8			10			12			40
C	0-8	4			6			6			8			8			60
	9-10	6			6			6			8			8			40
	11-15	6			6			6			8			8			
D	6-10	4			6			6			6			8			40
	12	6			6			6			6			8			
	16	6			6			6			6			8			
E	4-5	4			4			4			4			6			60
	6-9	4			4			4			4			6			
F	1-3	4			4			4			4			6			40
	4-5	4			4			4			4			6			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

H-11. See tables H-25 through H-27 (on pages H-26 through H-28) for M60A2 smoke tables.

Table H-25. M60A2 WP Munition Expenditure Table (Visible, 80% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	8/6			13/11			*			*			*			40
B	3-6	6/4			9/7			12/10			15/13			*			40
	6-10	6/4			9/7			12/10			15/13			*			
C	0-8	4/3			6/5			8/7			10/9			13/12			60
	9-10	4/3			6/5			8/7			10/9			13/12			40
	11-15	4/3			6/5			8/7			10/9			13/12			40
D	6-10	4/3			5/4			6/5			7/6			9/8			40
	12	4/3			5/4			6/5			7/6			9/8			
	16	4/3			5/4			6/5			7/6			9/8			
E	4-5	2			2			3			4			5			30
	6-9	2			3			3			4			5			
F	1-3	2			2			2			2			3			30
	4-5	2			2			2			3			4			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	10			15			*			*			*			40
B	3-6	8			11			14			*			*			40
	6-10	8			11			14			*			*			
C	0-8	6			8			10			12			15			60
	9-10	6			8			10			12			15			40
	11-15	6			8			10			12			15			
D	6-10	6			7			8			9			11			40
	12	6			7			8			9			11			
	16	6			7			8			9			11			
E	4-5	4			4			5			6			7			30
	6-9	4			5			5			6			7			
F	1-3	4			4			4			4			5			30
	4-5	4			4			4			5			6			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-26. M60A2 WP Munition Expenditure Table (Visible, 50% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	10/8			16/14			*			*			*			40
B	3-6	7/5			11/9			14/12			*			*			40
	6-10	7/5			11/9			14/12			*			*			
C	0-8	5/4			7/6			9/8			12/11			16/15			60
	9-10	5/4			7/6			9/8			12/11			16/15			
	11-15	5/4			7/6			9/8			12/11			16/15			
D	6-10	4/3			5/4			7/6			8/7			11/10			60
	12	4/3			5/4			7/6			8/7			11/10			
	16	4/3			5/4			7/6			8/7			11/10			
E	4-5	2			3			4			5			6			30
	6-9	2			3			4			5			7			
F	1-3	2			2			2			3			4			30
	4-5	2			2			3			3			4			
HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	12			*			*			*			*			40
B	3-6	9			13			16			*			*			40
	6-10	9			13			16			*			*			
C	0-8	7			9			11			14			*			60
	9-10	7			9			11			14			*			40
	11-15	7			9			11			14			*			
D	6-10	6			7			9			10			13			40
	12	6			7			9			10			13			
	16	6			7			9			10			13			
E	4-5	4			5			6			7			8			30
	6-9	4			5			6			7			9			
F	1-3	4			4			4			5			6			30
	4-5	4			4			5			5			6			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Table H-27. M60A2 WP Munition Expenditure Table (Visible, 20% Relative Humidity).

CROSSWIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	12/10			*			*			*			*			40
B	3-6	9/7			14/12			*			*			*			40
	6-10	9/7			14/12			*			*			*			
C	0-8	6/5			9/8			12/11			15/14			*			40
	9-10	6/5			9/8			12/11			15/14			*			
	11-15	6/5			9/8			12/11			15/14			*			
D	6-10	4/3			6/5			8/7			10/9			14/13			40
	12	4/3			6/5			8/7			10/9			14/13			
	16	4/3			6/5			8/7			10/9			14/13			
E	4-5	3			4			5			6			9			30
	6-9	3			4			5			6			9			
F	1-3	2			2			3			4			6			30
	4-5	2			3			4			4			6			

HEAD OR TAIL WIND																	
SCREEN WIDTH (METERS)		100			200			300			400			600			
SCREEN TIME (MINUTES)		5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	
PASQUILL CAT	WIND SPEED (KN)	ROUNDS REQUIRED TO ESTABLISH AND/OR SUSTAIN SMOKE SCREEN1															FIRE INT (SEC)
A	2-5	14			*			*			*			*			40
B	3-6	11			16			*			*			*			40
	6-10	11			16			*			*			*			
C	0-8	8			11			14			*			*			40
	9-10	8			11			14			*			*			
	11-15	8			11			14			*			*			
D	6-10	6			8			10			12			16			40
	12	6			8			10			12			16			
	16	6			8			10			12			16			
E	4-5	4			6			7			8			11			30
	6-9	5			6			7			8			11			
F	1-3	4			4			5			6			8			30
	4-5	4			5			5			6			8			

[1] 10 AND 15 MINUTE SCREENS NOT SHOWN REQUIRE THE SAME NUMBER OF INITIAL AND / OR SUSTAINING ROUNDS AS A 5 MINUTE SCREEN REQUIRES

* EXCEEDS 16 ROUNDS

Legend: CAT – category INT – interval KN – knots MIN – minutes

Glossary

The glossary lists acronyms and terms with Army or joint definitions. Where Army and joint definitions differ, (Army) precedes the definition. The proponent publication for other terms is listed in parentheses after the definition.

SECTION I – ACRONYMS AND ABBREVIATIONS

AC	aiming circle
ADAM	area denial artillery munition
ADP	Army doctrine publication
ADRP	Army doctrine reference publication
AF	adjust fire
AFATDS	Advanced Field Artillery Tactical Data System
ALT	altitude
AMC	at my command
AO	aerial observer
AOF	azimuth of fire
AOL	azimuth of lay
APICM	antipersonnel improved conventional munitions
AZ	azimuth
BCT	brigade combat team
BMA	battery minefield angle
BOC	battery operations center
BP	base piece
BRAMC	by round at my command
CAS	complementary angle of site
CFF	call for fire
COB	center of battery
CSF	complementary site factor
DA	Department of the Army
DA PAM	Department of the Army Pamphlet
DEFL CORR	deflection correction
DF	deflection
DHD	did hit data
DNL	do not load
DPICM	dual-purpose improved conventional munitions
EFC	equivalent full charge
EGL	elevation gauge line
EL	elevation
EOL	end of the orienting line
EOM	end of mission

ET	electronic time
FA	field artillery
FASCAM	family of scatterable mines
FDC	fire direction center
FDO	fire direction officer
FFE	fire for effect
FM	field manual
FO	forward observers
FPF	final protective fires
FS	fuze setting
FSCOORD	fire support coordinator
FSO	fire support officer
FT	firing table
G-3	assistant chief of staff, operations
GFT	graphical firing tables
GPS	global positioning system
GST	graphical site tables
GTL	gun-target line
HA	high angle
HB	high-burst
HC	hexachloroethane
HCO	horizontal control operator
HE	high explosive
HERA	high explosive rocket-assisted projectiles
HOB	height of burst
HQ	headquarters
ICAO	International Civil Aviation Organization
ICM	improved conventional munitions
IR	infrared
JMEM/AS	Joint Munitions Effectiveness Manual/Air-surface
JWS	Joint Munitions Effectiveness Manuals Weaponeering System
LARS	left add, right subtract rule
LLHC	lower left-hand corner
M	meter
MACS	Modular Artillery Charge System
MBL	mean burst location
MDP	meteorological datum plane
MHL	manufacturer’s hairline
MLRS	multiple launch rocket system
mm	millimeter
MPI	mean point of impact

MT	mechanical time, maneuver-target
MTO	message to observer
MTSQ	mechanical time super-quick
MV	muzzle velocity
MVCT	muzzle velocity correction table
MVS	muzzle velocity system
MVV	muzzle velocity variation
OBS	observer
OIC	officer in charge
OP	observation post
ORSTA	orienting station
OT	observer-target
PCR	piece-to-crest range
PD	point-detonating
PE	propellant efficiency
PE_D	probable error in deflection
PE_{HB}	height-of-burst probable error
PE_R	probable error in range
PGK	precision guidance kit
POG	pullover gauge reading
PRF	pulse repetition frequency
Q	quick
QE	quadrant elevation
RAAMS	remote anti-armor mine
RALS	right add, left subtract rule
RAP	rocket-assisted projectile
RATT	record, apply, transfer, table
RDP	range-deflection protractor
RG	range
ROF	record of fire
RTO	radiotelephone operator
S-3	operations staff officer
SADARM	sense and destroy armor
SD	self destruct
SHD	should hit data
SI	site
SOP	standard operating procedure
SS	shooting strength
TA	target acquisition
TAG	target above gun
TBG	target below gun

TC	training circular
TF	time fuze
TFT	tabular firing tables
TGL	time gauge line
TGPC	terrain gun position correction
TI	time
TM	technical manual
TOF	time of flight
TOT	time on target
US	United States
USDA	up, subtract; down, add
USMC	United States Marine Corps
VA	vertical angle
VCO	vertical control operator
VE	velocity error
VI	vertical interval
VL	visible light
VT	variable time
WP	white phosphorus
WR	when ready
XO	executive officer

SECTION II – TERMS

***achieved range**

The range attained as a result of firing the cannon at a particular elevation.

***ammunition efficiency**

The change in velocity which is the sum of the projectile efficiency and propellant efficiency.

***angle of elevation**

The vertical angle between the base of the trajectory and the axis of the bore required for a projectile to achieve a prescribed range under standard conditions.

***angle of site**

The smaller angle in a vertical plane from the base of the trajectory to a straight line joining the origin and the target.

***angle T**

The interior angle formed at the target by the intersection of the observer-target and the gun-target lines.

***apex angle**

The angle formed by the lines from each observer to the orienting point.

***ascending branch**

The part of the trajectory that is traced as the projectile rises from the origin.

azimuth

The horizontal angle, measured clockwise by degrees or mils between a reference direction and the line to an observed or designated point (TC 3-25.26).

***ballistics**

The study of the firing, flight, and effect of ammunition.

***base of the trajectory**

The straight line from the origin to the level point.

***bore**

The rifled portion of the tube (lands and grooves).

***bourrelet**

The widest part of the projectile and is located immediately to the rear of the ogive.

***calibrated muzzle velocity**

An MVS readout average that has been corrected to standard projectile square weight and propellant temperature. MVV= Calibrated MV- Standard MV.

***calibration**

The process of measuring the muzzle velocity of a weapon and then performing a comparison between the muzzle velocity achieved by a given howitzer and the accepted standard.

call for fire

A request for fire containing data necessary for obtaining the required fire on a target (FM 3-09).

***centering slope**

The tapered portion at or near the forward end of the chamber that causes the projectile to center itself in the bore during loading.

***chart range**

The range opposite a given elevation in the firing tables.

common grid (or common survey)

Can be defined as orienting all concerned fire support assets in the same fashion with respect to direction and location (FM 3-09).

***complementary angle of site**

An angle that is algebraically added to the angle of site to compensate for the non-rigidity of the trajectory.

***complementary range**

The number of meters (range correction) equivalent to the number of mils of complementary angle of site.

***constant errors**

Are errors that are known and are constant throughout the mission.

***corrected range**

The range corresponding to the elevation that must be fired to reach the target.

deflection

The horizontal clockwise angle measured from the line of fire, or the rearward extension of the line of fire, to the line of a designated aiming point with the vertex of the angle at the sight (ATP 3-09.50).

***descending branch**

The part of the trajectory that is traced as the projectile is falling.

***destruction fire**

An element of the method of engagement portion of the call for fire requesting destruction fire; fire delivered for the sole purpose of destroying materiel.

***did hit data**

Data fired under nonstandard conditions that will cause.

***direction**

A horizontal clockwise angle measured from a fixed reference.

***dispersion**

The result of minor variation from round to round (caused by inherent systemic errors).

***distance**

The horizontal space between the observer and the target.

***erosion**

The wear in a howitzer tube that is the result of firing rounds.

***exterior ballistics**

The science that deals with the factors affecting the motion of a projectile after it leaves the muzzle of a howitzer.

***fire control**

All operations connected with the planning, preparation, and actual application of fire on a target.

***fire direction**

The tactical employment of firepower exercising the tactical command of one or more units in the selection of targets, the concentration and distribution of fire, and the allocation of ammunitionfor each mission; the methods and techniques used to convert target information into the appropriate fire commands.

***fire for effect**

A command to indicate that fire for effect is desired; fire that is intended to achieve the desired result on a target.

***fire mission**

The specific assignment given to a fire unit as part of a definite plan; an order used to alert the weapon/battery area and indicate that the message following is a call for fire.

***firing chart**

A graphic representation of a portion of the earth's surface used for determining distance (or range) and direction (azimuth or deflection).

***forcing cone**

The tapered portion near the rear of the bore that allows the rotating band to be gradually engaged by the rifling, thereby centering the projectile in the bore.

***fork**

The change in elevation (in mils) needed to move the mean point of impact 4 probable errors in range.

***gas check seat**

The tapered surface in the rear interior of the tube on weapons firing separate-loading ammunition.

***grid sheet**

A plain sheet of paper or plastic (mylar) on which equally spaced horizontal and vertical lines, called grid lines, are printed.

***gunnery**

The practical application of ballistics so that the desired effects are obtained by fire.

***gun-target line**

An imaginary straight line from gun to target.

***high-angle fire**

The delivery of fire at elevations greater that ther elevation corresponding to the maximum range for a charge.

***historical muzzle velocity**

A calibrated muzzle velocity which has been recorded in a muzzle velocity logbook.

***human errors**

Are mistakes made by any member of the gunnery team.

***indirect fire**

The fire delivered at a target not visible to a firing unit; the fire delivered to a target that is not itself used as a point of aim for the weapons or the director.

***interior ballistics**

The science that deals with the factors that affect the motion of the projectile within the tube.

***jump**

The displacement of the line of departure from the line of elevation that exists at the instant the projectile leaves the tube.

***level point**

The point on the descending branch that is the same altitude as the origin.

map

A graphic representation, drawn to scale, of a portion of the earth's surface (TC 3-25.26).

***met corrections**

Met corrections are all measurable nonstandard conditions for which you can account.

***meteorological datum plane**

The altitude of the met station from which all met computations are based it also refers to an area where the target and battery needs to fall within to be valid.

***mil**

The unit of measure for angles that is based on the angle subtended by l/6400 of the circumference of a circle.

***muzzle velocity**

The velocity achieved by a projectile as it leaves the muzzle of the weapon (measured in 0.1 meters per second).

***muzzle velocity system readout average**

The average MV measured by the MVS which has not been corrected for standard projectile square weight and standard propellant temperature.

***muzzle velocity variation**

The change in muzzle velocity of a weapon (expressed in ±0.1 meters per second) from the standard muzzle velocity or arbitrary selected standard.

***observed firing chart**

A firing chart on which all units and targets are plotted relative to each other from data determined by firing a registration.

observer-target line

An imaginary straight line from the observer/spotter to the target (ATP 3-09.30).

***obturating band**

A plastic band seated around the body of certain projectiles.

***origin**

The location of the center of gravity of the projectile when it leaves the muzzle.

photomap

A reproduction of an aerial photograph or a mosaic of aerial photographs on which grid lines, marginal information, and place names are superimposed (TC 3-25.26).

***position constants**

Are all nonstandard conditions that are difficult to identify, relatively small in magnitude, and remain relatively constant.

***precision registration**

A technique that requires an observer to adjust a group of rounds fired from the same howitzer so that their mean point of impact occurs at a point of known location (that is, a known point).

***probable error**
An error that is exceeded as often as it is not exceeded.

***projectile efficiency**
The known deviations from the standard for a particular projectile which affect the achieved velocity.

***propellant**
A low-order explosive that burns rather than detonates.

***quadrant elevation**
The angle at the origin measured from the base of the trajectory to the line of elevation. It is the algebraic sum of site and the angle of elevation.

***rotating band**
A band of soft metal (copper alloy) that is securely seated around the body of the projectile.

***shooting strength**
The reduction in the achieved muzzle velocity of a howitzer overtime caused by erosion, which is a function of erosion and projectile family ballistics.

***shot-start pressure**
The pressure at which this motion begins.

***should hit data**
Data fired under standard conditions that will cause the round to impact at a point of known location.

***site**
The algebraic sum of the angle of site and the complementary angle of site.

***special corrections**
Individual howitzer corrections applied to fuze settings, deflection, and quadrant elevation to place the FFE bursts in a precise pattern on the target.

***standard muzzle velocity**
An established muzzle velocity used for comparison.

***summit**
The highest point of the trajectory.

***surveyed firing chart**
A chart on which the location of all required points (battery or platoon positions, known points, and observation points) are plotted.

***swiss groove**
The cutaway portion of the powder chamber that allows the propellant to sit flush against the obturator spindle when the breech is closed.

***target grid**
A circular paper device on which grid lines are printed.

***terminal ballistics**
The study of the effects of projectiles on a target.

***terrain gun position corrections**
Individual howitzer corrections applied to the gunner's aid on the panoramic telescope (pantel), the correction counter on the range quadrant, and the fuze setting of each howitzer.

***tick mark**
The symbol used to mark and identify the location of a point plotted on a firing chart.

***transit ional ballistic**
The study of the transition from interior to exterior ballistics

***vertical angle**

the angle measured vertically, up or down, from a horizontal plane of reference and expressed in plus or minus in mils depending on whether the position is above or below the horizontal plane.

***vertical interval**

The difference in altitude between the (or observer) and the target or point of burst.

weaponeering

The process of determining the quantity of a specific type of weapon required to achieve a specific level of target damage; considering factors such as target vulnerability, weapon effects, munitions delivery accuracy, desired effect, probability of kill (PK), weapon reliability, etc (61 JTCG/ME-88-7).

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Index

Entries are by paragraph number unless indicated otherwise.

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