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16-120

DEPARTMENT OF THE ARMY FIELD MANUAL

THE FIELD ARTILLERY OBSERVATION BATTALION AND BATTERIES

DEPARTMENT OF THE ARMY • JULY 1951

[redacted]

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DEPARTMENT OF THE ARMY FIELD MANUAL
FM 6-120

This manual supersedes FM 6-120, 1 May 1945

THE FIELD ARTILLERY OBSERVATION BATTALION AND BATTERIES

DEPARTMENT OF THE ARMY • JULY 1951

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This manual supersedes FM 6–120, 1 May 1945

CHAPTER I

GENERAL

Section I. PURPOSE AND SCOPE

1. PURPOSE

This manual is a guide for unit commanders and section leaders in the tactics and technique of the employment of the field artillery observation battalion and batteries.

2. SCOPE

a. The manual covers the organization, duties of personnel, training, and tactical employment of the field artillery observation battalion and batteries. It also covers techniques involved in sound, flash, and radar ranging; and survey and meteorological operations.

b. For tactics and technique common to all field artillery battalions and batteries, not contained in this manual, see FM 6–101 and FM 6–140.

Section II. MISSIONS

3. GENERAL

Six principal missions are performed by the field artillery observation battalion. These missions are discussed in the following paragraphs.

4. LOCATION OF HOSTILE ARTILLERY

Location of hostile artillery is performed by sound, flash, and radar platoons.

5. REGISTRATION AND ADJUSTMENT OF FRIENDLY ARTILLERY

Precise registration and adjustment of friendly artillery can be conducted by flash and radar ranging. Registration and adjustment can also be conducted by sound ranging. Sound and radar units should not be diverted from their target location mission if other means of registration or adjustment are available.

6. COLLECTION OF INFORMATION

Collection of information is a duty of all personnel of the observation battalion. Flash observers provide most of the combat information reported by the battalion.

7. CONDUCT AND COORDINATION OF CORPS ARTILLERY SURVEY OPERATIONS

The observation battalion survey officer coordinates the survey operations of all artillery operating within the corps area. Plans for use of the organic survey parties of the observation battalion and attached topographic engineer parties must be coordinated with the survey plans of the divisions of the corps to avoid duplication of effort. A survey information center (SIC) is maintained in continuous operation near the observation battalion headquarters or the corps artillery fire-direction center.

8. COMPARATIVE CALIBRATION OF FRIENDLY ARTILLERY

The flash ranging platoon can perform comparative calibration of friendly artillery. The flash observation posts locate each round, and the flash survey parties locate each piece being calibrated.

9. PROVISION OF BALLISTIC METEOROLOGICAL DATA FOR FRIENDLY ARTILLERY AND FOR SOUND RANGING

Meteorological messages are provided by the meteorological section of headquarters battery.

Section III. ORGANIZATION, EQUIPMENT, AND DUTIES OF PERSONNEL

10. GENERAL

All operations and methods described in this manual are applicable with any current table of organization and equipment for the field artillery observation battalion.

11. OBSERVATION BATTALION

a. The observation battalion consists of a headquarters and headquarters battery and three observation batteries. The battalion is motorized.

b. Normally, one observation battalion is assigned to a corps.

12. BATTALION HEADQUARTERS

The observation battalion headquarters consists of the commander and his staff; its organization is similar to that of any other type artillery battalion headquarters. For the detailed duties of headquarters personnel common to all types of artillery battalions, see FM 6–101.

a. Battalion Commander. For the detailed duties of the battalion commander, see FM 6–101. In addition to his other duties, the observation battalion commander is also the corps artillery survey officer; for his duties as corps artillery survey officer, see paragraph 60.

b. Battalion Executive. For duties of the executive officer, see FM 6–101.

c. Personnel Officer (S1). For duties of the S-1, see FM 6–101.

d. Intelligence Officer (S2). In the field artillery observation battalion, the S2 and the S3 function as a team in which the S2 may be assigned as the assistant to the S3. The principal duties of the S2 are—

(1) Keep the battalion commander and staff informed of the enemy situation.

(2) Coordinate observation agencies within the battalion.

(3) Receive, evaluate, and record shelling, counterbattery, and countermortar reports from observation battalion agencies; and disseminate information and resulting intelligence to subordinate units and the next higher artillery headquarters.

(4) Make a continuous study of the terrain.

(5) Keep the S2 situation map. Foresee the need for, obtain, and distribute maps and air photographs in the battalion.

(6) Insure dissemination of periodic weather reports to the using agencies.

(7) Plan for and supervise all counter-intelligence activities within the battalion.

(8) Coordinate and supervise intelligence training of all personnel in the battalion, and the specialized training of intelligence personnel and observers.

(9) Study and supervise the interpretation of air photos.

(10) Furnish the executive with pertinent S2 data for inclusion in the unit report.

e. Operations and Training Officer (S3). The S3's primary function is the locating of targets. The principal duties of the S3 are—

(1) Assist the battalion commander in the planning, preparation, and issuance of operation orders and instructions.

(2) Keep the battalion commander, staff, and battery commanders informed of the situation.

(3) Prepare plans for the movement of the battalion, including warning and march orders, march graphs, plans and orders for rail and water movements, and other directives as may be required.

(4) Work in close cooperation with the battalion S2 on target information and loca-

tion; keep the S2 informed of map and photographic needs and probable observation requirements.

(5) Maintain the S3 situation map and other pertinent S3 records as required by the battalion commander and higher headquarters.

(6) Plan and supervise all training within the battalion to include the preparation of battalion training programs and review of battery schedules, organization and schedules for unit schools, coordination of specialist training with appropriate staff officers, procurement of training facilities, and provisions for continuous training of all elements of the battalion throughout combat.

(7) Furnish the battalion executive with pertinent S3 information for inclusion in the unit report.

f. Supply Officer (S4). The duties of the battalion S4 conform to those described in FM 6–101, with the exception that the S4 in the observation battalion does not command a service battery. As munitions officer of the observation battalion, he is concerned only with small arms ammunition.

g. Communication officer. The battalion communication officer is charged with the planning, installation, and supervision of all signal communications for the battalion. For additional duties of the communication officer, see FM 6–101.

h. Radar Officer. The radar officer advises the commander concerning radar operations and training. He coordinates radar operations, maintenance of radar equipment and the procurement of spare parts.

i. Battalion Survey Officer. The battalion survey officer advises the observation battalion commander in survey planning and assists him in the supervision and execution of survey operations.

j. Survey Assistant. The survey assistant assists the battalion survey officer.

k. Survey Warrant Officer. The survey warrant officer assists the battalion survey officer and is in charge of the survey information center.

13. EQUIPMENT

Techniques of employment of the observation battalion discussed in this manual are not limited to specific models of items of equipment. See current tables of organization and equipment and the appropriate technical manuals for information on particular items of equipment.

14. HEADQUARTERS BATTERY

Headquarters battery consists of a battery headquarters, operations platoon, topographical platoon, communication platoon, service platoon, personnel section, and battery maintenance section (fig. 1).

a. Operations Platoon. The operations platoon contains the operation section and the meteorological section. The operation section establishes and operates the battalion command post. The

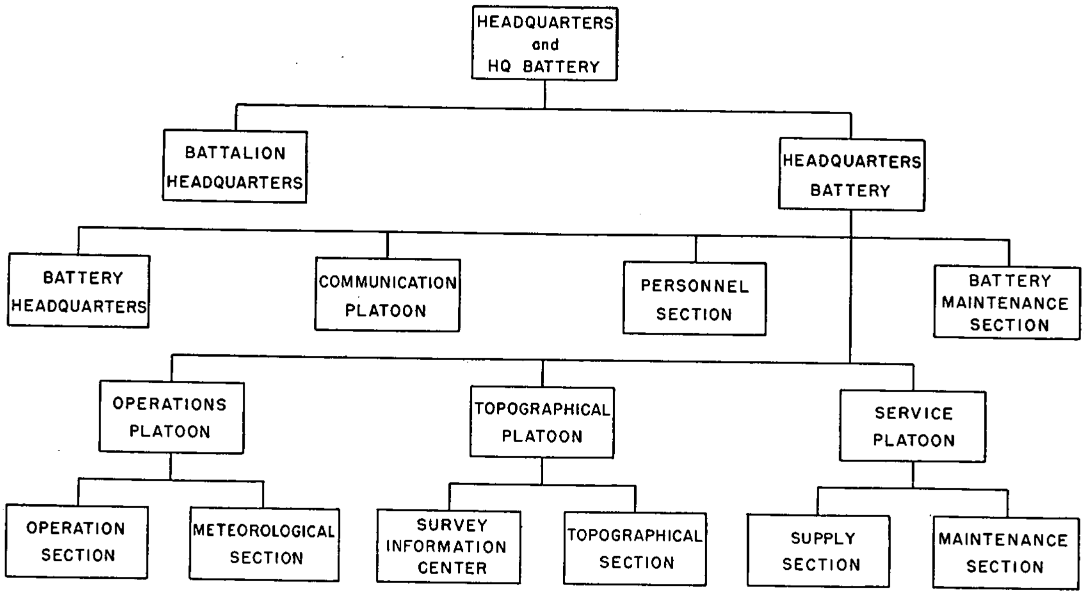

Figure 1. A type organization of the observation battalion headquarters and headquarters battery.

meteorological section obtains meteorological data for artillery, sound ranging, and, when requested, for the Air Force.

b. Topographical Platoon. The topographical platoon contains the survey information center and the topographical section. The topographical section performs the field work necessary for the coordination of surveys performed by artillery operating within the corps area and by the observation battalion. The survey information center collects and disseminates survey information.

c. Service Platoon. The service platoon has a supply section and a maintenance section (FM 6–140). This platoon supervises and assists the observation batteries in the performance of maintenance.

d. Others. The battery headquarters, communication platoon, battery maintenance section, and the personnel section have the normal functions required in all separate battalions (FM 6–140).

e. Principal Duties of Key Personnel. The principal duties of key personnel of the headquarters battery are listed below.

Individual	*Duties*
	BATTERY HEADQUARTERS
Battery commander..	The battery commander of headquarters battery has a dual function — battery commander and headquarters commandant. As a battery commander, he is responsible for—
	Training the battery in conformance with the battalion training program, and attaining the

Individual	*Duties*
	training objectives on time. Keeping the battery administration and supply systems functioning efficiently in conformance with regulations and the policies of the battalion commander. Maintaining the matériel and equipment. Preserving the health and physical fitness of the personnel of the battery. Maintaining the morale and discipline at high standards. Informing the battery of the general and specific situations encountered. Keeping the battery ready to accomplish its mission either alone or as a part of the battalion team. As headquarters commandant, he— Locates the elements of, organizes, and supervises the displacement of the command post. Supervises and coordinates the administration of the headquarters, including mess, transportation, and supply. Organizes local security.
Warrant officer, unit administrator.	For duties of the warrant officer, unit administrator, see FM 6–140.
First sergeant	For duties of the first sergeant, see FM 6–140.
Battery clerk	For duties of the battery clerk, see FM 6–140.

OPERATIONS PLATOON

Intelligence sergeant.	Assists the S2 in— Intelligence training of the battalion.

Individual	*Duties*
	Reconnoitering for routes, positions, bivouacs, and assembly areas.
	Collecting, collating, evaluating, interpreting, and disseminating information.
	Exchanging information with intelligence sections of adjacent units.
	Obtaining and distributing maps, and air photographs.
	Keeping the S2 situation map and other records current.
	Keeping the target locations on the record of sound, flash, and radar locations; shell reports; and working log for periodic reports current.
Operations sergeant.	Assists the S3 in preparing plans and supervising the—
	Organization and training for combat operations.
	Movement of the battalion.
	Organization, training, and operations of the operation section on the command post.
	Preparation of the situation and operation maps and overlays.
	Keeping of target locations on the record of sound, flash, and radar locations.
Sergeant major	For duties of the sergeant major, see FM 6–140.
Artillery meteorological warrant officer.	Acts as advisor to the battalion commander and to the corps artillery commander on ballistic meteorological matters.
	Supervises, coordinates, and participates in the operations of an

Individual	Duties
	artillery meteorology section.
	Selects the operating area for the meteorology section, and directs installation and operation of the section.
	Maintains close liaison with Air Weather Service detachments, and with other artillery meteorology sections in the vicinity.
	Exercises technical supervision over the section.
Artillery meteorological chief.	Acts as principal assistant to the artillery meteorological warrant officer.
	Supervises and advises computers, plotters, operators, and maintenance personnel on technical matters.
Weather equipment technician.	Supervises the operation of all equipment in the meteorology section.
	Performs the maintenance and authorized repair of meterological equipment.

TOPOGRAPHICAL PLATOON

Individual	Duties
Chief artillery survey specialist.	Supervises, coordinates, and participates in survey operations.
	Acts as principal enlisted assistant to the survey officer to facilitate rapid, accurate, and common survey control for artillery units.
	Instructs the members of the topographical platoon in their duties.
Chief of survey party.	Supervises, coordinates, and participates in the operation of an artillery survey party.
	Reconnoiters area to be surveyed.
	Instructs members of the survey party in their duties.

Individual	*Duties*
Survey and instrument man.	Operates survey instruments. Reads, interprets, and announces stadia distances. Measures stellar or solar angles. Performs minor and emergency maintenance on survey instruments. Reads and interprets maps and aerial photographs.
Topographic draftsman.	Plots survey data on charts, such as grid sheets, maps, or plotting boards. Assembles aerial photographs into area or rough strip mosaics. Prepares overlays of survey points. Collects, files, and distributes survey data at the survey information center. Extracts pertinent data from survey charts, overlays, reports, and other documents.
Artillery survey computer.	Computes survey data. Applies trigonometric principles for solution of triangles in determining the coordinates of traverse, triangulation, and resection points. Computes true coordinates from assumed coordinates. Computes coordinates of straight or curved base microphone arrays. Computes grid azimuth from stellar or solar observations. Computes survey locations by use of mechanical computing machines.
Survey recorder	Prepares accurate sketches and diagrams of the survey problem.

Individual	*Duties*
	Keeps an accurate record of survey information determined in the field.
Artillery rodman and tapeman.	Assists other members of the survey party.
	Clears a line of sight in advance of survey by removing brush, small trees, and other removable obstacles.
	Drives and marks stakes for instrument locations and other reference points.
	Measures horizontal distances using tape.
	Carries and holds surveying rods in position.

COMMUNICATION PLATOON

For duties of the personnel of this platoon, see FM 6–140.

PERSONNEL SECTION

Personnel sergeant..	For duties of the personnel sergeant, see FM 6–140.

SERVICE PLATOON

Radar sergeant.....	Performs repair and maintenance of radar equipment.

For duties of the supply sergeant, motor sergeant, automotive parts clerk, and mechanics, see FM 6–140.

BATTERY MAINTENANCE SECTION

For duties of the personnel of this section, see FM 6–140.

15. OBSERVATION BATTERY

Each observation battery contains a battery headquarters, flash ranging platoon, sound ranging platoon, radar platoon, communication platoon, and maintenance section (fig. 2).

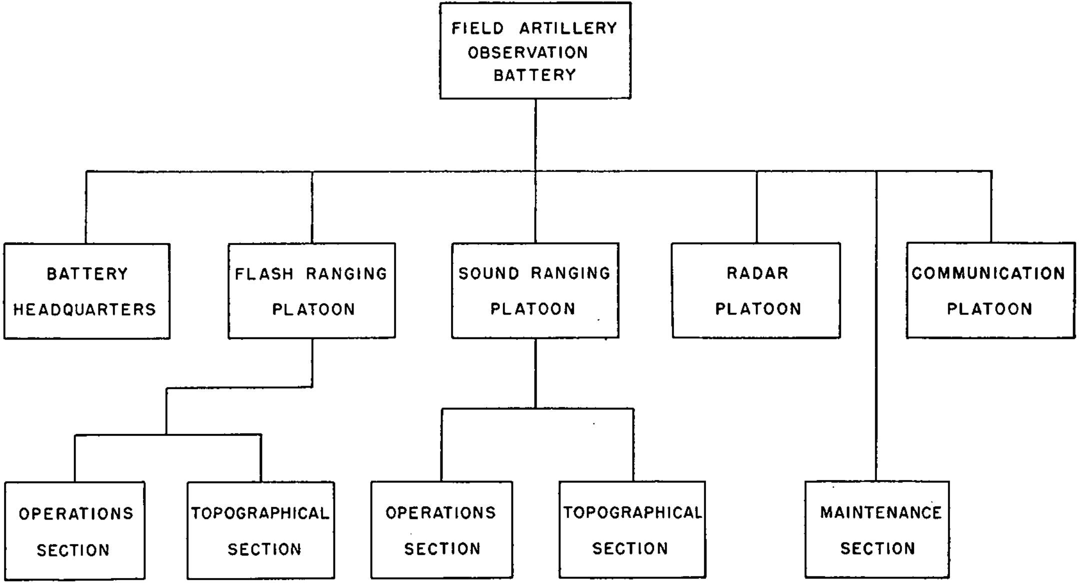

Figure 2. A type organization for the observation battery.

a. Battery Headquarters. The battery headquarters contains the clerks, messengers, and command post personnel of the battery.

b. Flash Ranging Platoon. The flash ranging platoon is divided into an operations section and topographical section. It is commanded by a lieutenant, who is the flash ranging officer of the battery. He has as an assistant, a lieutenant, who is the survey officer for the flash ranging platoon. The flash ranging platoon is subdivided as follows:

(1) The operations section performs the necessary drafting, plotting, and computation for the platoon; installs and operates the flash ranging central; and normally furnishes the observers and recorders for four observation posts.

(2) The topographical section consists of two survey parties which perform the necessary survey operations for the platoon.

c. Sound Ranging Platoon. The sound ranging platoon is divided into an operations section and a topographical section. It is commanded by a lieutenant who is the sound ranging officer of the battery. He has as an assistant, a lieutenant, who is the survey officer for the sound ranging platoon. The platoon is subdivided as follows:

(1) The operations section performs the necessary drafting, plotting, and computation for the platoon; installs and operates the sound ranging central; and furnishes the sound outpost observers.

(2) The topographical section consists of two survey parties which perform the

necessary survey operations for the platoon.

d. Radar Platoon. The radar platoon contains the personnel necessary for radar ranging. It is commanded by a lieutenant who is the radar officer of the battery. He has as an assistant, a warrant officer, who is the technical advisor and chief repairman in the platoon. The platoon contains two sections, each capable of operating one radar set. The platoon leader normally exercises his supervision from one of the two sections. Communication is provided by the battery communication platoon. Suitable survey control for the radar positions is normally provided by sound or flash topographical sections.

e. Communication Platoon. The communication platoon is responsible for the installation and maintenance of the wire and radio systems of the radar, sound, and flash platoons, and for the installation, operation, and maintenance of the wire and radio nets of the battery.

f. Maintenance Section. The maintenance section furnishes the personnel for the battery mess and supply, and for the maintenance of motor transportation.

g. Principal Duties of Key Personnel. The principal duties of key personnel of the observation battery are listed below.

Individual	*Duties*
BATTERY HEADQUARTERS	
Battery commander..	For duties of the battery commander, see paragraph 14, except that this officer does not function as headquarters commandant.

Individual	*Duties*
Executive	Assists the battery commander in performing his duties.
Warrant officer, unit administrator.	For duties of the warrant officer, unit administrator, see FM 6–140.
First sergeant	For duties of the first sergeant, see FM 6–140.
Battery clerk	For duties of the battery clerk, see FM 6–140.

FLASH RANGING PLATOON

Platoon leader	Makes reconnaissance for the observation posts and the flash ranging central for a flash ranging base. Recommends and advises the unit commander on the type of base required to properly cover the assigned zone of observation. Decides on the best method of survey to locate and orient each observation post. Maintains liaison with adjacent units to assure local security for the entire installation. Supervises the training of the platoon. Reconnoiters aggressively, prepares future plans, and recommends displacements when they become necessary.
Survey officer	Supervises and coordinates the survey parties of the topographical section. Reconnoiters and plans battery survey operations as directed. Assists the battalion survey officer. Acts as assistant platoon leader.
Flash ranging chief.	Assists the platoon leader in reconnaissance, selection and occupa-

Individual	*Duties*
	tion of flash observation posts and the flash ranging central.
	Supervises the preparation of an overlay of the operations area.
	Coordinates survey methods in the installation of the base.
	Informs the chief flash ranging observer and the survey chief of intervisibility and accessibility of intervening terrain and the friendly and enemy tactical situation.
	Verifies plotting and computations.
	Evaluates flash reports and inspects records.
	Trains members of the section in individual duties.
	Supervises the testing and preventive maintenance of all flash ranging equipment.
	Inspects, tests, and spot checks equipment to insure proper operating condition.
	Coordinates the supply of flash observation posts to provide for their continuous operation.
Chief flash switchboard operator.	Serves as flash switchboard operator.
	Installs, tests flash switchboard.
	Relays orientation data from plotting team to observation posts.
	Coordinates flash reports from observers.
	Relays target data from plotting team to observers.
	Enforces communication discipline.
Chief flash ranging computer.	Supervises the computing and plotting team at the flash ranging central.

Individual	*Duties*
	Computes and verifies, during the initial installation of the base, short traverses, three-point resection problems, and azimuths for orientation of each OP. During operation of the base, he computes altitudes and checks azimuths on high-burst and center-of-impact registration.
Chief plotter	Operates the flash ranging plotting board as required.
	Plots the OP's in their proper position on the board, after assigning proper numbers to the grid lines on the board.
	Assists and supervises in the operation of the board when plots are being made to determine coordinates of targets or to determine orienting azimuths for observers.
	Determines, when necessary in either deliberate or rapid installations, fire commands to be sent to the fire-direction center of any artillery unit.
	Computes ranges, using a military slide rule, and polar-plots, using a range-deflection fan, in rapid installations.
Chief flash ranging observer.	Supervises the work of the flash ranging observers to insure that the OP's of the flash base are installed at the proper location and are oriented properly.
	Informs the flash ranging observers of the friendly and enemy situation.

Individual	Duties
	Checks, calibrates, and adjusts all observing instruments.
	Assists the flash ranging chief in the procurement and distribution of equipment, rations, and supplies to each OP.
Flash ranging observer.	Assists the chief flash ranging observer in the selection, survey, and installation of observation posts.
	Verifies personally the orientation of the observing instruments and the construction and camouflage of the emplacements.
	Insures that supplies and rations reach each OP.
Assistant flash ranging observer.	Supervises or assists in the operation of an individual observation post as required.
	Sets up the instrument and verifies its orientation.
	Measures and verifies the angles and distances on the initial installation of the OP.
	Insures that the zone of observation is correct and that proper reports and records are made.
	Coordinates all matters of supply and rations with the flash ranging observer.

For duties of the chief artillery survey specialist, chief of survey party, artillery survey computer, survey recorder, and artillery rodman and tapeman, see paragraph 14.

SOUND RANGING PLATOON

Platoon leader	Supervises all sound ranging operations.
	Makes reconnaissance for and se-

Individual	Duties
	lects the sites of sound ranging installations.
	Coordinates operations of the sound ranging, communications and survey personnel in the establishment of sound ranging installations.
	Advises the battery commander relative to sound ranging tactics.
	Supervises sound platoon training and administration.
Survey officer	Supervises and coordinates the survey parties of the topographical section.
	Reconnoiters and plans battery survey operations as directed.
	Assists the battalion survey officer.
	Acts as assistant platoon leader.
Sound ranging chief.	Carries out the instructions of the sound officer relative to installation of sound outpost, base, and central, and assists in the selection of position.
	Supervises sound central operations.
	Instructs key personnel in individual duties and team operations.
	Performs administrative duties as chief of section.
Chief sound recorder.	Installs and supervises the care and maintenance of sound recording apparatus.
	Operates the sound recorder; relays the record obtained; and transmits the information to and from the outpost observers.
	Performs duties of the sound chief when necessary.

Individual	*Duties*
Chief record reader	Interprets and disposes of sound records. Performs duties of the sound chief when necessary.
Chief sound ranging plotter.	Supervises the installation, operation, and care and maintenance of sound plotting equipment. Operates the plotting board.
Chief sound ranging observer.	Installs and operates the sound outpost. Activates the recording apparatus. Reports, when appropriate, information relative to hostile artillery. Performs battlefield surveillance. Adjusts artillery fire.
Sound ranging computer.	Makes entries and performs arithmetical operations on the sound plotting record. Determines time interval corrections with charts.
Sound ranging maintenance specialist.	Maintains storage batteries. Operates battery charger. Aligns and makes minor repairs on radios.

For duties of the chief artillery survey specialist, chief of survey party, artillery survey computer, and artillery rodman and tapeman, see paragraph 14.

RADAR PLATOON

Radar officer, platoon leader.	Selects radar sites and directs operation of the platoon. Conducts training in radar operation.
Radar warrant officer.	Supervises and performs repair and maintenance of radar equipment.
Radar chief	Assists the radar officer.
Radar section chief	Supervises the radar section. Di-

Individual	*Duties*
	rects operation of the section.
	Conducts section training and directs operator radar maintenance.
Radar operator repairman.	Assists the radar section chief. Performs and supervises radar repair and maintenance.

COMMUNICATION PLATOON

Communication officer, platoon leader.	Supervises and maintains all communication facilities in the battery.
	Maintains close contact with the battalion communication officer to assure that proper communication procedures are used.
Communication sergeant.	For duties of the communication sergeant, see FM 6–140.
Repairman, radio ...	For duties of the radio repairman, see FM 6–140.
Wire sergeant	For duties of the wire sergeant, see FM 6–140.

MAINTENANCE SECTION

For duties of the personnel of this section, see FM 6–140.

CHAPTER 2

TACTICAL EMPLOYMENT

Section I. PRINCIPLES OF EMPLOYMENT

16. GENERAL

The field artillery observation battalion with its sound, flash, and radar equipment is employed to assist the artillery with the corps by locating hostile installations *(particularly hostile artillery)*; registering and adjusting fire of friendly artillery, providing survey control, collecting combat intelligence, and furnishing meteorological and comparative calibration data for artillery. Technical considerations involved in the effective accomplishment of these functions should be left to the observation battalion or battery commander, who should advise higher headquarters of the capabilities and limitations of his unit under the existing conditions.

17. PRINCIPLES OF EMPLOYMENT

The observation battalion normally is employed under centralized control. When the observation battalion commander cannot exercise centralized control, batteries may be attached to divisions or task forces. An observation battery attached to a division or task force is employed as a unit to provide the division with combat intelligence (particularly the location of hostile artillery) and to adjust artillery fire. Survey is provided to assist the division in establishing survey control.

Observation units should be employed in such a manner as to exploit their inherent capabilities of coördinated, long-range observation. The battalion is capable of operating for prolonged periods of time; this capability should not be compromised by placing installations so far forward as to subject them to frequent interruptions from enemy action or hostile mortar fire. The observation batteries are employed in such a manner as to cover most effectively the Corps front. The tactical situation and the extent of the front will govern deployment of the observation batteries and the installations required. The sound, flash, and radar installations of a battery should be located to cover so far as practicable the same zone of observation. For a typical installation of an observation battalion, see figure 3.

18. CAPABILITIES AND LIMITATIONS

The observation battalion is capable of fulfilling the six missions outlined in paragraphs 3 to 9, inclusive. In general, the limitations of sound and flash ranging do not apply to radar ranging. Conversely, the limitations of counterbattery radar do not apply to sound or flash ranging. The over-all efficiency of counterbattery intelligence is greatly increased by the ability of these agencies to reinforce and complement each other.

a. Sound Ranging. Sound ranging normally is capable of producing locations with an accuracy of 50 to 100 yards at ranges up to 15,000 yards. It is most valuable because of its ability to locate artillery pieces which are hidden from visual

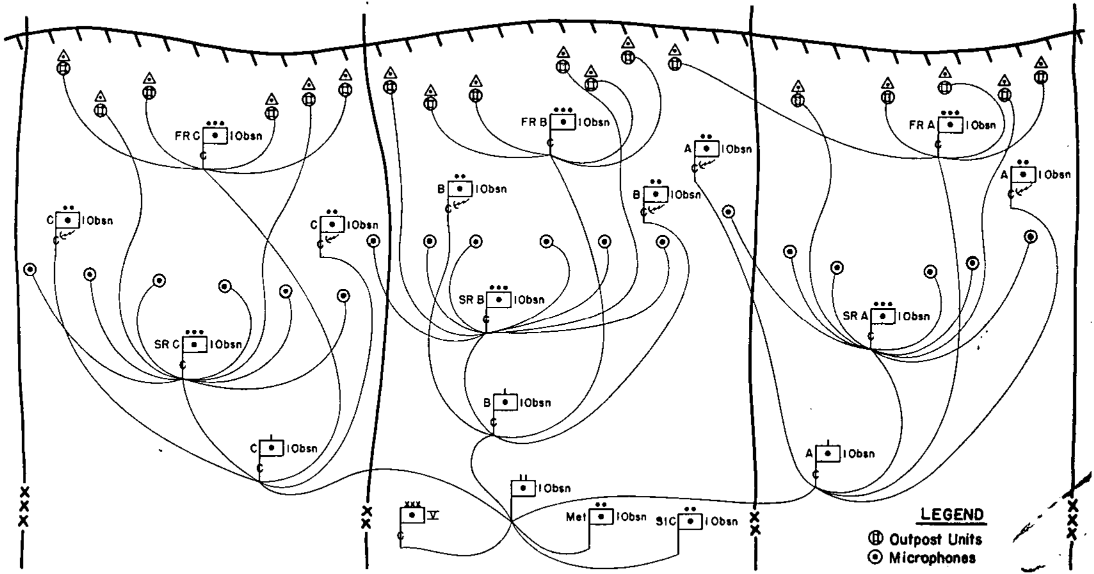

Figure 3. Typical tactical installations of an observation battalion.

observation. Sound ranging is particularly effective in fog; it does not require a clear line of sight to the target. The sound ranging set normally provides artillery locations at ranges from 3,500 to 20,000 yards. The maximum range is limited only by the intensity of the sound. Mountainous terrain may or may not materially affect operations, depending on the relative locations of the base and sound sources and the ground contours in the area under consideration. Normal battlefield noises tend to confuse interpretation of the sound record. High winds impair accuracy.

b. Flash Ranging. Flash ranging locations are extremely reliable, under favorable conditions the most accurate available means of target location and a valuable source of intelligence information. Flash ranging is limited in its effectiveness, however, by unfavorable terrain and weather conditions which impair visibility.

c. Counterbattery Radar. Radar determines both range and direction to the target from a single position whereas sound and flash ranging systems determine target locations essentially by the intersection of lines of direction from an array of well separated and multiple positions. The establishment of a radar position normally is much less time consuming than the installation of either sound or flash ranging systems. For such operations as a pursuit or rapid exploitation, where neither a broad front nor time permits sound and flash ranging installations to the desired degree, radar ranging lends itself most readily. F.A. Radar sets in current use are less effected by adverse weather than sound ranging, and are not so dependent on favorable terrain as flash ranging. Since the radar detects the hostile mortar by locating points on or a part of its trajectory, the accuracy of the actual ground location of the weapon is impaired by mountainous terrain concealing all but a small upper portion of the trajectory. Heavy rain and snow will seriously reduce the radar range. Radar is also susceptible to electronic countermeasures.

Section II. CENTRALIZED CONTROL

19. GENERAL

The observation battalion usually is employed as a unit. Counterbattery intelligence from the observation battalion is transmitted directly to the corps artillery counterbattery intelligence officer; other combat information is transmitted to the corps artillery fire-direction center in accordance with established procedure. Common survey control is provided for the artillery operating within the corps area. All installations of the battalion are accurately located by survey, and complete wire communication systems are established within the battalion.

20. DEPLOYMENT

The deployment of the observation battalion in a typical situation under centralized control is shown in figure 3. The battalion command post is located where it can most efficiently control its batteries and is accessible to the corps artillery fire-direction center. Normally, the battalion command post is located near the corps artillery fire-direction center. All three observation batteries are deployed abreast, unless the sector width is such that two batteries in position are sufficient. A salient may require the normal installations of all three observation batteries plus additional installations, using the spare or emergency equipment of the battalion. In this case, the capacity of the battalion to operate for prolonged periods of time is substantially reduced. Sound, flash, and radar installations should be deployed in such a manner as to cover the suspected location of the mass of hostile artillery. Separate zones of observation for flash, sound, and radar should be avoided wherever possible.

21. OCCUPATION AND ORGANIZATION OF POSITION

Normally, complete reconnaissance, survey, and communication installations should precede the occupation of position; however, the battalion is capable of going into position rapidly. The organization of a position consists of all the operations necessary to prepare the unit for the effective accomplishment of its mission. The completed installation shown in figure 3 may be the result of a progressive development following an initial hasty occupation of position. The mission, terrain, enemy activity, and disposition of our own troops will determine the type of installation that will be used.

22. DISPLACEMENT

Displacement is made by battery, or by any of the elements of a battery, in the assigned zone of action (usually the zone of action of the corps) and in such a manner that observation is continuous. Prior planning and continuous reconnaissance are essential so that displacement can be made either forward or to the rear in the shortest possible time.

Section III. DECENTRALIZED CONTROL

23. GENERAL

The observation battery is equipped to sustain itself in action; it can execute all of the missions of the observation battalion except determine and furnish meteorological data. (The meteorological section from headquarters battery may be attached to the most centrally located battery or to any separate battery which does not have access to antiaircraft or air weather service meteorological data.) The observation battery should be employed as a unit. It is employed as the counterbattery intelligence agency for a division in much the same manner as the observation battalion is employed by corps. To facilitate early entry into action, reconnaissance elements of the observation battery should be well forward in the leading march columns of the division (fig. 4).

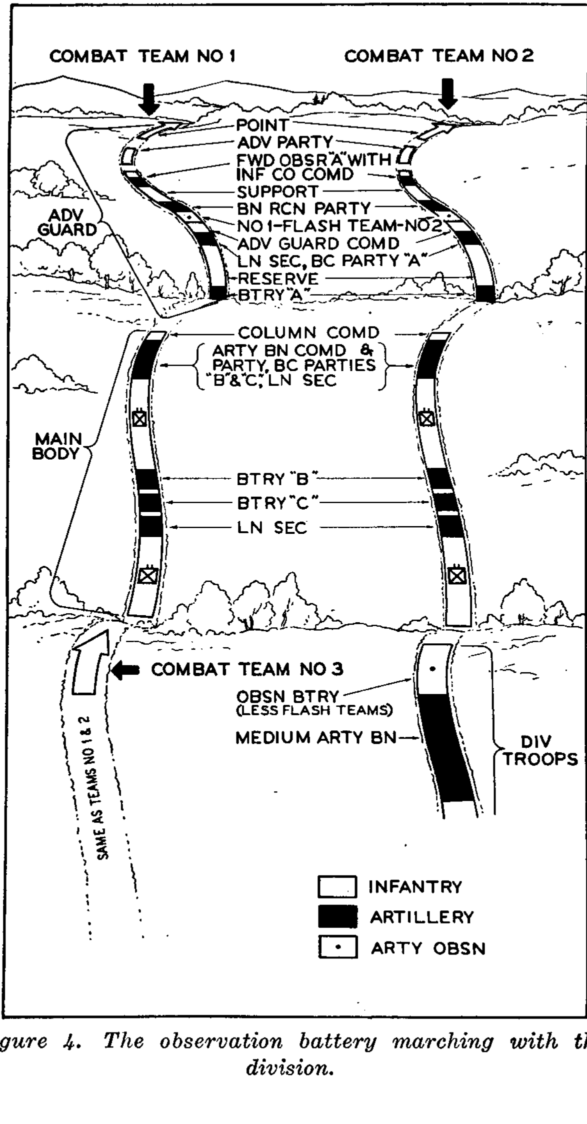

Figure 4. The observation battery marching with the division.

24. FACTORS TO BE CONSIDERED IN DEPLOYMENT

a. Before setting up their installations, the sound, flash, and radar officers should have, or should obtain, information as to the following:

(1) Situation.
(2) Zone of observation.
(3) Base points, check points, and other critical points.
(4) Priorities for observation.
(5) Firing chart (map, photograph, surveyed, observed).
(6) Survey and registration.
(7) Location of the division artillery command post (fire-direction center).
(8) Position area of firing batteries.
(9) Restrictions on areas for bases.
(10) Communication.

b. The type, location, and method of installation depend upon the mission, terrain, time available, and the tactical situation. For a full discussion of types and methods of installation of sound, flash, and radar systems, see chapters 7, 8, and 9, respectively.

25. DEPLOYMENT

The deployment of the observation battery in a typical situation under decentralized control is shown in figure 5. The battery command post is located where it can most efficiently control its platoons and is accessible to the division artillery fire-direction center. Normally, the battery command post is located near the division artillery fire-direction center. Each platoon should be deployed so as to cover the entire division front.

26. OCCUPATION AND ORGANIZATION OF POSITION

a. When the observation battery is attached to a division, the initial occupation and organization of sound, flash, and radar positions usually is rapid with a minimum of survey and wire communication completed before occupation.

b. The installations are progressively and continuously developed by—

(1) Improving the survey of the sound and flash bases and radar sites.

(2) Connecting the sound and flash bases and radar surveys with the division fire-direction survey.

(3) Establishing common survey control.

(4) Establishing communication appropriate to the organization for combat.

(5) Expanding to deliberate installations.

(6) Relocating and reorienting, if necessary.

27. DISPLACEMENT

Displacement usually is made by elements of the sound, flash, and radar platoons in such a manner as to provide continuous observation. Reconnaissance and planning are carried on continuously. Survey and communication should be established in the new position area prior to displacement from the old.

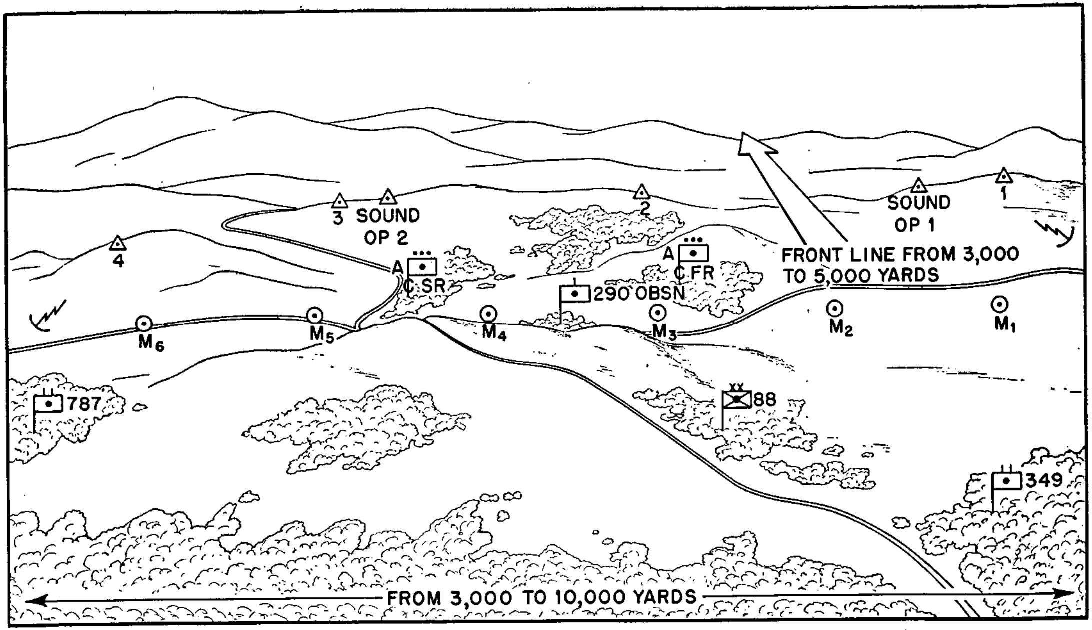

Figure 5. The observation battery in a typical position.

Section IV. ORDERS

28. GENERAL

a. The field artillery subparagraph of a corps field order will contain only those instructions to the observation battalion which are necessary to provide for its coordinated employment. Frequently, only brief instructions pertinent to organization for combat, survey, and observation will be included. Where employment of the observation battalion requires no special instructions, written orders usually are omitted from corps orders and oral instructions are given. The observation battalion commander advises the corps artillery commander concerning the employment of the observation battalion. See FM 6–20 for details of corps artillery plans and orders.

b. The observation battalion commander's orders to his batteries usually are oral, although they may be fragmentary or complete. Full use should be made of warning orders.

29. CHECK LIST FOR BATTALION ORDER

Paragraph 1.

a. Enemy Situation:

General disposition.

Artillery—known or suspected.

b. Own Troops:

Plan of supported unit.

Artillery—disposition and general plan employment.

Paragraph 2. Mission of this battalion, including priority and zones of observation.

Paragraph 3.

a. Battery A:

Zones of observation—sound, flash, and radar; priorities.

Flash observation posts, limitations, locations of observation posts.

Sound base—type and location.

Radar position areas.

Special instructions:

Survey.

Communication.

Counterbattery plan.

Registrations—sound, flash, and radar.

b. Battery B: (Same as battery A.)

c. Battery C: (Same as battery A.)

x. (1) *Survey:*

Control.

Firing chart.

Plan—organization and assignment of survey parties.

Survey information center—location and time of opening.

(2) *Meteorological message:*

Schedule for artillery and sound ranging messages.

Special instructions concerning preparation of meteorological messages and distribution of meteorological messages.

(3) *Local and individual security:*

Local protection against aircraft, tank, ground, and airborne attack.

Obstacles and mines.

Warning systems.

(4) *Instructions regarding movement:*

Route.

Destination.

Speed.

Special instructions for march security, route marking, order of march, initial point, release point, and other details appropriate to the situation.

Paragraph 4. Administrative matters (reference will be made usually to a separate administrative order). Instructions to batteries concerning—

Supplies and supply points.

Location of battalion aid stations.

Salvage.

Captured materiél and prisoners of war.

Traffic restrictions, route marking.

Traffic priorities.

Restricted areas.

Mail.

Shelter.

Reports.

Miscellaneous matters.

Paragraph 5. Communication:

Wire.

Radio.

Codes.

Location of command posts.

30. CHECK LISTS FOR BATTERY ORDERS

a. Movement Orders.

Present location.

Route.
Destination.
Speed.
Special instructions for marching security, route marking, order of march, initial point, release points, and other details appropriate to the situation.

b. Orders for Occupation of Position.

Situation: Enemy and our own troops.

Mission: Include status—attached or support.

Observation:
Zone.
Priorities.
Base and check points.
Locations of installations.
Location of survey information center.

Survey:
Plan and organization.
Firing chart.
Registration.
Control.
Location of battalion SIC and time of opening.

Local security:
Defense against aircraft, tank, ground, and airborne attack.
Obstacles and mines.
Location of machine guns.
Location of sentinels.
Warning system.
Location of truck park.

Administrative details (par. 29):

Location of kitchens; schedules and method of feeding.

Location of supply points.

Location of battalion aid station (covered in battalion field order).

Communication (covered in battalion field order).

31. PRECAUTIONARY INSTRUCTIONS

a. Upon concluding an oral order, the commander should synchronize time and ask for questions.

b. Orders must be given to fit a situation and not a check list. Many points listed here may be covered in the standard operating procedure of the unit.

c. Orders must be clear, concise, and timely.

d. For other details, see FM 101–5.

CHAPTER 3

RECONNAISSANCE, SELECTION, OCCUPATION, AND ORGANIZATION OF POSITION

Section I. GENERAL

32. PURPOSE

The purpose of reconnaissance, selection, and occupation of position is to move a unit from its present position area, rendezvous or bivouac area, or from a march, into a position from which it can effectively accomplish its mission. An established procedure for the reconnaissance and occupation of position is necessary in order to deploy the unit rapidly. It is neither possible nor desirable to lay down rigid rules for the composition of parties and the procedure to be adopted in every situation. Commanders are expected to make such modifications as the particular circumstances may require.

33. TASK INVOLVED

Placing a battalion into position involves—

a. Reconnaissance for battery positions; sound, flash, and radar installations; command posts; routes into positions; wire routes; truck parks; and aid station.

b. Formulation of a plan for occupying the position selected.

c. Issuance of orders to carry out the plan.

d. Execution of the order, that is, the actual emplacement of the various elements of the battalion.

Section II. RECONNAISSANCE

34. GENERAL

Reconnaissance is continuous in anticipation of orders for the employment of the observation battalion in conformity with the general plan. As soon as the order for the employment of the battalion in a specific area is received, a map and ground reconnaissance of that area is made by the battalion commander and certain members of his staff. The battalion commander then issues his order to the battery commanders who, with their sound, flash, radar, and communication officers, make a more detailed map and ground reconnaissance of positions for their installations. The position and type of sound base to be used, the location and type of flash installation, the radar positions, the wire routes, the locations of command posts, flash and sound ranging centrals, and the survey plan are determined from this reconnaissance. The considerations which determine the type of installation are fully discussed in chapters 2, 7, 8, and 9.

35. PRINCIPLES

a. General. The time allotted to reconnaissance generally is limited, and the procedure must be so organized that it can be accomplished as completely as possible in the time allotted. A map reconnaissance can be made at any time, but a ground reconnaissance is most effective during daylight hours. The size of the reconnaissance party usually is restricted to a minimum—*only essential vehicles and personnel.* The remainder of the unit stays in bivouac or rendezvous. If the situation permits, communication and survey personnel should be included in the reconnaissance echelon so that survey and the installation of communications can be started at once.

b. The Battalion Commander's Party. The battalion commander's party consists of such personnel and equipment as are needed to assist the battalion commander in his reconnaissance, formulation of his plan, issuance of orders, and initiation of the occupation of position. The composition of the party will vary widely according to the mission and restrictions on the number of vehicles in the forward area. In general, it is desirable that the battalion commander take with him his S3, communication officer, survey officer, sergeant major, and a messenger. If possible and appropriate, he may take with him any or all of the following:

(1) Radar officer.
(2) Battery commanders and their parties.
(3) Survey section.
(4) Communication chief.
(5) Wire laying vehicles.
(6) Battalion surgeon or a member of the medical detachment.
(7) Battery agents.
(8) S4 or his representative.

c. The Battery Commander's Party. When re-

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porting to the battalion commander for orders, the battery commander is accompanied by his party. The composition and loading of this party is based on the initial tasks to be performed and the number of vehicles that the battery commander is authorized to take with him. It should contain personnel and equipment to assist in reconnaissance, to initiate the establishment of observation and communication, and to conduct the battery into its position. The following is an example of the composition of the battery commander's party:

(1) Platoon leader and survey officer from flash platoon.
(2) Platoon leader and survey officer from sound platoon.
(3) Communication officer and communication chief.
(4) Radar officer.
(5) Sound and flash survey sections.
(6) Wire laying vehicles.

Section III. SELECTION OF POSITION

36. GENERAL

a. Position Areas. For a full discussion of selection of positions, see chapters 2, 7, 8, 9, and 10. Figure 5 shows a typical lay-out of an observation battery in position; figure 6 illustrates a typical lay-out of a battalion command post.

b. Battalion Command Post. The location of the corps artillery fire-direction center generally determines the location of the battalion command

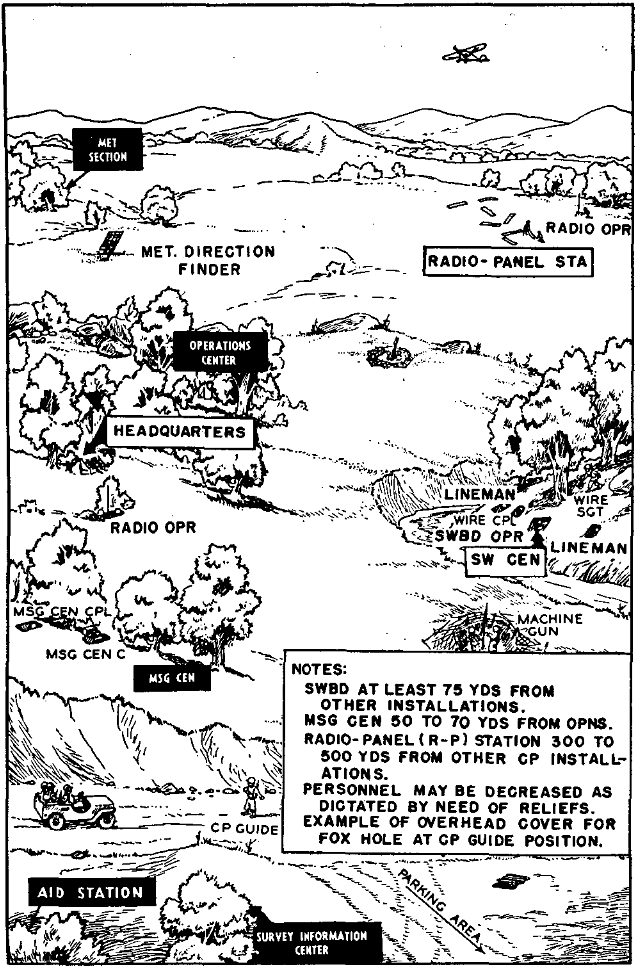

Figure 6. Type layout of an observation battalion command post.

post. Local security, communication with the batteries and the supported artillery, and the tactical situation must be considered when selecting a location for the command post. Ample and adequate area must be provided for headquarters and headquarters battery and for the meteorological section. In general, the battalion command post is in rear of, and centrally located laterally with respect to, the three observation batteries.

c. Rear Echelon. In certain types of operations, it may be desirable or necessary to establish a rear echelon where the personnel sections and the administrative, supply, and maintenance activities are located.

37. SELECTION OF BATTERY POSITION

The battery command post generally is located in the center laterally and behind the sound, flash, and radar installations. The flash ranging central and sound ranging central are usually located in the center laterally and behind their respective installations. Local security, the tactical situation, and communication considerations determine the positions to be occupied. The selection of sound and flash bases and radar positions are discussed in chapters 7, 8, and 9.

Section IV. OCCUPATION AND ORGANIZATION OF POSITION

38. GENERAL

After the reconnaissance and selection of position has been completed, survey and communication personnel commence preparing the new position. The battalion will remain in bivouac or continue to operate in its old position until ordered to displace. The battalion often displaces by battery or by any element thereof. Installations are manned immediately, and normal operations are commenced as soon as possible.

39. SECURITY

a. Without interfering with the operation of the unit, the position is organized for security. Dispersal, camouflage, field fortification, establishment of machine gun positions, and posting of sentries are accomplished with the least possible delay by all personnel available. The organization of position begins when the position is selected, and continues throughout the occupation as opportunity permits. See FM 6–101 and FM 6–140 for further details on defensive measures.

b. All units must be prepared to participate in operations against attacks by armored and airborne troops. Planning should include the coordination of all available defense organizations.

c. An efficient warning system to provide early warning and information as to armored attacks, parachute drops, and air landings is paramount.

40. INSTALLATIONS OF BATTALION COMMAND POST

The elements of a typical battalion command post (fig. 6) are described in paragraph 43. In

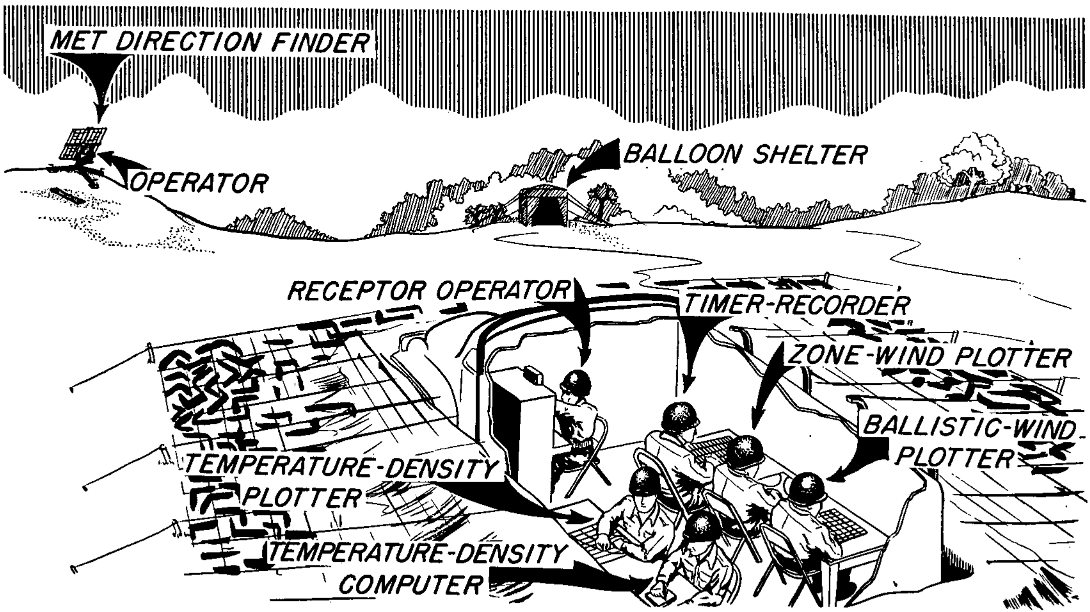

Figure 7. Type organization of a meteorological section position.

addition, the meteorological section normally will be located near the command post. Figure 7 shows a typical meteorological installation. A 2½-ton shop van, or other type of shelter, normally will be used to provide blackout protection and shelter in inclement weather for the meteorological section.

41. ORGANIZATION OF BATTERY POSITION AREA

a. Battery Command Post. The battery command post is organized in the same manner as the battalion command post. Battery administrative personnel usually are located near the battery command post.

b. Flash and Sound Ranging Centrals. The flash and sound ranging centrals (figs. 8 and 9) provide their own local security since these positions

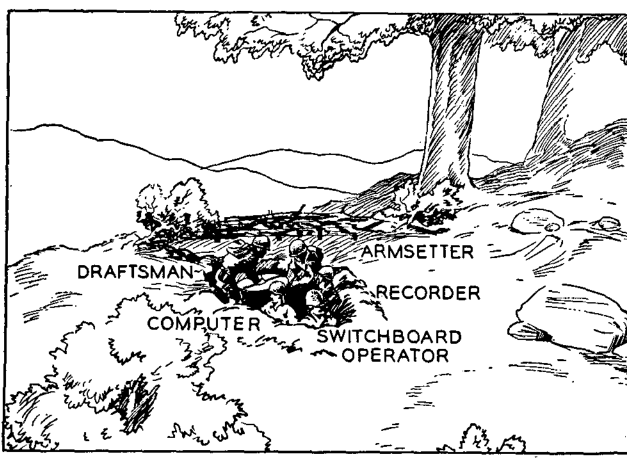

Figure 8. Type organization of a hasty position for a flash ranging central.

may be at some distance from the battery position area. Security measures are adapted to the situation. A command post tent, or other type of shelter, will be used normally to provide blackout protection and shelter in inclement weather.

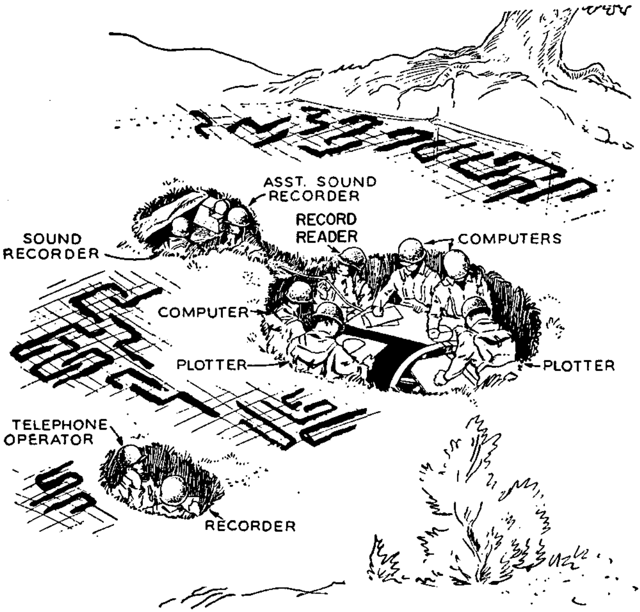

Figure 9. Type organization of a hasty position for a sound ranging central.

c. Counterbattery Radar. The radar positions (fig. 10) provide their own local security, since these positions may be situated on the flank of the battery and may be some distance from the battery position area. Cover and camouflage measures are taken to fit the situation.

CHAPTER 4
COMMUNICATION

Section I. GENERAL

42. GENERAL

This chapter covers only such information on signal communication as relates specifically to the observation battalion. For general principles and procedures for field artillery signal communication, see FM 6–101. Communication training in the observation battalion must include training in all means of communication. All personnel within the battalion, regardless of principal duty, must be trained in the installation, operation, and maintenance of these means of communication. Adequate communications must be provided both within the battalion and with supported and adjacent units. An alternate means of communication must be provided for each existing means to insure continuous operation of the communication system; no one means can be considered infallible.

43. COMMAND POST

a. General. The command post comprises the several elements of the headquarters used by a commander in the exercise of command of his unit. It is the center of all agencies of communication available within the battalion. Operation of all elements of the command post is continuous. A guide is posted near the entrance to the command post to guide visitors, control traffic, and indicate the locations of mines if necessary.

b. Elements of the Command Post. The elements of a field artillery observation battalion command post are the headquarters, operations center, message center, switching central, and the radio and panel station.

(1) *Headquarters.* The headquarters element consists of the battalion commander, executive, and communication personnel and equipment necessary to enable the battalion commander to supervise the battalion in the accomplishment of its mission. It must be located in a position which affords safety and security, yet is accessible for personnel required to visit it.

(2) *Operations center.* The operations center consists of the S3, S2, and personnel and equipment of the operations section necessary to supervise the operations of the battalion. It is a critical point in the communication system. All means of communication used for the transmission of tactical information and orders are centered in or near this installation. It is located where maximum safety and security are available and where interference and interruptions may be avoided.

(3) *Message center.* The message center consists of the message center chief and

his assistant. It is located near the entrance to the command post area. All incoming and outgoing messages and mail pass through it. For information concerning message center procedure, see FM 6–101.

(4) *Switching central.* The battalion switching central consists of the battalion switchboard and communication personnel necessary to maintain and operate the wire system. The switching central should be accessible to incoming wire crews. It should be located where maximum safety and security is provided for operating personnel and where interference and interruptions may be avoided.

(5) *Radio and panel station.* The radio and panel station includes the relatively high-powered radio sets, an area suitable for panel displays, and a message pick-up station for Army aircraft. For security reasons, it is located several hundred yards from the other elements of the command post, preferably on a flank; the high-powered radio sets may be detected by hostile intercept methods and thus become a target for hostile artillery. Radio sets at this installation are connected to the appropriate elements of the command post by remote control.

Section II. WIRE COMMUNICATION

44. GENERAL

The principal means of communication in an observation battalion is wire. As the wire system is very extensive, great effort must be exerted to install and maintain it. It is imperative that the wire system be supplemented by radio communication. A typical wire system for a field artillery observation battalion is shown in figure 12. These circuits are installed unless orders to the contrary are issued. The responsibility for the installation of circuits is indicated by directional arrows. When an observation battery is attached to a division for operational control, the division artillery installs a wire circuit to the battery. Variations from the wire systems as shown herein must be considered and appropriate orders issued to meet whatever situation arises. Procedures outlined in FM 24–20 are followed in the installation of observation battalion wire circuits.

45. BATTALION WIRE SYSTEM

Headquarters battery wire personnel install two trunk circuits to each observation battery. Local circuits within the battalion command post as shown on figure 12 are the minimum requirements. Wire communication with higher headquarters is established by the higher headquarters. Two wire circuits usually are installed, and either simplexed or phantom circuits are estab-

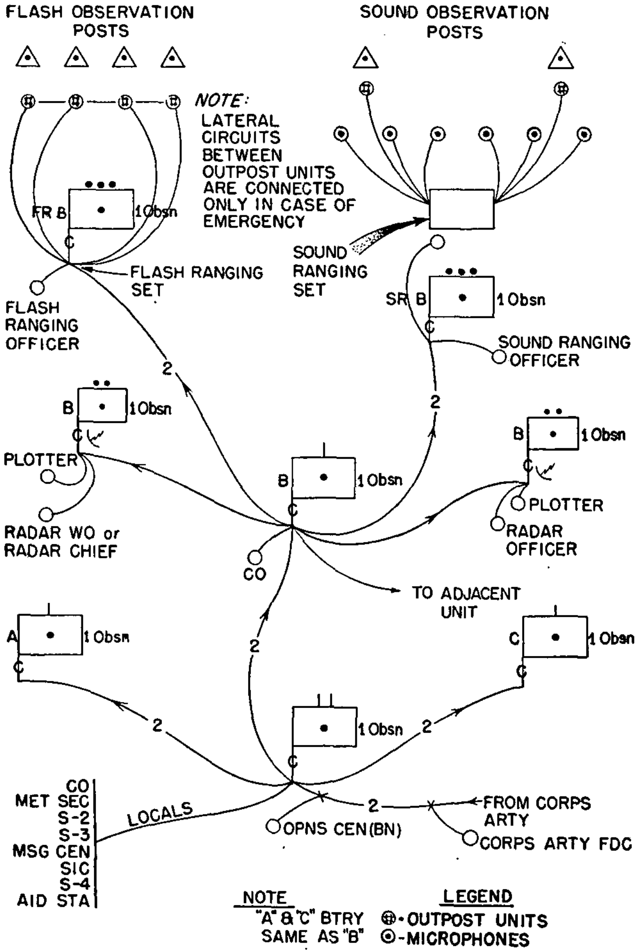

Figure 12. A type wire system for a field artillery observation battalion.

lished to the observation battalion operations center.

46. BATTERY WIRE SYSTEM

Circuits to the subordinate elements of the battery are installed by battery communication personnel. Wire is the usual means of communication for the transmission of sound signals from the sound ranging microphones to the sound recording equipment. See paragraphs 50 and 109 for the radio-sound data transmission system.

Section III. RADIO COMMUNICATION

47. GENERAL

Radio frequencies are allotted to the observation battalion by corps. Seven frequency modulated *(FM)* channels and two amplitude modulated *(AM)* channels should be made available. Figure 13 shows a normal battalion radio system. If, because of a shortage of frequencies within a corps, the observation battalion is allotted a lesser number of frequencies, the system as shown herein may be modified by grouping more stations under each frequency. All elements of this system are installed by the observation battalion and its batteries.

48. BATTALION RADIO SYSTEM

One *FM* frequency is assigned to battalion headquarters to be used as the battalion control channel. This net includes the battalion headquarters,

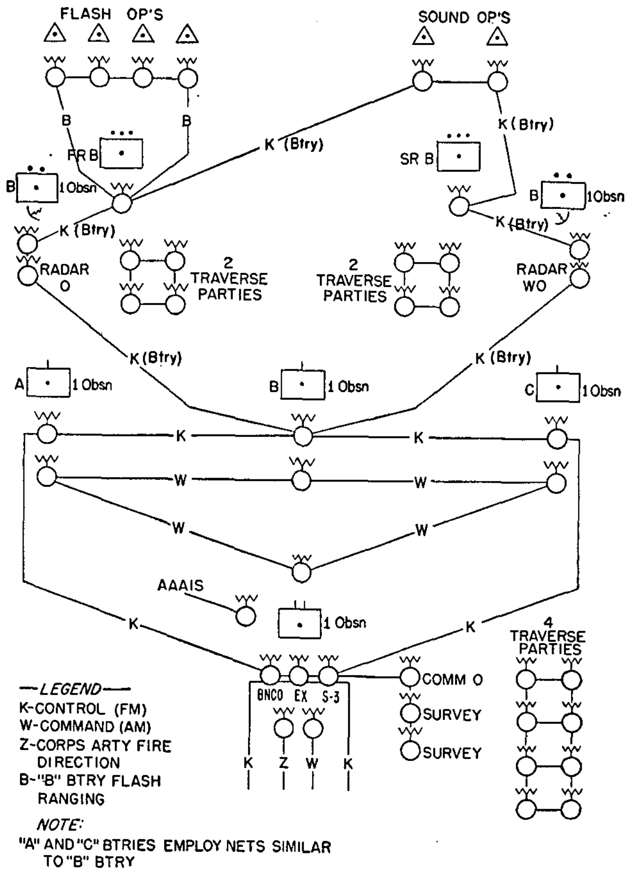

Figure 13. A type radio system for a field artillery observation battalion.

battalion staff officers, and each battery headquarters. One *AM* frequency is used for the battalion command net which operates before installation of and during interruption of wire com-

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munication. The battalion command net consists of battalion and each battery headquarters. The observation battalion headquarters is in constant communication with the corps artillery headquarters and fire-direction center using a 25-mile, vehicular radio set, operating in the corps artillery fire-direction net. This set is the primary means for rapid transmission of meteorological messages. The battalion also operates a 25-mile, vehicular radio set as a secondary station in the corps artillery command net. The observation battalion commander, executive, and S3 operate in the corps artillery control net.

49. BATTERY RADIO SYSTEM

Each observation battery is assigned one radio frequency for battery control and one for flash ranging. The battery control channel includes the battery headquarters, flash ranging central, sound ranging central, sound ranging observation posts, and each radar position. Each traverse party in the observation battery, as well as in the battalion headquarters battery, is equipped with two light weight portable radio sets for intraparty communication. All of these sets within the battalion are preset to the same frequency. Because of the dispersion of the traverse parties and the limited range of the 1-mile, portable radio set, a minimum of interference should occur between parties.

50. RADIO-SOUND DATA TRANSMISSION SYSTEM

The sound ranging platoon may operate with radio communication between outposts, microphones, and the sound ranging central. For this purpose, additional specially adapted radios are required—one at each outpost and microphone position and a corresponding number of radios at the sound ranging central. Additional radio channels are required to provide a separate frequency for the radio set at each microphone.

CHAPTER 5
INTELLIGENCE

Section I. GENERAL

51. INTELLIGENCE MISSION

The field artillery observation battalion is the principal agency for obtaining counterbattery targets in the corps zone of action. The measure of success of the battalion is determined, not only by its ability to obtain accurate information, but also by the speed with which this information is transmitted to higher headquarters in order that it may be acted upon. All locations and all information must be reported without delay, no matter how inaccurate or unimportant they seem. The rule is—*First, early information and then, accurate information.* For a discussion of field artillery intelligence, see FM 6–130.

52. AGENCIES

The information-collecting agencies in an observation battalion are discussed below. Many of these agencies use electronic equipment and can operate both day and night and during periods of poor visibility, when other means are relatively ineffective.

a. Meteorological Section. The meteorological section obtains ballistic and sound ranging weather data (ch. 10).

b. Sound Ranging Platoons. Sound ranging platoons locate enemy artillery with sound ranging equipment and may furnish information on the effect of friendly artillery fire (ch. 7).

c. Flash Ranging Platoons. Flash ranging platoons obtain information and locations of enemy artillery by visual means from accurately located observation posts; they also observe and report the effect of friendly artillery fire (ch. 8). Flash ranging observers have the additional mission of general battlefield surveillance.

d. Radar Platoons. Radar platoons locate hostile weapons, friendly front lines, friendly and enemy troop movements, and may assist in performing survey and obtaining meteorological data (ch. 9.)

53. TRANSMISSION OF INFORMATION

The observation battalion carefully evaluates all information received from its subordinate units. During centralized operation, this information is transmitted to the corps artillery fire-direction center with the least possible delay. In decentralized operations, information is furnished directly to the artillery unit to which the battalion is assigned or attached. Locations of friendly and enemy troops and installations usually are transmitted by wire or overlay. When transmitted by radio, they should be encoded; the code used is that prescribed by the current SOI. Enemy locations may be sent in clear text if immediate attack of the target is contemplated.

54. OPERATIONS SECTION

a. Missions. The operations section is the focal point of combat information in the observation battalion; it is under the direction of the S3, assisted by the S2. The missions of this section are—

(1) Planning for installation and movement of the battalion.

(2) Maintaining situation and operation maps.

(3) Preparing intelligence and operation reports.

(4) Collecting, evaluating, and disseminating combat information.

b. Evaluation of Locations. When target locations are received at the operations section, they are plotted on the evaluation overlay where they are evaluated with respect to—

(1) Terrain.

(2) Previous locations already plotted on the locations overlay.

c. Forwarding Information. The target location is forwarded to the corps artillery fire-direction center, where, when confirmed, it may be assigned as a fire mission to a field artillery unit with the corps.

55. RECORDS

a. General. A battalion journal is kept at the command post under the supervision of the battalion executive. All reports except target locations received at the command post are entered in the journal. Target locations are kept on the record of sound, flash, and radar locations (par. 144). A situation map and an operations map are maintained at the command post under the supervision of the battalion S3 by personnel of the operations section.

b. Situation Map. Friendly and enemy front lines, division and corps boundaries, and enemy information other than enemy artillery locations are posted on the situation map.

c. Operations Map. This is the battle map of the corps zone of action. The position, hostile battery, evaluation, and visibility overlays are placed over the operations map. Under certain circumstances, one or more of these overlays may be deleted or combined with another, depending on the stability of the situation and the length of time the battalion has been in position. These overlays are discussed below in order of use.

(1) *Position overlay.* The front lines, present installations and locations of friendly units, and future installations and locations of friendly units based on planning are plotted on the position overlay.

(2) *Hostile battery overlay.* All hostile batteries which have been assigned a name by corps artillery and included in the corps counterbattery file are plotted on the hostile battery overlay.

(3) *Evaluation overlay.* New locations made by elements of the battalion are plotted on this overlay for evaluation. Hostile battery locations remain on this overlay until they have been assigned a name or file by the corps artillery fire-direction center.

(4) *Visibility overlay.* This overlay shows the limits of the fields of vision from each of the observation posts of the battalion.

Section II. COUNTERBATTERY INTELLIGENCE

56. COUNTERBATTERY INTELLIGENCE

Counterbattery intelligence involves the location and identification of enemy batteries and the study of the capabilities, limitations, tactics, and technique of employment of hostile artillery. The observation battalion often is assigned the mission of confirming reports made by prisoners of war or photo interpreters on hostile battery locations. Usually the observation battalion or reconnaissance aircraft are the only elements available to corps artillery to verify such reports. The observation battalion may use one, or a combination, of the agencies available in the battalion for this purpose.

57. ACCURACY OF LOCATIONS

The normal accuracies of locations determined by flash, sound, or radar ranging, under average conditions, are as follows:

Ranging Means	*Normal Accuracy*
Flash	25– 50 yards.
Radar	50–100 yards.
Sound	50–100 yards.

58. COORDINATION WITH CORPS ARTILLERY FIRE-DIRECTION CENTER

The corps artillery fire-direction center and the observation battalion operations section usually are located close to each other and cooperate closely in their work of locating hostile artillery. Personal liaison with the corps artillery is established by the observation battalion commander or his representative.

CHAPTER 6

SURVEY

Section I. GENERAL

59. GENERAL

This chapter contains a general description of the survey operations of the observation battalion, with particular emphasis on types of survey, computation, required accuracies, survey missions, and surveying equipment used. For general theory and technical discussion of surveying, see any standard surveying text, FM 6–40, TM 5–235, and TM 44–225.

a. Missions. The survey mission of the observation battalion includes the coordination of the survey of all artillery with the corps. The observation battalion is responsible for the establishment of common control for all artillery in the corps area; for the collection and dissemination of all survey information within the corps artillery area; and for the survey of flash, sound, and radar installations.

b. Organization. The observation battalion is provided equipment and personnel for 16 survey parties—four in headquarters battery and four in each observation battery. There are two parties in each sound ranging and each flash ranging platoon. Normally, these survey parties survey the sound, flash, and radar installations. The battalion survey officer may pool these survey parties in any manner that will best accomplish the survey mission.

60. CORPS ARTILLERY SURVEY RESPONSIBILITY

The observation battalion commander is the corps artillery survey officer. Under the direction of the corps artillery commander and assisted by the battalion survey officer, he—

a. Plans the corps artillery survey.

b. Coordinates the survey of the observation battalion with all other artillery units in the corps area.

c. Maintains liaison with and obtains control data from the topographic engineer unit operating with the corps.

d. Establishes the survey information center.

61. SURVEY INFORMATION CENTER (SIC).

The survey information center is established to serve as an agency for the planning, collection, evaluation, and dissemination of survey data. Normally, the survey information center is located near the corps fire-direction center. Its location and time of opening should be announced in corps artillery orders. During the initial phases of an operation, the survey information center is generally well forward to coordinate the survey work in progress and to provide survey data to other artillery units. The survey information center records all available survey information on DA AGO Form 6–5, "Survey Locations" (fig. 14) and files the forms for future reference.

SURVEY LOCATIONS

DATE: 20 January 1950 | SHEET NUMBER: 7

STATION: NAME	STATION: COORDINATES	AZIMUTH AND DISTANCE TO OTHER STATIONS: STATION NAME	AZIMUTH	DISTANCE METERS	DESCRIPTION OF STATION LISTED IN FIRST COLUMN: GENERAL LOCATION	LOCATION AND DESCRIPTION
Hamblin	E 53401.93	Rabbit	357°20′25″	2673.82	Hamblin Peak Area	On summit of Hamblin Peak, aprx 75 meters SW of abandoned mine shaft.
	N 90480.42	Ware	37°01′53″	4140.59		
	Z 1059	Wolf	76°02′26″	2556.16		
Wolf	E 55882.60	Ware	0°16′38″	2688.84	Hamblin Peak Area	Near North summit of Wolf Hill, aprx 35 meters N of large twin oak trees.
	N 91097.05	Gorbet	46°49′40″	3978.39		
	Z 979	Squirrel	89°42′20″	2798.56		
Rabbit	E 53277.85	Laur	356°04′54″	2666.99	Alexander Creek Area	Near summit of Rabbit Mountain, aprx 750 meters N of Nisbett tank.
	N 93151.36	Fox	50°03′46″	4172.47		
	Z 1172	Ware	76°22′31″	2693.56		
Ware	E 55895.61	Fox	15°52′47″	2125.12	Alexander Creek Area	On Ware Knob, aprx 1600 meters NNW Otter Falls, aprx 2200 meters SW of bridge on Brunner Road across Thomas River.
	N 93785.86	Prairie D	55°15′32″	3597.16		
	Z 1149	Gorbet	89°20′31″	2888.62		
Laur	E 53095.60	Melton	20°45′54″	2740.28	Brunner Road Area	On Laur Mountain, aprx 600 meters N of Junction of Brunner and Masters Roads aprx 65 meters E of Fire Watch Tower.
	N 95812.12	Rosier	60°36′29″	4616.88		
	Z 1235	Fox	89°41′57″	3381.53		
Fox	E 56477.08	Rosier	15°55′02″	2337.75	Brunner Road Area	On Fox Hill, aprx 1100 meters SSW Duck Pond, aprx 1500 meters NW of bridge on Brunner Road across Thomas River.
	N 95829.98	Grapes	55°45′34″	3648.70		
	Z 1212	Prairie D	89°51′29″	1374.45		
Melton	E 54067.13	Bearer	12°46′51″	2313.58	Melton Ridge Area	On Melton Ridge, aprx 1200 meters ENE Warmus Springs, aprx 1000 meters N Coyote Fork of Thomas River.
	N 98374.40	McGee	51°53′12″	4677.22		
	Z 1349	Rosier	84°27′05″	3065.44		
	E					
	N					
	Z					

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Figure 14. DA AGO Form 6–5, "Survey Locations".

Section II. PLANNING

62. SURVEY PLANNING

In survey planning, the availability of survey control and suitable maps is determined initially. The corps topographic engineers are responsible for the extension of control to areas readily accessible to the observation battalion (FM 5–6). When control is not available, the observation battalion adopts an arbitrary grid system and proceeds with survey without delay. Normally, in such cases each sound, flash, and radar installation assumes its own starting data for the origin of its survey work. The headquarters battery survey platoon assumes arbitrary horizontal and vertical control of an initial survey station and ties in artillery position areas; the target area; and sound, flash, and radar installations to this assumed arbitrary control. When extension of true control is completed, all control is converted to the common grid. The type of firing chart used depends upon the availability of maps and survey control, the latter varying with progress in the execution of the survey plan (FM 6–40).

63. ORIGIN OF CONTROL

a. The origin of the common grid for corps artillery survey is based on either arbitrary or true control.

b. Arbitrary control is based on assumed coordinates and elevation for the starting point and an assumed direction. It should approximate true control to facilitate use with meteorological data.

When assumed coordinates closely approximate true coordinates the massing of fires of one unit with those of adjacent units is facilitated.

c. True control is based on coordinates, elevation of points, and directions taken from the military grid being used. Data are procured from topographic engineers, existing maps, or lists of locations and elevations of existing control points.

64. DEGREE OF ACCURACY IN COMPUTING AND REPORTING SURVEY INFORMATION

In computing and reporting the location of survey stations, the *E* and *N* coordinates are carried to the nearest one-hundredth of a *meter*; the *Z* coordinates are computed to the nearest one-tenth of a *yard* and reported to the nearest *yard.* For example, the coordinates of a survey station are written as follows:

(553, 675.26—3,842, 472.37) Z = 671 (yards)

65. CONVERSION TO COMMON SURVEY CONTROL

a. General. If a common survey control is not available when survey is started, each artillery unit must assume a control. As survey based upon this assumed control is being completed at each of the lower echelons, corps and division survey parties are extending common control to all units. Upon receipt of common control, each unit converts all completed survey to the common control. Conversion to the common control is simplified if the assumed control approximates true control as nearly as possible, i.e., if the assumed control is established using map coordinates and astronomical observation. Depending upon the type of data available, conversion is effected by azimuth and/or coordinate conversion.

b. Azimuth and Coordinate Conversion.

(1) Using the assumed control, compute the assumed azimuth and true distance from the established control point to each point in the survey to be converted.

(2) After common control is determined for the established control point, the azimuth correction is computed. This is the algebraic difference between the assumed and true azimuths.

(*a*) Apply the azimuth correction to the assumed azimuth of each line to be converted to obtain its true azimuth.

(*b*) Using the true azimuth and true distance of each line, compute the differences in the *E* and *N* coordinates between the established control point and the points to be converted.

(*c*) Apply these *E* and *N* differences to the true coordinates of the established control point to convert the points from assumed to common control.

(3) *Z* coordinates are converted as described in *c* (1) below.

c. Coordinate Conversion.

(1) For any specific conversion, the *Z* cor-

rection is constant for all points in the survey. This constant correction is added algebraically to the assumed-control, Z coordinate of each point to convert to common control.

(2) If the assumed-control direction and the common-control direction are the same, the E and N corrections are also constant and are added algebraically to the assumed control coordinates of each point to convert to common control.

66. METHODS OF SURVEY

a. All survey performed by the observation battalion is precise—precision instruments and solution by computation are required. Graphic methods may be used only for rough verification and approximation.

b. The greatest precision consistent with the time available should be sought. The hurried use of precise methods may cause mistakes and great inaccuracies. The following rules should be observed in survey work and training:

(1) Use the most precise method possible in in the time available.

(2) Even though time is pressing, never use a method that is not capable of producing satisfactory data.

(3) Check all work, if only by a rough method. Employ completely independent checks made by different men.

(4) Watch particularly the preparation of notes; notes must be legible, accurate,

and clear. More mistakes occur through poorly kept notes than through errors in measurements or calculations.

(5) Develop methods and procedure that produce accuracy and eliminate mistakes. Enforce these procedures rigidly.

(6) Study methods to avoid the *weak link.* One inaccurate step will destroy the accuracy of an otherwise precise survey.

(7) Use selected men. Remove men who do not become precise and methodical with reasonable training. A good survey man rarely makes a mistake.

c. Basic survey operations in the observation battalion consist of the location of points, the measurement of distances and angles, and the determination and transmission of direction. Points are located horizontally by traverse, resection, and triangulation. They may be located approximately by inspection if a map or photomap shows the desired point. Distance and direction are determined by traverse or by triangulation. Direction is determined from two known points or by astronomical methods. Direction is transmitted by measuring or computing angles. The altitudes of points are determined by computations using distances and vertical angles, or by using the altimeter.

67. SURVEY ACCURACY (FM 6–40)

a. Survey Accuracy of 1/3000.

(1) *Purpose.* This accuracy is required for a traverse or triangulation over long

distances, for the location of flash and sound installations, and the location of short bases.

(2) *Primary instruments required.* A 20-second transit, 100-foot steel tape, and accessories are necessary to obtain this accuracy.

(3) *Procedure.*

(*a*) *Taping.* The tape is read to the nearest one-hundredth foot. In horizontal taping, the tape is leveled to within 1½ feet with an estimated 25-pound pull being applied. In slope taping, the slope angle is measured with a transit or determined from the elevations of the tape points with a hand level and leveling rod to the nearest one-fourth foot. Slope corrections are applied.

(*b*) *Direction.* Direction is obtained to 10 seconds or better by reading two direct and two reversed angles with the 20-second transit, closing the horizon, and adjusting the angles (par. 71*a*(3)).

b. Survey accuracy of 1/5000.

(1) *Purpose.* This accuracy is necessary for exceptionally long traverses or triangulation schemes and for short bases where the angle of intersection is very small.

(2) *Primary instruments required.* A 20-

second transit, 100-foot steel tape, and accessories are necessary to obtain this accuracy.

(3) *Procedure.*

(*a*) *Taping.* The tape readings are estimated to one-thousandth foot, and slope corrections are applied for differences of elevation of tape ends of one-tenth foot. A standard pull on the tape is obtained by the use of spring balances. Great care must be exercised in the alinement of the tape. Temperature corrections are applied for temperature variations of more than 20° F. of the standard value for the tape (usually 68°F.).

(*b*) *Direction.* Direction is obtained to within 4 seconds by reading three direct and three reversed angles with the 20-second transit. If time permits, even better results are obtained if six direct and six reversed angles are read. The horizon is always closed and the angles are adjusted (par. 71*a*(3)).

68. EXECUTION OF SURVEY

The observation battalion executes the highest order of survey (1/3000 to 1/5000 accuracy) performed within the field artillery. The accuracy required depends on the mission. The required accuracy must never be sacrificed in the interest of speed, although speed is an ever-present requirement. In addition to providing control for its own installations, the battalion provides control points for the corps and division artilleries and any other artillery units operating in the corps area. The location, elevation, and an azimuth for each of these control points is furnished by the survey information center. The survey information center should be kept advised of all survey needs and all survey data should be obtained from this center. The extension of survey control to conform with the changing situation, such as an advance, a withdrawal, or a change from a hasty defense to a deliberate defense, is a continuous process. It is carried on by all available survey personnel. The headquarters battery topographical platoon performs the field work necessary to the coordination of all of the artillery survey in the corps area (fig. 15).

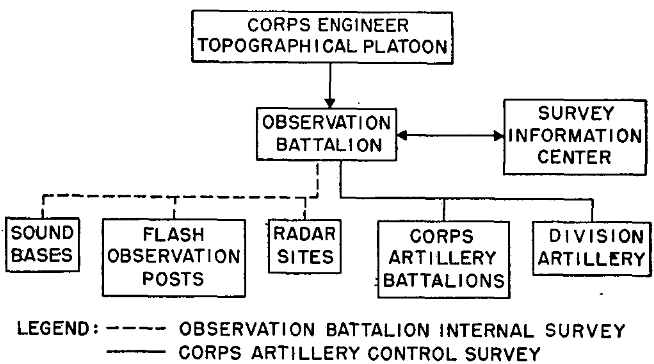

Figure 15. Survey responsibility of the field artillery observation battalion.

69. UNIVERSAL TRANSVERSE MERCATOR GRID

a. General. The universal transverse mercator (UTM) grid used in connection with the Department of the Army surveying and mapping operations is a system of coordinates on the earth's surface expressed in metric units. It is also the system of squares representing the coordinate system on a map. The necessary information for the use of the universal transverse mercator grid is contained in TM 5–241.

b. Conversion of Coordinates. Much existing survey control established by government agencies in preparation of maps and charts is furnished in geographic coordinates and geographic azimuths. For military use, these data must be converted to the universal transverse mercator grid for coordinates and azimuths. These conversions may be performed as described in TM 5–241.

c. Scale Factors. For accurate surveys, such as those executed by the field artillery observation battalion, all distances measured directly on the ground must be multiplied by a scale factor to give the corresponding grid distance. The scale factor is a multiplier (app. XI) which is used to convert distances measured on the ground to corresponding grid distances (TM 5–241).

d. Corrections for Grid Convergence. The corrections to reduce geographic azimuths to grid azimuths are given in TM 5–241 and are listed for the *E* and *N* coordinates of any point. In the northern hemisphere, the correction (convergence) is to be added to the astronomic or geographic azimuth to obtain the grid azimuth if west of the zone central meridian and subtracted if east of the zone central meridian (fig. 16). In the southern hemisphere, the opposite is true. The correction also may be computed by the formula:

Grid convergence (GC) = Difference in longitude between observer's meridian and central meridian of grid zone multiplied by sine of observer's latitude.

This equation will give the desired correction for accuracy required in artillery (app. XI).

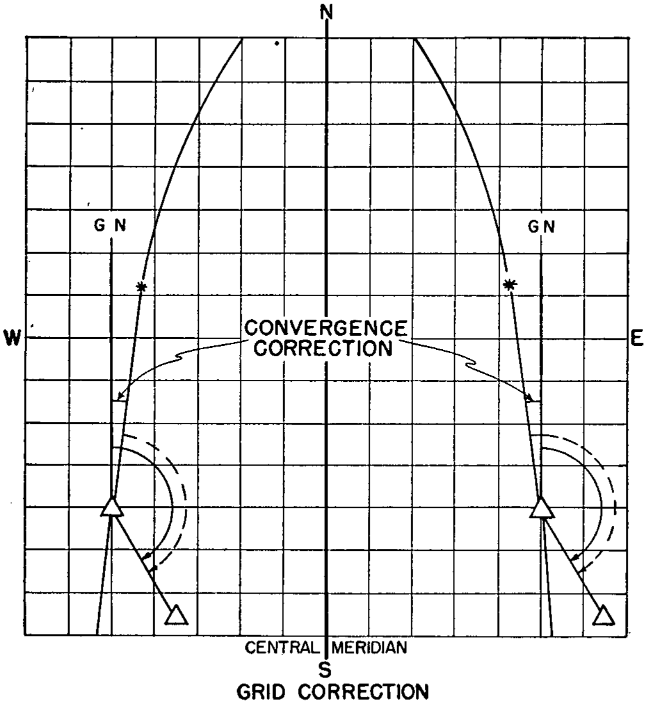

Figure 16. Grid convergence correction.

Section III. EQUIPMENT

70. GENERAL

a. Introduction. This section contains a general description of the equipment provided the observation battalion for execution of its survey mission. For further information, see TM 5–235.

b. Transit and Accessories.

(1) The transit is used for measuring horizontal and vertical angles, for prolonging straight lines with accuracy, for leveling, and for measuring distances by stadia. Transits (fig. 17) issued to the observation battalions are gradu-

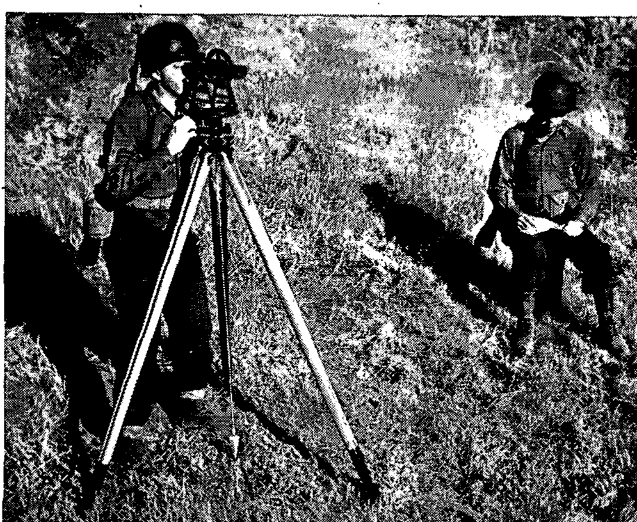

Figure 17. Instrument man and recorder using the 20-second transit.

ated in degrees, with a least reading of 20 seconds. All transits are equipped with verniers. A vernier is an auxiliary scale used for reading fractions of the smallest division of the main scale. The use of a vernier is based on the fact that it is easier to determine coincidence of two lines than to estimate fractions of a scale interval. Instructions for setting up the transit and reading verniers are contained in FM 6–40.

(2) Each transit is equipped with a plumb bob, sunshade, screwdriver and adjusting pins, waterproof cover, and reading glass for verniers. The plumb bob is used for centering the transit accurately over the station mark; the sunshade is used to shade the objective lens during operation; and the screwdriver and adjusting pins are used to adjust the transit. Transits are equipped with an auxiliary prismatic eyepiece which contains a dark glass. This eyepiece is designed to be attached to the regular eyepiece. This attachment is used to observe the sun or other objects at high altitudes.

c. Tapes and Accessories. Field artillery observation battalion survey sections are equipped with 300-foot and 100-foot tapes. Accessories for each tape consist of 1 spring balance, 2 plumb bobs, 2 notebooks, and 11 taping pins. See FM 6–40, for the care and use of tapes.

d. Marking Stations.

(1) Traverse stations should be marked by a suitable stake or hub driven flush with the ground, its center plainly marked. A reference stake should be placed near the station and plainly marked with the station number (fig. 18).

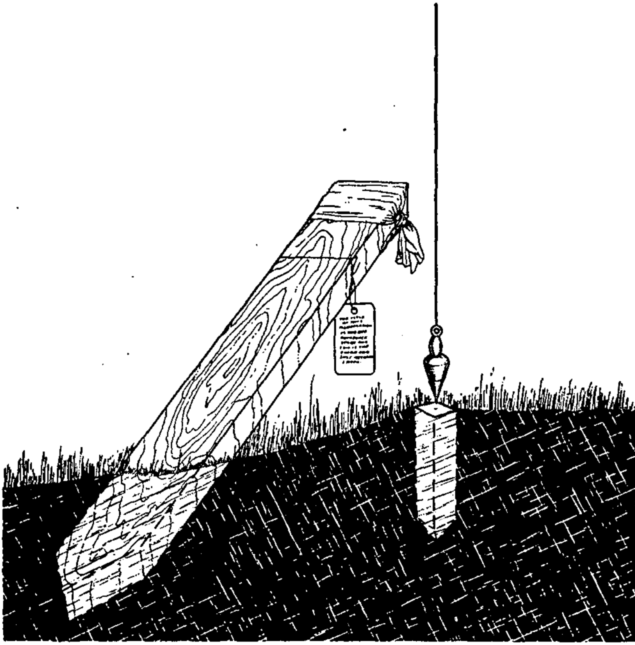

Figure 18. Hub and reference stake.

(2) Ranging poles are 6½ feet long and approximately 1⅛ inches in diameter with 6 feet of the range pole painted in contrasting 1 foot color bands (red and

Figure 19. Surveying altimeter.

white or orange and black). The range pole is used to mark a point on the ground so as to make it visible from a distance. The sharp point of the pole is placed over the station point and is plumbed by balancing it between the fingertips of both hands. The rodman stands behind it and faces the instrument.

(3) In triangulation work it is necessary to mark the stations with a good target

or signal that is clearly visible from a distance. See TM 5–235 for their construction.

(4) Night survey work requires special night lighting devices for the instrument and for marking the stations.

e. Altimeter. The surveying altimeter (fig. 19) is essentially an aneroid barometer which measures atmospheric pressure. The scale of the altimeter is graduated in feet. Since the pressure of the earth's atmosphere varies in the course of a day, or even in the course of an hour, the altimeter may be employed in field artillery survey to determine only relative altitudes when a more accurate method is not practicable. For a complete description and discussion of the use and care of these instruments, see TM 5–9418 and TM 5–9420.

71. MEASURING ANGLES WITH A 20-SECOND REPEATING TRANSIT

a. Horizontal Angles.

(1) *Angles by repetition.* The mean of a number of measurements of an angle gives a value of the angle more nearly accurate than any single measurement. As a minimum, one direct and one reversed reading should always be made. Three direct and three reversed readings usually will give the maximum desired accuracy for corps artillery survey. In any case, the same number of direct and reversed readings should be made. First, the transit operator makes the direct

readings cumulatively. Then he plunges the telescope, and, after sighting back on the first object with the lower motion, he makes the reversed readings cumulatively. If, for example, there are three direct and three reversed readings, the value of the angle read on the instrument is 6 times that of the desired angle. To obtain the value of the desired angle, divide the angle read on the instrument by 6.

(*a*) The reading of angles cumulatively will often give results larger than 360°; yet, the actual reading on the instrument can never be more than 360°. When the cumulative total of six measurements of the angle exceeds 360°, the greatest multiple of 360° contained in this total is added to the last reading on the instrument, and this sum is divided by 6 to obtain the desired angle. For example:

1. Recorded below are the angles read for three direct and three reversed readings using a 20-second transit.

Transit		*Repetitions*		*Horizontal*	*Angles*	
D	—	0	=	00°	00′	00″
D	—	1	=	137°	55′	40″
D	—	3	=	53°	47′	20″
R	—	6	=	107°	33′	20″

2. The cumulative total of the six readings is about 828°. The greatest multiple of 360° contained in 828° is 720°. Therefore, 720° is added to the last reading on the instrument, and the sum is divided by 6.

Last reading	=	107°	33′	20″
Greatest multiple of 360°	=	720°	00′	00″
	6)	827°	33′	20″
Desired angle	=	137°	55′	33″

(*b*) A quick procedure for obtaining the mean of six measurements is described below.

1. Record the results of the initial (D0), first direct (D1), final direct (D3) and final reversed readings (R6).

2. Apply the D0 mean setting by addition or subtraction to the R6 mean value (4 for 2 *D* and *R* and 2 for 1 *D* and *R*) and compare this result with the first reading.

Final reading divided by 6 =	6) 107°	33′	20″
	17°	55′	33″

(*a*) If the resulting quotient is equal to, or approximately equal to, the first reading, this value is the desired angle (in the above example, this is not the case).

(*b*) If the resulting quotient does not equal the first reading, subtract it from the first reading. The remainder is the approximate value of one increment of the desired angle. The correct value of this increment is the multiple of 60 (when reading 3 *D* and *R*) (90 is used for 2 *D* and *R*, and 180 for 1 *D* and *R*) which it most nearly equals.

$$\begin{array}{rcrrr} \text{First reading} & = & 137^\circ & 55' & 40'' \\ \text{Quotient} & = & -17^\circ & 55' & 33'' \\ \hline \text{Remainder} & = & 120^\circ & 00' & 07'' \end{array}$$

The nearest multiple of 60 in this case is 120°. Add this multiple of 60 to the quotient obtained in *2* above to obtain the desired angle.

$$\begin{array}{rcrrr} \text{Quotient} & = & 17^\circ & 55' & 33'' \\ \text{Multiple of 60} & = & 120^\circ & 00' & 00'' \\ \hline \text{Desired angle} & = & 137^\circ & 55' & 33'' \end{array}$$

(2) *Use of the transit.* With the instrument set up over the station at which the angle is to be read, set the zero of the *A* vernier opposite the zero of the horizontal circle by using the upper clamp and tangent screw to bring them into coincidence. To partially eliminate the effects of errors in the horizontal circle of the transit, both the *A* and *B* verniers are read. Read the *B* vernier and record

only the seconds. If the reading on the *B* vernier is less than 180° insert a bar over the recorded seconds. Example: If the *A* vernier reads 00° 00′ 00″ and the *B* vernier reads 179° 59′ 40″, the *B* vernier reading would be recorded as $\overline{40}$ (such an angle is called a bar angle). The difference between 180° and the *B* vernier reading is 20 seconds. Half of this difference (10 seconds) is *added* to the final reading on the transit. If the reading on the *B* vernier is initially greater than 180°, one-half the difference is *subtracted* from the final reading. Using the lower motion, point approximately at the first object by looking over the top of the telescope. Move the telescope until the vertical cross hair is very nearly on the point, clamp the lower plate by means of the lower clamp thumb screw, and set exactly on the point by using the lower clamp tangent screw. The line of sight is now on the first object. To measure the angle, loosen the upper clamp, turn the telescope to the second point, set approximately on the point, clamp the upper plate, and set the vertical cross hair exactly on the point by the upper tangent screw. The degrees and minutes of the angle are then read, using the *A* vernier. If more than one direct reading is to be taken, the first and last direct readings are the ones to be recorded.

The telescope is plunged and, using the lower motion only, the first object is sighted upon; using the upper motion, the telescope is set exactly on the second object. The same number of readings are taken with the telescope in the reversed position as were taken with the telescope in the direct position. Both the *A* and *B* verniers are read and recorded on the last measurement. If the minute reading on the *B* vernier is one less than the minute reading on the *A* vernier, record the seconds reading on the *B* vernier as a bar angle. Never overrun the point in bringing the vertical cross hair upon it. Bring the cross hair to the point in such a manner that the tangent screw compresses the spring against which it works. This eliminates lost motion in the plates.

(3) *Closing horizon.* The accuracy of the desired angle can be increased by measuring the remaining part of the horizontal circle. The sum of the measured angles should equal 360°. The amount by which the sum of the measured angles differs from 360° should be divided by the number of angles. The resulting quotient should then be added to or subtracted from each measured angle so that their sum will equal 360°.

b. Vertical Angles. Level the horizontal plate accurately, sight on the point with the telescope direct, and read the vertical angle. Plunge the telescope, rotate the instrument in azimuth 180°, sight upon the point, and read the vertical angle again. The mean of the two readings is taken. When horizontal angles are read by repetition, the vertical angles are read and recorded when the first direct and last reversed readings of the horizontal angles are read.

c. Recording Angles. Figure 20 shows the filled in pages of a field note book and shows how the measured angles are recorded, meaned, and adjusted.

72. DETERMINATION OF DISTANCES

The distances between two stations may be determined by horizontal or slope taping. To avoid confusion and error a methodical procedure should be followed (FM 6–40).

73. RECORDING DATA

a. General. The recorder should have a notebook, a hard pencil, a small scale for drawing sketches, and a protractor for drawing angles.

b. Notebook. The notebook used to record survey data should be made of good quality paper, have a durable cover, and be of convenient size. Survey is exacting work, and the recording of this data in a good notebook is important to insure a permanent record of the survey operation.

(1) *Title.* An appropriate title page will be printed on the first page of the notebook.

(2) *Index.* A systematic index of the field

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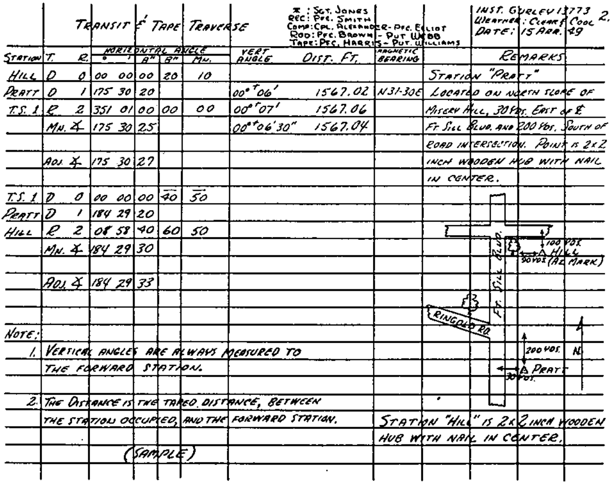
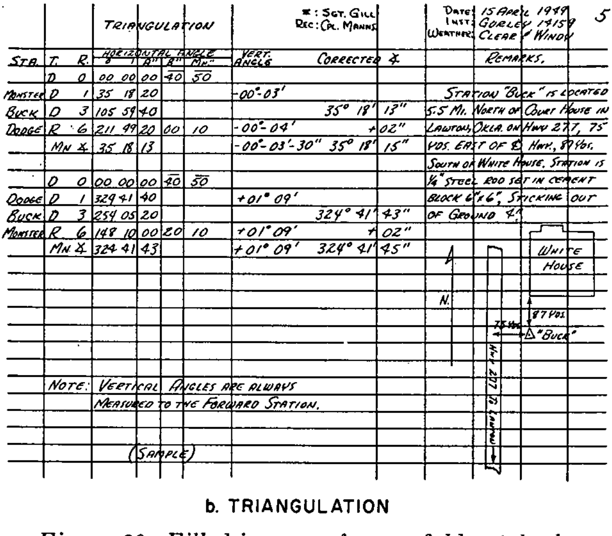


Station	T.	R.	Horizontal Angle °	′	A″	B″	Mn.	Vert. Angle	Dist. Ft.	Magnetic Bearing	Remarks
HILL	D	0	00	00	00	20	10				STATION "PRATT"
PRATT	D	1	175	30	20			00°+06′	1567.02	N31-30E	LOCATED ON NORTH SLOPE OF
T.S. 1	R	2	351	01	00	00	00	00°+07′	1567.06		MISERY HILL, 30 YDS. EAST OF ℄
	MN. ∡		175	30	25			00°+06′30″	1567.04		FT. SILL BLVD. AND 200 YDS. SOUTH OF
											ROAD INTERSECTION. POINT IS 2×2
	ADJ. ∡		175	30	27						INCH WOODEN HUB WITH NAIL
											IN CENTER.
T.S. 1	D	0	00	00	00	$\overline{40}$	$\overline{50}$				
PRATT	D	1	184	29	20						
HILL	R	2	08	58	40	60	50				
	MN. ∡		184	29	30						
	ADJ. ∡		184	29	33						

a. TRANSIT AND TAPE TRAVERSE



Sta.	T.	R.	Horizontal Angle °	′	A″	B″	Mn.″	Vert. Angle	Corrected ∡	Remarks
	D	0	00	00	00	$\overline{40}$	$\overline{50}$			
MONSTER	D	1	35	18	20			-00°-03′		STATION "BUCK" IS LOCATED
BUCK	D	3	105	59	40				35° 18′ 13″	5.5 MI. NORTH OF COURT HOUSE IN
DODGE	R	6	211	49	20	00	10	-00°-04′	+02″	LAWTON, OKLA. ON HWY 277, 75
	MN ∡		35	18	13			-00°-03′-30″	35° 18′ 15″	YDS. EAST OF ℄ HWY., 87 YDS.
										SOUTH OF WHITE HOUSE. STATION IS
	D	0	00	00	00	$\overline{40}$	$\overline{50}$			¼" STEEL ROD SET IN CEMENT
DODGE	D	1	329	41	40			+01° 09′		BLOCK 6"×6", STICKING OUT
BUCK	D	3	254	05	20				324° 41′ 43″	OF GROUND 4".
MONSTER	R	6	148	10	00	20	10	+01° 09′	+02″	
	MN ∡		324	41	43			+01° 09′	324° 41′ 45″	

b. TRIANGULATION

Figure 20. Filled in pages from a field notebook.

notes will be kept on the two pages following the title page. Related notes on different pages will be liberally and plainly cross referenced. The pages of the notebook will be numbered to facilitate indexing, two pages facing each other to constitute one page.

(3) *Miscellaneous data.* In addition to the title of the job and the record of the data observed, the field notes should include the date, organization of party, equipment used, weather, and any other information which is likely to be of service in connection with the work. No item properly belonging to the notes should be trusted to memory. Data relating to different jobs will not be recorded on the same pages. Field notes must not be made on loose slips or sheets of paper or in other notebooks, but the original record must be entered in the field notebook during the progress of the field work.

(4) *Sketches.* Sketches will be used liberally in the notes and will be made in the field. The field sketches should be bold and clear, in fair proportion, and of liberal size to avoid confusion of detail. The sketches should be supplemented by descriptive statements, and important points of the sketch should be lettered for reference.

(5) *Erasures.* Erasures in the field notes are *not* permitted. In case a figure is incor-

rectly recorded, it should be lined out and the correct entry made above the wrong figure. The neat cancellation of an item in the notes inspires confidence, but evidence of an erasure or alteration casts doubt upon its genuineness. Rejection of a page of notes should be indicated by neatly crossing the entire page and printing the word *void*. A cross reference should be made between the rejected page and substituted pages.

Section IV. TRAVERSE

74. GENERAL

a. Definitions.

(1) A *traverse* is a series of connecting course lines whose lengths and relative directions have been determined. Stations on the traverse are located with respect to one another.

(2) A *closed traverse* is a traverse which returns to the starting point, or terminates at another point of known location.

(3) An *open traverse* is a traverse which does not end at a known point.

(4) A *station* is a marked point, usually where the course or direction changes.

(5) A *leg* is a straight line between two adjacent stations.

b. Procedure.

(1) Distances are determined by taping between adjacent stations.

(2) Angles measured are the clockwise angles from the last station occupied to the next forward station to be occupied.

(3) In running a traverse, altitudes are determined by measuring the vertical angles between stations.

(4) The closing of a traverse is a valuable check against errors and should always be performed if possible. It also permits the traverse to be adjusted, if necessary.

75. PERSONNEL AND DUTIES OF A TRAVERSE PARTY

a. Normally a traverse party of an observation battalion consists of the following personnel:

1 Chief of party (transitman)
1 Recorder
2 Computers
2 Rodmen
2 Tapemen

8 Total

b. When required, axmen supplement the party.

c. The computers determine the coordinates of the station and the leg directions of the traverse as the survey progresses, computing independently as a mutual check.

d. The rodmen hold the rods on the foresight (front rodman) and backsight (rear rodman).

e. Tapemen perform their duties as described in FM 6–40. They must be trained to use proper procedure. Prescribed methods must be rigidly enforced. Tapemen must exercise constant vigilance to avoid errors and blunders. The most common errors are reading the tape incorrectly and failing to count a complete tape length.

76. TRAVERSE COMPUTATIONS

a. General. Computations in the observation battalions are precise. Seven-place logarithms are habitually used to reduce interpolation and to obtain the accuracy desired.

b. Types. Traverse computations consist of determining coordinates from measured azimuths and taped distances. To facilitate field computations in this operation, DA AGO Form 6–2 is provided. Initial azimuth may frequently be determined from the known coordinates of two intervisible points. For this operation, DA AGO Form 6–1 is provided.

c. Example. The coordinates of BM 1 and BM 2 (fig. 21) are known. BM 1 is visible from BM 2. The azimuth from BM 2 to BM 1 is computed

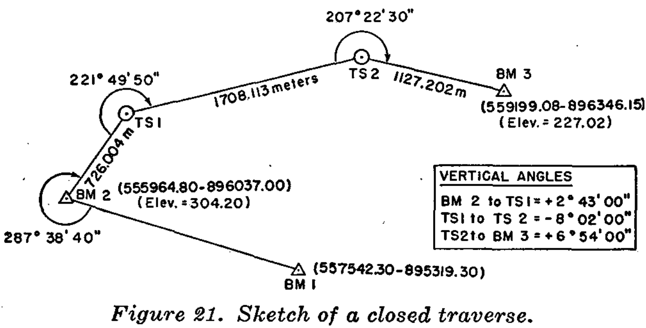
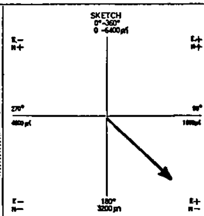


Figure 21. Sketch of a closed traverse.

on DA AGO Form 6–1 (fig. 22). Station BM 2 is occupied and the clockwise angle from BM 1 to TS 1 is turned. The distance from BM 2 to TS 1 is determined by taping. Coordinates of

AZIMUTH AND DISTANCE FROM COORDINATES

STATIONS	E	N
FROM BM - 2	(−) 555964.80	(−) 896037.00
TO BM - 1	(+) 557542.30	(+) 895319.30
	dE 1577.50	dN 717.70
LOG dE 3.1979694	TAN BEARING = dE/dN D = dE/SIN BEARING = dN/COS BEARING	
−LOG dN 2.8559429	179° 59′ 60″	SKETCH
LOG TAN BEARING 0.3420265	BEARING 65° 32′ 11″	
LOG dE¹ 3.1979694	AZIMUTH 114° 27′ 49″	
−LOG SIN BEARING¹ 9.9591485		
LOG D 3.2388209	D 1733.09 ~~YARDS~~ METERS	



STATIONS	E	N
FROM	(−)	(−)
TO	(+)	(+)
	dE	dN
LOG dE	TAN BEARING = dE/dN D = dE/SIN BEARING = dN/COS BEARING	
−LOG dN		SKETCH 0°-360° 0 -6400₥ E− N+ E+ N+
LOG TAN BEARING	BEARING	
LOG dE¹	AZIMUTH	270° 4800₥ 90° 1600₥
−LOG SIN BEARING¹		
LOG D	D YARDS METERS	E− N− 180° 3200₥ E+ N−

¹If dE is less than ½dN, enter Log dN instead of Log dE and Log Cos Bearing instead of Log Sin Bearing in these spaces.

DA AGO FORM 1 JUN 52 6-1 EDITION OF 1 MAY 49 MAY BE USED. Army-Ft.Sill,Okla.12490 L6639

Figure 22. Computation of azimuth and distance from coordinates.

COORDINATES FROM AZIMUTH AND DISTANCE			FROM BM-2	TO BM-3		SHEET 1 OF 1 SHEETS		
STATION BM-1	AZIMUTH		VERTICAL ANGLE DISTANCE BEARING	LOGARITHMS*			COORDINATES AND E, N, AND Z DIFFERENCES	
STATION BM-2	AZ TO REAR STATION	114 27 49	VERTICAL ANGLE +2 43 00				E 555964.80	N 896037.00 Z 304.2
	ANGLE	287 38 40						
	SUM	402 06 29	S 726.00 FT	** 9.9998400	9.9998400	0.0388629		
	360° 6400 mil	360 00 00	D ~~726.004~~ YD M	D 2.8609366	D 2.8609366	D 2.8609366		
	AZ TO FWD STATION	42 06 29	BEARING 42 06 29	SIN BEARING 9.8264188	COS BEARING 9.8703356	TAN VERTICAL ANGLE 8.6762393		
	180° 3200 mil ±	180 00 00		dE 2.6871954	dN 2.7311122	dZ 1.5760388	dE +486.63	dN +538.41 dZ +37.7
STATION TS-1	AZ TO REAR STATION	222 06 29	VERTICAL ANGLE −8 02 00				E 556451.43	N 896575.41 Z 341.9
	ANGLE	221 49 50						
	SUM	443 56 19	S 1708.11 FT	9.9998400	9.9998400	0.0388629		
	360° 6400 mil	360 00 00	D ~~1708.113~~ YD M	D 3.2325158	D 3.2325158	D 3.2325158		
	AZ TO FWD STATION	83 56 19	BEARING 83 56 19	SIN BEARING 9.9975652	COS BEARING 9.0236391	TAN VERTICAL ANGLE 9.1496321		
	180° 3200 mil ±	180 00 00		dE 3.2299210	dN 2.2559949	dZ 2.4210108	dE +1697.93	dN +180.30 dZ −263.6
STATION TS-2	AZ TO REAR STATION	263 56 19	VERTICAL ANGLE +6 54 00				E 558149.36	N 896755.71 Z 78.3
	ANGLE	207 22 30						
	SUM	471 18 49	S 1127.20 FT	9.9998400	9.9998400	0.0388629		
	360° 6400 mil	360 00 00	D ~~1127.202~~ YD M	D 3.0520010	D 3.0520010	D 3.0520010		
	AZ TO FWD STATION	111 18 49	BEARING 68 41 11	SIN BEARING 9.9692317	COS BEARING 9.5604716	TAN VERTICAL ANGLE 9.0828331		
	180° 3200 mil ±			dE 3.0210727	dN 2.6123126	dZ 2.1736970	dE +1049.72	dN −409.56 dZ +149.2
STATION BM-3	AZ TO REAR STATION		VERTICAL ANGLE				E 559199.08	N 896346.15 Z 227.5
	ANGLE							
	SUM		S FT					
	360° 6400 mil		D YD M	D	D	D		
	AZ TO FWD STATION		BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE		
	180° 3200 mil ±			dE	dN	dZ	dE	dN dZ
STATION	AZ TO REAR STATION			**LOCAL UTM SCALE FACTOR			E	N Z
COMPUTER J.J. JAY, SGT.	CHECKER J.J. JONES, SGT.			*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft. To find dZ in Yds. add 9.5228787 to Log D in Ft. To find dZ in Yds. add 0.0388629 to Log D in meters.			DATE 24 August 1949	

DA AGO FORM 6-2

Figure 23. Computation of coordinates from azimuth and distance.

TS 1 are computed on DA AGO Form 6–2 (fig. 23). Successively, stations TS 1 and TS 2 are occupied, the distance taped, and the angle turned from the respective preceding stations to the respective succeeding stations. Coordinates of each successive station are computed on DA AGO Form 6–2 as the survey progresses. The traverse is closed on BM 3 whose coordinates are known.

Section V. TRIANGULATION

77. GENERAL

Triangulation is the method used to extend survey control rapidly through a large sector by means of a series of triangles. The lines of a triangulation scheme form a network, tying together the stations at which the angles in the scheme are measured. The vertices of the angles are the triangulation stations. In densely wooded country, without points of vantage, triangulation may be rendered impossible; but where triangulation is possible and carefully done, it usually will be both rapid and accurate.

78. TRIANGULATION SCHEMES

a. The basic figure from which triangulation schemes are built is the triangle. The triangle alone affords no proof of the accuracy of the observations or computations except that the three interior angles of the triangle total 180°. A triangulation scheme of single triangles (a of fig. 24), while very rapid, is weak because of insufficient verification of the accuracy of the survey. A triangulation scheme of two independent chains of triangles is strong because at least two independent computations can be made for each point (b and c of fig. 24). If time permits, a triangulation scheme which extends through

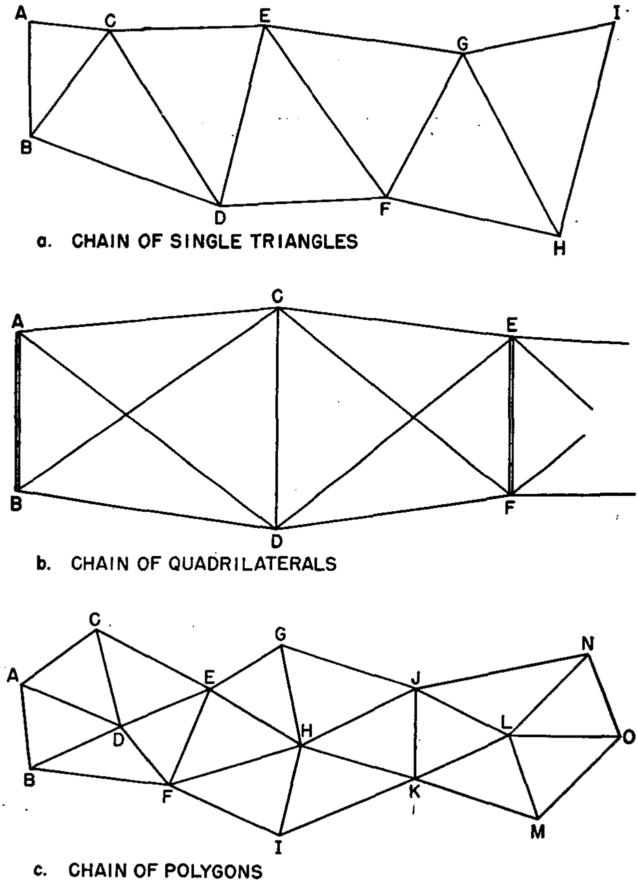


Figure 24. Triangulation schemes.

several triangles should consist of multiple chains of triangles, overlapping frequently to provide verification of observations and computations.

b. The simple figures which provide adequate proof of accuracy are the quadrilateral with both diagonals observed (b of fig. 24) and the four- (or more) sided, central-point figure (c of fig. 24). These figures are composed of properly arranged combinations of triangles to provide checks on computations.

79. TRIANGULATION PROCEDURE

Execution of a triangulation scheme consists of the following steps:

a. Reconnaissance for Triangulation Stations. Selection of triangulation stations must be made by thorough map reconnaissance followed by ground reconnaissance.

b. Marking Stations. Each station to be occupied must be marked with a stake or other means to fix its exact location. In addition, each station to be observed must be marked by some means to make it visible from all stations from which it is to be observed. A tripod or similar marker which will allow the station to be occupied without disturbing the marker frequently will be necessary.

c. Measurement of Angles. All angles at each station, including the angle closing the horizon, are measured. The angles are adjusted so that their sum equals 360°; any error is distributed equally among the angles measured regardless of the size of the angles.

d. Measurement of Base Line when Necessary. Measurement of a base line will be unnecessary if there are two or more control stations, the positions of which have been or will be fixed by higher survey control.

80. ACCURACY

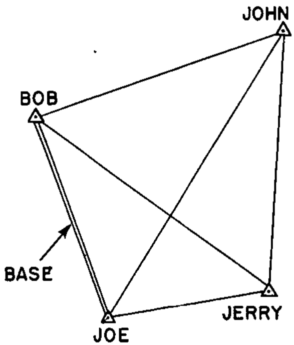
a. General. In extending corps artillery survey control through a corps zone of action, the accuracy required is 1/3000.

b. Angular Accuracy. To obtain the required over-all accuracy, it is necessary to have a horizon closure of 4 seconds or less per angle measured at each station. It also is necessary to have an average triangle closure of not greater than 12 seconds. The angles opposite the known base and side required should be between the limits of 30° and 150°. The required side is the first side solved for and is a diagonal or a forward side. Triangles whose angles fall within these limits are known as strong figures.

c. Base-Line Measurement. The base-line is taped by two taping teams. The two taped distances must agree to within 1 part in 7,000 parts (1/7000).

81. PERSONNEL AND DUTIES OF A TRIANGULATION PARTY

a. The observing party for triangulation consists of a survey and instrument man and a survey recorder. The party may move from station to station or, if sufficient personnel are available,



MEASURED ANGLES:

HORIZONTAL (ADJUSTED FOR CLOSURE)

AT JOE	
BOB TO JOHN	65° 01' 46"
JOHN TO JERRY	49° 25' 16"
AT BOB	
JOHN TO JERRY	51° 01' 59"
JERRY TO JOE	36° 08' 52"
AT JOHN	
JERRY TO JOE	33° 51' 10"
JOE TO BOB	27° 47' 20"
AT JERRY	
JOE TO BOB	29° 24' 04"
BOB TO JOHN	67° 19' 15"

VERTICAL (ADJUSTED FOR CURVATURE AND REFRACTION)

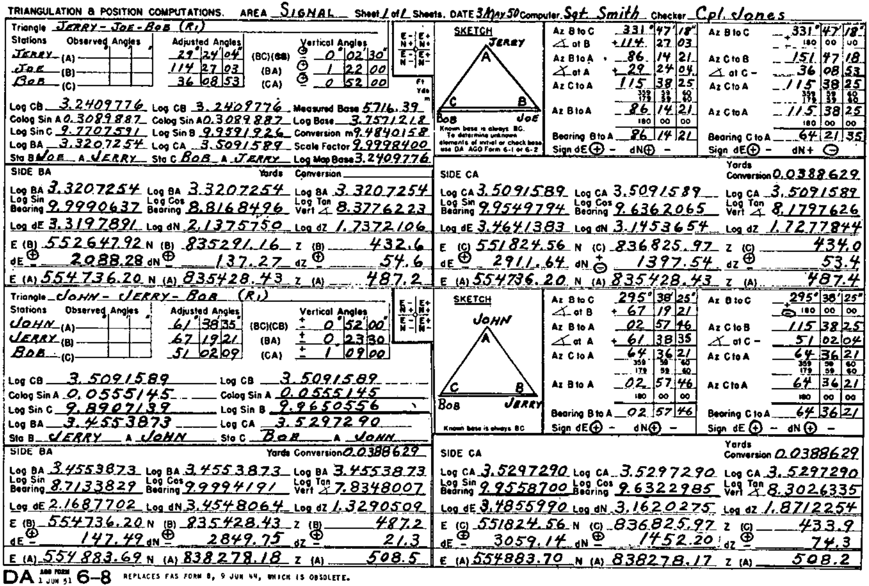
JOE TO BOB	+0° 02' 30"
BOB TO JERRY	+0° 52' 00"
JOE TO JERRY	+1° 22' 00"
JERRY TO JOHN	+0° 23' 30"
BOB TO JOHN	+1° 09' 00"
JOE TO JOHN	+1° 09' 54"

LENGTH OF MEASURED BASE = 5716.39 feet

AZIMUTH JOE TO BOB = 331° 47' 18"

COORDINATES JOE = (552 647.92—835 291.16) ELEVATION 432.6 yards

Figure 25. Quadrilateral.



TRIANGULATION & POSITION COMPUTATIONS. AREA SIGNAL Sheet 1 of 1 Sheets. DATE 3 May 50 Computer Sgt. Smith Checker Cpl. Jones

Triangle JERRY - JOE - BOB (R1)

Stations		Observed Angles	Adjusted Angles		Vertical Angles
JERRY	(A)		29° 24' 04"	(BC)(CB)	⊕ 0° 02' 30"
JOE	(B)		114 27 03	(BA)	⊖ 1 22 00
BOB	(C)		36 08 53	(CA)	⊖ 0 52 00

Log CB 3.2409776 Log CB 3.2409776 Measured Base 5716.39
Colog Sin A 0.3089887 Colog Sin A 0.3089887 Log Base 3.7571218
Log Sin C 9.7707591 Log Sin B 9.9591926 Conversion m 9.4840158
Log BA 3.3207254 Log CA 3.5091589 Scale Factor 9.9998400
Sta B JOE A JERRY Sta C BOB A JERRY Log Map Base 3.2409776

SKETCH: JERRY (A), C (BOB), B (JOE)
Known base is always BC. To determine unknown elements of initial or check base use DA AGO Form 6-1 or 6-2

Az B to C	331°	47'	18"	Az B to C	331°	47'	18"
∠ at B	+114	27	03		−180	00	00
Az B to A	86	14	21	Az C to B	151	47	18
∠ at A	+29	24	04	∠ at C −	36	08	53
Az C to A	115	38	25	Az C to A	115	38	25
	359 / 179	59 / 59	60 / 60		359 / 179	59 / 59	60 / 60
Az B to A	86	14	21	Az C to A	115	38	25
	180	00	00		180	00	00
Bearing B to A	86	14	21	Bearing C to A	64	21	35
Sign dE ⊕ − dN ⊕ −				Sign dE ⊕ − dN + ⊖			

SIDE BA — Yards Conversion
Log BA 3.3207254 Log BA 3.3207254 Log BA 3.3207254
Log Sin Bearing 9.9990637 Log Cos Bearing 8.8168496 Log Tan Vert ∠ 8.3776223
Log dE 3.3197891 Log dN 2.1375750 Log dZ 1.7372106
E (B) 552647.92 N (B) 835291.16 Z (B) 432.6
dE ⊕ 2088.28 dN ⊕ 137.27 dZ ⊕ 54.6
E (A) 554736.20 N (A) 835428.43 Z (A) 487.2

SIDE CA — Yards Conversion 0.0388629
Log CA 3.5091589 Log CA 3.5091589 Log CA 3.5091589
Log Sin Bearing 9.9549794 Log Cos Bearing 9.6362065 Log Tan Vert ∠ 8.1797626
Log dE 3.4641383 Log dN 3.1453654 Log dZ 1.7277844
E (C) 551824.56 N (C) 836825.97 Z (C) 434.0
dE ⊕ 2911.64 dN ⊖ 1397.54 dZ ⊕ 53.4
E (A) 554736.20 N (A) 835428.43 Z (A) 487.4

Triangle JOHN - JERRY - BOB (R1)

Stations		Observed Angles	Adjusted Angles		Vertical Angles
JOHN	(A)		61° 38' 35"	(BC)(CB)	± 0° 52' 00"
JERRY	(B)		67 19 21	(BA)	± 0 23 30
BOB	(C)		51 02 09	(CA)	± 1 09 00

Log CB 3.5091589 Log CB 3.5091589
Colog Sin A 0.0555145 Colog Sin A 0.0555145
Log Sin C 9.8907139 Log Sin B 9.9650556
Log BA 3.4553873 Log CA 3.5297290
Sta B JERRY A JOHN Sta C BOB A JOHN

SKETCH: JOHN (A), C (BOB), B (JERRY)
Known base is always BC

Az B to C	295°	38'	25"	Az B to C	295°	38'	25"
∠ at B	+67	19	21		⊖180	00	00
Az B to A	02	57	46	Az C to B	115	38	25
∠ at A	+61	38	35	∠ at C −	51	02	04
Az C to A	64	36	21	Az C to A	64	36	21
	359 / 179	59 / 59	60 / 60		359 / 179	59 / 59	60 / 60
Az B to A	02	57	46	Az C to A	64	36	21
	180	00	00		180	00	00
Bearing B to A	02	57	46	Bearing C to A	64	36	21
Sign dE ⊕ − dN ⊕ −				Sign dE ⊕ − dN ⊕ −			

SIDE BA — Yards Conversion 0.0388629
Log BA 3.4553873 Log BA 3.4553873 Log BA 3.4553873
Log Sin Bearing 8.7133829 Log Cos Bearing 9.9994191 Log Tan Vert ∠ 7.8348007
Log dE 2.1687702 Log dN 3.4548064 Log dZ 1.3290509
E (B) 554736.20 N (B) 835428.43 Z (B) 487.2
dE ⊕ 147.49 dN ⊕ 2849.75 dZ ⊕ 21.3
E (A) 554883.69 N (A) 838278.18 Z (A) 508.5

SIDE CA — Yards Conversion 0.0388629
Log CA 3.5297290 Log CA 3.5297290 Log CA 3.5297290
Log Sin Bearing 9.9558700 Log Cos Bearing 9.6322985 Log Tan Vert ∠ 8.3026335
Log dE 3.4855990 Log dN 3.1620275 Log dZ 1.8712254
E (C) 551824.56 N (C) 836825.97 Z (C) 433.9
dE ⊕ 3059.14 dN ⊕ 1452.20 dZ ⊕ 74.3
E (A) 554883.70 N (A) 838278.17 Z (A) 508.2

DA AGO FORM 1 JUN 51 6-8 REPLACES FAS FORM 8, 9 JUN 44, WHICH IS OBSOLETE.

Figure 26. Triangulation and position computation.

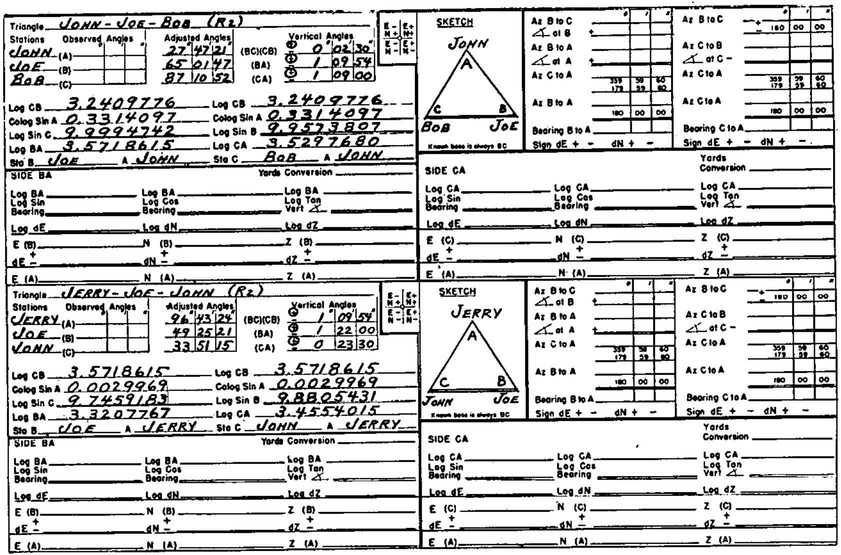


Figure 26—Continued.

several observing parties may be working at the same time.

b. If the triangulation scheme is not started from a known base, it will be necessary to determine the length of the base by double taping. For observation battalion work, a taping party consisting of two men is sufficient.

c. In addition to the observing parties and taping team, there also should be a chief of party to supervise the entire operation.

82. COMPUTATIONS

In order to illustrate the computations involved in a complete triangulation problem, an example is shown in the following paragraphs. The triangulation scheme used in this example is shown first. Then the form used for triangulation and position computation is shown.

a. Triangulation Scheme Used. Figure 25 shows the triangulation scheme used and the data obtained by the survey party or parties.

b. Computation in Solving Triangles. Figure 26 shows the computation involved in solving triangles using DA AGO Form 6–8. This form is so arranged that the station opposite the known base is labeled *A* and the stations at each end of the base labeled *B* and *C* in a clockwise direction from station *A*.

c. Triangulation Position Computations. As soon as the triangles are solved, it is necessary to determine the positions (coordinates) of the unknown stations. Figure 26 illustrates the triangulation and position computations using DA

AGO Form 6–8. The coordinates of the positions are determined by computing the coordinates of the unknown station from both ends of the known base. Both sets of coordinates should agree. To continue the position computation, the side of the triangle that forms the diagonal of the quadrilateral forms the base for the next triangle; the two stations forming the ends of this base are used as starting points for position computation for the next unknown station. This procedure is continued through each successive quadrilateral throughout the scheme.

Section VI. THREE-POINT RESECTION

83. GENERAL

Three-point resection is a specialized form of triangulation. It is one of the most useful methods in survey. In three-point resection, the coordinates of three points which form a triangle and are visible from the position of the observer must be known to determine the coordinates of

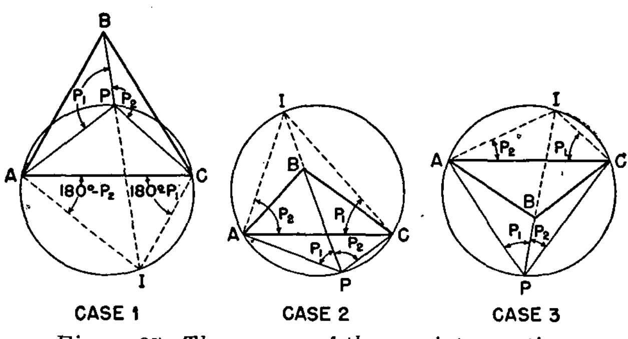


Figure 27. Three cases of three-point resection.

948797°—51—8

the position of the observer. In figure 27, point *P* represents the position of the observer and points *A*, *B*, and *C* represent the three points of known coordinates. To determine the coordinates of his position, *P*, it is necessary for the observer to measure angles P_1 and P_2 with an instrument.

84. APPLICATION

a. Three cases of the application of three-point resection are shown in figure 27. They differ depending upon the location of the point, *P*, with reference to the sides of the triangle formed by the three known points. Notice that in *case 1* (fig. 27), *P* falls inside the triangle *ABC*, whereas, in *cases 2* and *3*, P falls outside the triangle.

b. There are two situations that may develop in which a three-point resection solution appears possible, but actually is not usable. First, if *P* falls upon the prolongation of a side of the triangle *ABC*, the problem resolves itself into the solution of a triangle with a side and angles given. This solution is not acceptable since no check on the solved elements of the single triangle is made (par. 78). Secondly, if *P* falls on the circumference of the circle passing through the vertices of the triangle, the problem is indeterminate (par. 86). A sketch of the problem in question is necessary before the computer undertakes the problem. This sketch should be supplied by the observer in the field.

85. SOLUTION

a. Method. The three-point problem may be solved graphically but with limited accuracy. In observation battalion survey, the accuracies specified above for triangulation are applicable to resection operations; therefore, the three-point problem is always solved mathematically.

b. Measuring Angles. In figure 27, *A, B,* and *C* are the known points and *P* is the position of the observer from which the angles *APB* (P_1), *BPC* (P_2), and *CPA* (to close the horizon) are measured. These angles are adjusted for horizon closure.

c. Solving for Coordinates of P. The steps outlined below are followed in solving for the coordinates of *P*.

(1) *First step.* Compute from the coordinates of *A, B,* and *C,* the azimuth and length of lines *AB, AC,* and *BC.* From these azimuths, compute the angles *BAC, ACB,* and *CBA.*

(2) *Second step.* Construct a circle so that it passes through the points *A, P,* and *C.* The line *BP,* prolongated, cuts the circle at *I.* Situations will fall in one of two categories: *Case 1,* where *P* is within the triangle *ABC,* and *cases 2* and *3,* where *P* is outside the triangle *ABC.*

(3) *Third step.* Determine the value of angles *ACI* and *CAI.*

(*a*) *Case 1.* The angle *ACI* is equal to angle *API* since both are angles whose vertices lie on the circumference of a circle and subtend the same arc of the circle. Angle *API* is equal to 180° minus angle P_1; therefore, angle ACI is also equal to 180° minus angle P_1. In a similar manner, it may be shown that angle CAI is equal to 180° minus angle P_2.

(*b*) *Cases 2 and 3.* The angle ACI is equal to angle P_1 because both angles are on the circumference of the circle and subtend the arc AI. Similarly, angle CAI is equal to angle P_2.

(4) *Fourth step.* The solution of the following triangles is also outlined on the three-point resection form shown in figure 30:

(*a*) Triangle IAC

Solve for AI

$$AI = \frac{AC \text{ Sin } ACI}{\text{Sin } AIC}$$

Solve for CI

$$CI = \frac{AC \text{ Sin } IAC}{\text{Sin } AIC}$$

(*b*) Triangles IBA and CBI

Solve for angle IBA

$$\text{Tan } IBA = \frac{AI \text{ Sin } BAI}{AB - AI \text{ Cos } BAI}$$

Solve for angle CBI

$$\text{Tan } CBI = \frac{CI \text{ Sin } BCI}{BC - CI \text{ Cos } BCI}$$

Angle ABC should equal angle $IBA + CBI$.

(c) Triangles PAB and PBC

Solve for PA and PB

$$PA = \frac{AB \text{ Sin } ABP}{\text{Sin } P_1}$$

$$PB = \frac{AB \text{ Sin } PAB}{\text{Sin } P_1}$$

Solve for PC and PB

$$PC = \frac{BC \text{ Sin } PBC}{\text{Sin } P_2}$$

$$PB = \frac{BC \text{ Sin } BCP}{\text{Sin } P_2}$$

The two values for the length of PB should agree within the accuracy of the logarithm tables.

(d) *Computing coordinates.*

Compute the coordinates of P from point A or B.

Compute the coordinates of P from point C or B.

Coordinates of P should agree when computed from PA, PB, or PC.

d. *Sample Three-Point Resection Problem.*

(1) *Initial data.* The sketch, coordinates of three known points, and the measured angles of a *case 2* three-point resection problem are shown in figure 28.

(2) *Solution.*

(a) The computations necessary to determine azimuth and distance from coordinates using DA AGO Form 6–1 are shown in figure 29.

(b) The computations necessary to determine the logarithms of the distances AP, BP, and CP and the unknown angles using the three-point resection form are shown in figure 30.

(c) The computations necessary to determine coordinates from azimuth and

KNOWN COORDINATES:

	E	N
Heyls Hill (A)	551 533.62	838 808.51
Station 30 (B)	552 224.85	841 112.62
Welsh Hill (C)	554 065.08	842 439.48

MEASURED ANGLES:

P_1 = 52° 10' 20"

P_2 = 34° 32' 00"

(VERTICAL CONTROL OMITTED)

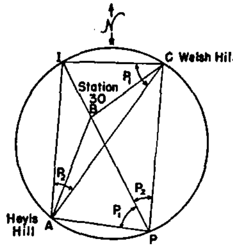


Figure 28. Sketch, known coordinates, and measured angles for a three-point resection problem.

distance using DA AGO Form 6–2 are shown in figure 31.

86. THREE-POINT FAILURE

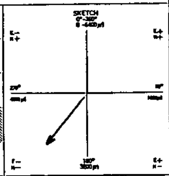
If the unknown stations should fall on the circle through the three known points, the problem is indeterminate as shown in figure 32. This situation can only occur when P and B are on the opposite side of the line AC (case 2), and when the sum of angles CBA, P_1, and P_2 is equal to 180°. The sum of angle APC (P_1—P_2) and angle CBA should vary from 180° by at least 20° in order to obtain an accurate computed location.

87. SUMMARY

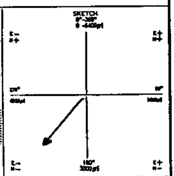
The three-point resection problem will give a quick and accurate solution if accurate observations are made. When there is some doubt about the reliability of the observations, they should be

AZIMUTH AND DISTANCE FROM COORDINATES

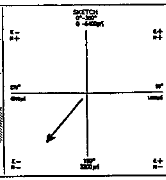
STATIONS	E	N
FROM WELSH HILL "C"	(−) 554065.08	(−) 842439.48
TO STATION 30 "B"	(+) 552224.85	(+) 841112.62
	dE 1804.23	dN 1326.86
LOG dE 3.2648721	TAN BEARING = dE/dN D = dE/SIN BEARING = dN/COS BEARING	
−LOG dN 3.1226251	180° 00′ 00″	SKETCH
LOG TAN BEARING 0.1420470	BEARING 54° 12′ 26″	
LOG dE¹ 3.2648721	AZIMUTH 234° 12′ 26″	
−LOG SIN BEARING¹ 9.9090945		
LOG D 3.3557776	D 2268.70 YARDS METERS	



STATIONS	E	N
FROM STATION 30 "B"	(−) 552224.85	(−) 841112.62
TO HEYLS HILL "A"	(+) 551533.62	(+) 838808.51
	dE 691.23	dN 2304.11
LOG dE 2.8396226	TAN BEARING = dE/dN D = dE/SIN BEARING = dN/COS BEARING	
−LOG dN 3.3625032	180° 00′ 00″	SKETCH
LOG TAN BEARING 9.4771194	BEARING 16° 41′ 57″	
LOG dE¹ 3.3625032	AZIMUTH 196° 41′ 57″	
−LOG SIN BEARING¹ 9.9812869		
LOG D 3.3812163	D 2405.56 YARDS METERS	



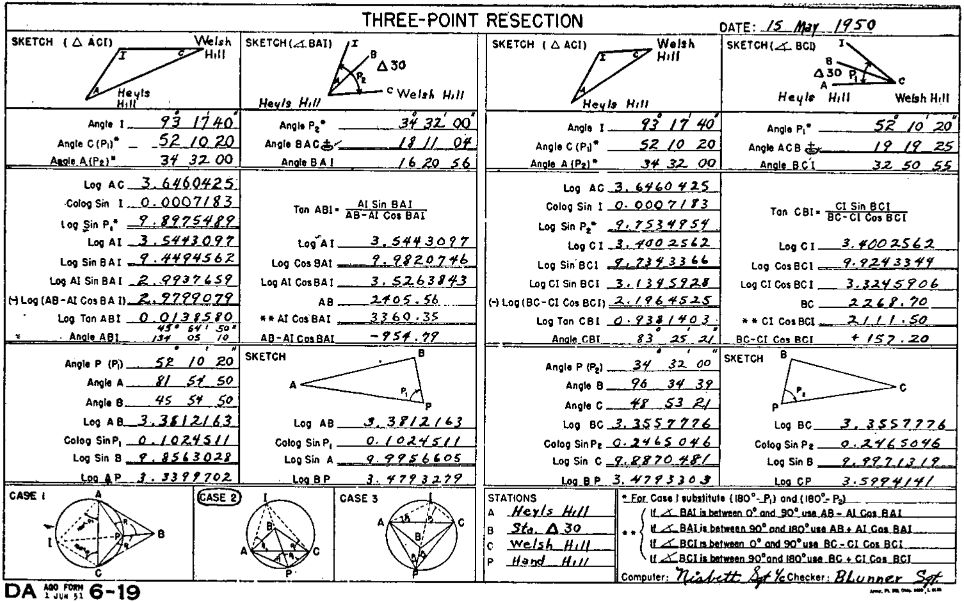
STATIONS	E	N
FROM WELSH HILL "C"	(−) 554065.08	(−) 842439.48
TO HEYLS HILL "A"	(+) 551533.62	(+) 838808.51
	dE 2531.46	dN 3630.97
LOG dE 3.4033711	TAN BEARING = dE/dN D = dE/SIN BEARING = dN/COS BEARING	
−LOG dN 3.5600226	180° 00′ 00″	SKETCH
LOG TAN BEARING 9.8433485	BEARING 34° 53′ 01″	
LOG dE¹ 3.4033711	AZIMUTH 214° 53′ 01″	
−LOG SIN BEARING¹ 9.7573286		
LOG D 3.6460425	D 4426.32 YARDS METERS	



¹If dE is less than ½dN, enter Log dN instead of Log dE and Log Cos Bearing instead of Log Sin Bearing in these spaces.

DA FORM 1 JUN 51 6-1 EDITION OF 1 MAY 49 MAY BE USED.

Figure 29. Computing azimuth and distance from coordinates using DA AGO Form 6–1.



THREE-POINT RESECTION

DATE: 15 May 1950

SKETCH (Δ ACI)

Angle I	93° 17′ 40″
Angle C (P₁)*	52 10 20
Angle A (P₂)*	34 32 00
Log AC	3.6460425
Colog Sin I	0.0007183
Log Sin P_1*	9.8975489
Log AI	3.5443097
Log Sin BAI	9.4494562
Log AI Sin BAI	2.9937659
(-) Log (AB-AI Cos BAI)	2.9799079
Log Tan ABI	0.0138580
Angle ABI	45° 64′ 50″ 134 05 10
Angle P (P_1)	52° 10′ 20″
Angle A	81 54 50
Angle B	45 54 50
Log AB	3.3812163
Colog Sin P_1	0.1024511
Log Sin B	9.8563028
Log AP	3.3399702

SKETCH (∠ BAI)

Angle P_2*	34° 32′ 00″
Angle BAC ±	18 11 04
Angle BAI	16 20 56

$$\text{Tan ABI} = \frac{\text{AI Sin BAI}}{\text{AB} - \text{AI Cos BAI}}$$

Log AI	3.5443097
Log Cos BAI	9.9820746
Log AI Cos BAI	3.5263843
AB	2405.56
** AI Cos BAI	3360.35
AB-AI Cos BAI	-954.79

SKETCH

Log AB	3.3812163
Colog Sin P_1	0.1024511
Log Sin A	9.9956605
Log BP	3.4793279

SKETCH (Δ ACI)

Angle I	93° 17′ 40″
Angle C (P_1)*	52 10 20
Angle A (P_2)*	34 32 00
Log AC	3.6460425
Colog Sin I	0.0007183
Log Sin P_2*	9.7534954
Log CI	3.4002562
Log Sin BCI	9.7343366
Log CI Sin BCI	3.1345928
(-) Log (BC-CI Cos BCI)	2.1964525
Log Tan CBI	0.9381403
Angle CBI	83° 25′ 21″
Angle P (P_2)	34° 32′ 00″
Angle B	96 34 39
Angle C	48 53 21
Log BC	3.3557776
Colog Sin P_2	0.2465046
Log Sin C	9.8770481
Log BP	3.4793303

SKETCH (∠ BCI)

Angle P_1*	52° 10′ 20″
Angle ACB ±	19 19 25
Angle BCI	32 50 55

$$\text{Tan CBI} = \frac{\text{CI Sin BCI}}{\text{BC} - \text{CI Cos BCI}}$$

Log CI	3.4002562
Log Cos BCI	9.9243344
Log CI Cos BCI	3.3245906
BC	2268.70
** CI Cos BCI	2111.50
BC-CI Cos BCI	+157.20

SKETCH

Log BC	3.3557776
Colog Sin P_2	0.2465046
Log Sin B	9.9971319
Log CP	3.5994141

CASE 1

CASE 2

CASE 3

STATIONS

A	Heyls Hill
B	Sta. Δ 30
C	Welsh Hill
P	Hand Hill

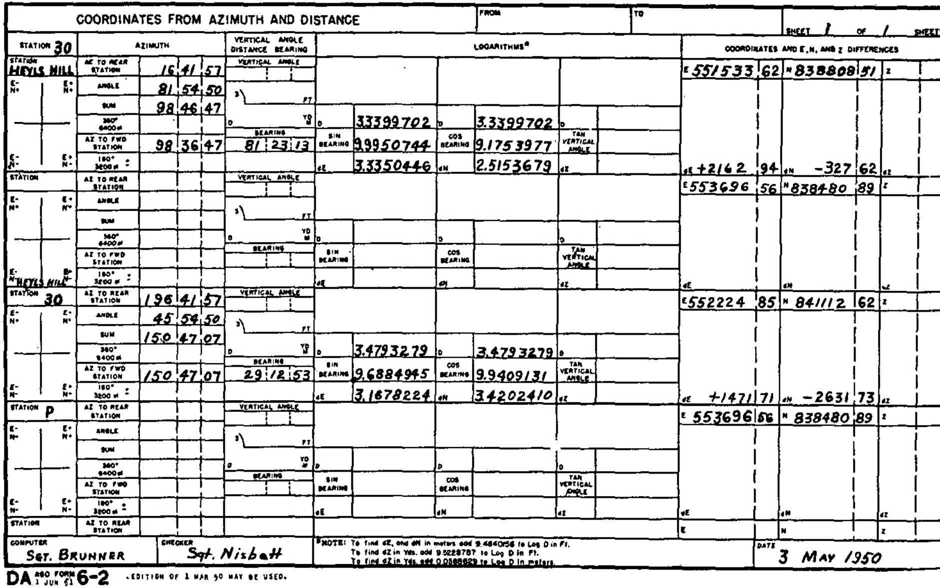
* For Case I substitute (180°-P_1) and (180°-P_2)

** If ∠ BAI is between 0° and 90° use AB - AI Cos BAI
If ∠ BAI is between 90° and 180° use AB + AI Cos BAI
If ∠ BCI is between 0° and 90° use BC - CI Cos BCI
If ∠ BCI is between 90° and 180° use BC + CI Cos BCI

Computer: Nisbett Sgt ½ Checker: Blunner Sgt

DA AGO FORM 1 JUN 51 6-19

Figure 30. Computing the log distance AP, BP, and CP and the unknown angles using the three-point resection form.



COORDINATES FROM AZIMUTH AND DISTANCE — FROM — TO — SHEET 1 OF 1 SHEETS

STATION 30

Station	Azimuth item	Azimuth	Vertical angle / Distance / Bearing	Logarithms			Coordinates and E, N, and Z differences	
HEYLS HILL	AZ TO REAR STATION	16 41 57					E 551533 62	N 838808 51
	ANGLE	81 54 50						
	SUM	98 46 47		D 3.3399702	D 3.3399702	D		
	AZ TO FWD STATION	98 36 47	BEARING 81 23 13	SIN BEARING 9.9950744	COS BEARING 9.1753977	TAN VERTICAL ANGLE		
	180° ±			dE 3.3350446	dN 2.5153679	dZ	dE +2162 94	dN −327 62
							E 553696 56	N 838480 89
HEYLS HILL								
STATION 30	AZ TO REAR STATION	196 41 57					E 552224 85	N 841112 62
	ANGLE	45 54 50						
	SUM	150 47 07		D 3.4793279	D 3.4793279	D		
	AZ TO FWD STATION	150 47 07	BEARING 29 12 53	SIN BEARING 9.6884945	COS BEARING 9.9409131	TAN VERTICAL ANGLE		
	180° ±			dE 3.1678224	dN 3.4202410	dZ	dE +1471 71	dN −2631 73
STATION P	AZ TO REAR STATION						E 553696 56	N 838480 89

COMPUTER: SGT. BRUNNER — CHECKER: Sgt. Nisbett — DATE: 3 MAY 1950

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft. To find dZ in Yds. add 9.5228787 to Log D in Ft. To find dZ in Yds. add 0.0388629 to Log D in meters.

DA AGO FORM 6-2, 1 JUN 51. EDITION OF 1 MAR 50 MAY BE USED.

Figure 31. Computing coordinates using DA AGO Form 6-2.

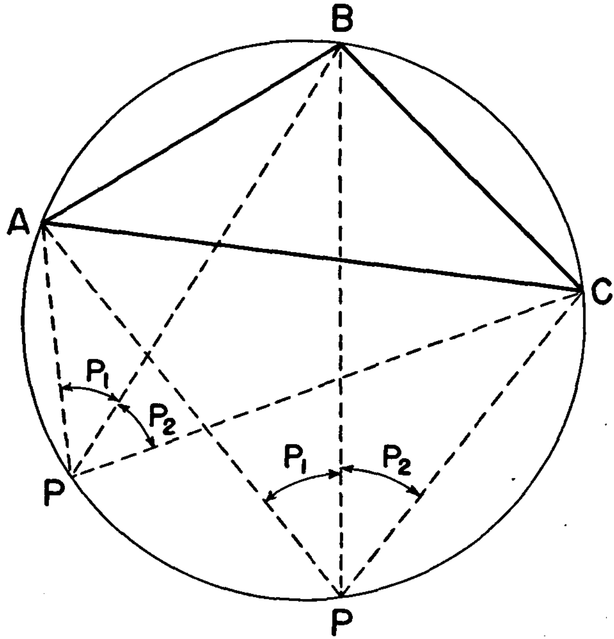


Figure 32. Failure of three-point resection.

repeated for verification before the results are used. Proof can be obtained if a visible fourth point whose coordinates are known is used and if a second computation is made using two of the points involved in the first computations. Also, a verification may be obtained by making an astronomical observation (corrected to grid) on a computed direction. The computer should always be certain that the problem, which is being computed, is not of the indeterminate type and that the unknown point lies sufficiently far from the danger circle to insure accurate results.

88. GENERAL

Two-point resection is a specialized form of triangulation. It is characterized by two known, inaccessible points which are both visible from two unknown accessible points whose location is desired. In figure 33, points *A* and *B* represent the inaccessible points of known coordinates and points *Q* and *P* represent the unknown points. Points *Q* and *P* must be intervisible. After stations *Q* and *P* have been occupied and the angles, represented by the arrows in figure 33, have been measured, the coordinates of points *Q* and *P* can be determined. Two-point resection is of value in cases wherein, after regular triangulation has been completed, additional points are still required for artillery survey. It is used primarily when triangulation stations are inaccessible and only two such stations are available. In observation battalion control survey, the two-point problem is always solved mathematically, although in flash ranging operations it is solved graphically with resulting limited accuracy. When the coordinates of the two known points are of *doubtful reliability* (for example, obtained from captured enemy "trig" lists), the auxiliary base is *taped*. When the coordinates of the two known points are *known* to be *accurate*, the auxiliary base is *assumed*. Assuming the base eliminates the work of taping and the possibility of taping errors.

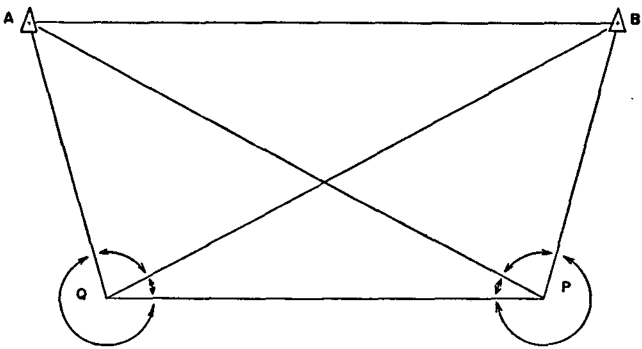


Figure 33. Two-point resection.

89. SOLUTION

a. General Mathematical Solution. In the following solution the auxiliary base (*QP*) was taped (fig. 33). The solution of a problem using an assumed base is identical except that results obtained using the assumed distances must be converted to true distances (*b* (2) below).

(1) *Situation.* Points *A* and *B* (fig. 33) are control points of doubtful accuracy which cannot be occupied. The accuracy of the coordinates of points *A* and *B* should be verified before using them as a basis for the extension of survey control.

(2) *Necessary field work.*

(*a*) Select, by reconnaissance, points *Q* and *P* so that they are intervisible and *A* and *B* can be seen from both points. It is essential that a quadrilateral composed of combinations of strong triangles be used (par. 80).

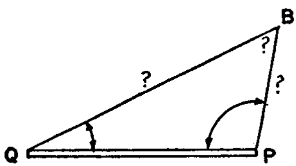
(*b*) Measure the indicated angles at *Q* and *P*, three direct and three reversed; close the horizon; and adjust the angles.

(*c*) Determine the length of the auxiliary base *QP* by taping.

(3) *Outline of computations.*

(*a*) From the coordinates of *A* and *B*, compute the length and azimuth of line *AB*.

(*b*) Solve triangle *BQP* for the sides *BP* and *BQ* using the law of sines (fig. 34).



Known: Angle BQP
Angle QPB
Side QP

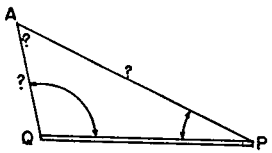
Angle PBQ = 180° - (angle BQP + angle QPB)

$$BQ = \frac{QP \text{ Sin } QPB}{\text{Sin } PBQ}$$

$$BP = \frac{QP \text{ Sin } BQP}{\text{Sin } PBQ}$$

Figure 34. Solving triangle BQP by the law of sines.

(*c*) Solve triangle *AQP* for sides *AQ* and *AP* using the law of sines (fig. 35).



Known: Angle AQP
Angle QPA
Side QP

Angle PAQ = 180° - (Angle AQP + Angle QPA)

$$AQ = \frac{QP \text{ Sin } QPA}{\text{Sin } PAQ}$$

$$AP = \frac{QP \text{ Sin } AQP}{\text{Sin } PAQ}$$

Figure 35. Solving triangle AQP by the law of sines.

(*d*) Solve triangle *ABQ* for angle *QBA* using the short tangent law (fig. 36).

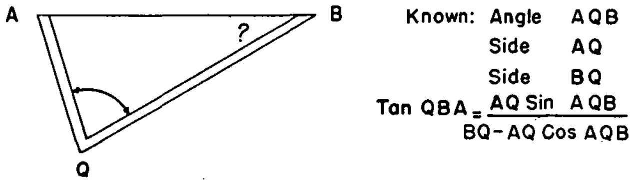


Figure 36. Solving triangle ABQ by the short tangent law.

(*e*) Check the solution by solving triangle *ABP* for angle *BAP* using the short tangent law. All angles in the quadrilateral should total 360°. This provides a check on all computations thus far (fig. 37).

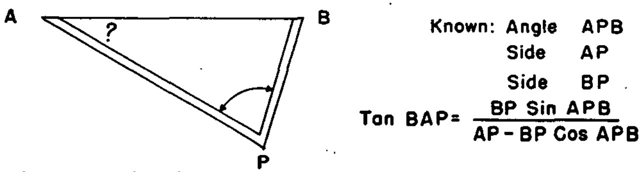
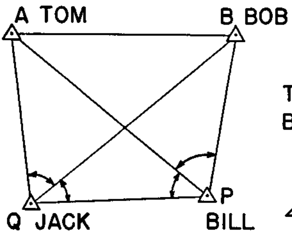


Figure 37. Solving triangle ABP by the short tangent law.

(*f*) Select the strongest triangle *ABP* or *ABQ*, and compute the distance *AB* using the law of sines.

(*g*) Compare the two computed lengths of the line *AB* determined in (*a*) and (*f*) above. If the two lengths disagree, the coordinates of points *A* and *B* are not usable as a basis for extending control. If the two lengths agree and the coordinates of *A* and *B* are urgently needed, their use as a basis for extending control is justifiable. However, the azimuth of the line *AB* should be verified as soon as time permits. This is done by computing the azimuth of the line *QP* from the coordinates of points *A* and *B* and verifying the resulting azimuth



COORDINATES

TOM (A) 550920.00–835360.00
BOB (B) 552448.19–837170.52

MEASURED ANGLES

∡AQB	53° 17' 20"
∡BQP	42° 39' 45"
∡QPA	45° 07' 13"
∡APB	60° 19' 27"

VERTICAL CONTROL OMITTED

TAPED DISTANCE P to Q = 5315.06 FEET

Figure 38. Initial data for a two-point resection problem using a taped base.

of *QP* by an astronomical observation.

(*h*) Solve for the coordinates of *Q* and *P* using DA AGO Form 6–2.

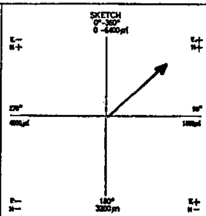
b. Examples of the Two Methods of Solving a Two-Point Resection Problem.

(1) *Taped base.*

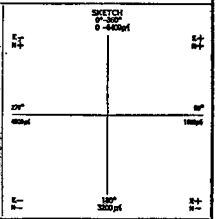
(*a*) *Initial data.* The sketch, the coordinates of two control points of doubtful reliability, the measured angles, and the taped length of the base are shown in figure 38.

AZIMUTH AND DISTANCE FROM COORDINATES

STATIONS	E	N
FROM Tom (A)	(−) 550920.00	(−) 835360.00
TO Bob (B)	(+) 552448.19	(+) 837170.52
	dE +1528.19	dN +1810.52
LOG dE 3.1841774	TAN BEARING $= \frac{dE}{dN}$ D $= \frac{dE}{\text{SIN BEARING}} = \frac{dN}{\text{COS BEARING}}$	
−LOG dN 3.2578033		SKETCH
LOG TAN BEARING 9.9263741	BEARING 40° 09′ 59″	
LOG dE¹ 3.1841774	AZIMUTH 40° 09′ 59″	
−LOG SIN BEARING¹ 9.8095661		
LOG D 3.3746113	D YARDS METERS	



STATIONS	E	N
FROM	(−)	(−)
TO	(+)	(+)
	dE	dN
LOG dE	TAN BEARING $= \frac{dE}{dN}$ D $= \frac{dE}{\text{SIN BEARING}} = \frac{dN}{\text{COS BEARING}}$	
−LOG dN		SKETCH
LOG TAN BEARING	BEARING	
LOG dE¹	AZIMUTH	
−LOG SIN BEARING¹		
LOG D	D YARDS METERS	



¹ If dE is less than ½dN, enter Log dN instead of Log dE and Log Cos Bearing instead of Log Sin Bearing in these spaces.

DA AGO FORM 1 JUN 51 6-1 EDITION OF 1 MAY 49 MAY BE USED.

Figure 39. Computing azimuth and distance from coordinates using DA AGO Form 6–1.

(*b*) *Solution.*

1. The computations necessary to determine azimuth and distance from coordinates using DA AGO Form

6–1 are shown in figure 39.

2. The computations necessary to determine the azimuths and distances from the points *A* and *B* to the ends of the taped base using the two-point resection form are shown in figure 40.

3. The computations necessary to determine coordinates from azimuths and distances using DA AGO Form 6–2 are shown in figure 41.

(2) *Assumed base.*

(*a*) *Initial data.* The sketch, the coordinates of two *known* points, the measured angles, and the assumed lengths (usually 1,000 meters for ease of computation) of the base are shown in figure 42.

(*b*) *Solution.*

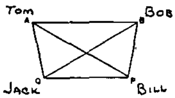
1. The computations necessary to determine azimuth and distance from coordinates using DA AGO Form 6–1 are shown in figure 43.

2. The computations necessary to determine the azimuths and distances from the points of known coordinates (*A* and *B*) to the ends of the assumed base using the two-point resection form are shown in figure 44.

3. The computations necessary to determine coordinates from azimuths and distances using DA AGO Form 6–2 are shown in figure 45.

948797°—51—9

TWO-POINT RESECTION



TRIANGLE BPQ Bob - Bill - Jack — SKETCH

Bob B	31	53	35
Bill P	105	26	40
Jack Q	42	39	45

Log QP	3.2093640	Log QP	3.2093640
Colog Sin PBQ	0.2770902	Colog Sin PBQ	0.2770902
Log Sin QPB	9.9840271	Log Sin BQP	9.8310237
Log BQ	3.4704813	Log BP	3.3174779
Sta. B Bob	Q Jack	Sta. B Bob	P Bill

CONVERTING QP TO MAP DISTANCE

Log QP (ft)(m)	3.7255082
Log Conv. Factor (m)	9.4840158
Log Scale Factor	9.9998400
Log QP (m)	3.2093640

TRIANGLE APQ Tom - Bill - Jack — SKETCH

Tom A	38	55	42
Bill P	45	07	13
Jack Q	95	57	05

Log QP	3.2093640	Log QP	3.2093640
Colog Sin PAQ	0.2017999	Colog Sin PAQ	0.2017999
Log Sin QPA	9.8503948	Log Sin AQP	9.9976529
Log AQ	3.2615587	Log AP	3.4088168
Sta. A Tom	Q Jack	Sta. A Tom	P Bill

360° CHECK

49°	37'	04"
38	09	54
31	53	35
60	19	27
45	07	13
42	39	45
53	17	20
38	55	42
360	00	00

ANGLE AQB 53° 17' 20" **TRIANGLE ABQ** Tom A B Bob Q Jack — SKETCH

$$\text{Tan } QBA = \frac{AQ \text{ Sin } AQB}{BQ - AQ \text{ Cos } AQB}$$

Log AQ	3.2615587	Log AQ	3.2615587
Log Sin AQB	9.9039901	Log Cos AQB	9.7765418
Log AQ Sin AQB	3.1655488	Log AQ Cos AQB	3.0381005
-Log(BQ-AQ Cos AQB)	3.2701639	BQ	2954.48
Log Tan QBA	9.8953849	-AQ Cos AQB	1091.69
Angle QBA	38° 09' 54"	BQ-AQ Cos AQB	1862.79

ANGLE APB 60° 19' 27" **TRIANGLE ABP** Tom A B Bob P Bill — SKETCH

$$\text{Tan } BAP = \frac{BP \text{ Sin } APB}{AP - BP \text{ Cos } APB}$$

Log BP	3.3174779	Log BP	3.3174779
Log Sin APB	9.9389400	Log Cos APB	9.6946861
Log BP Sin APB	3.2564179	Log BP Cos APB	3.0121640
-Log(AP-BP Cos APB)	3.1861084	AP	2563.40
Log Tan BAP	0.0703095	-BP Cos APB	1028.40
Angle BAP	49° 37' 04"	AP-BP Cos APB	1535.00

TRIANGLE AB(P)(Q)* Tom - Bob - Bill — SKETCH Tom A B Bob P Bill

Tom A	49	37	04
Bob B	70	03	29
Bill (P)(~~Q~~)	60	19	27

Log (BP)(~~BQ~~)	3.3174779	Log (AP)(~~AQ~~)	3.4088168
Colog Sin A	0.1181936	Colog Sin B	0.0269543
Log Sin (P)(~~Q~~)	9.9389400	Log Sin (P)(~~Q~~)	9.9389400
Log AB	3.3746115 CHECK	Log AB	3.3746111 [illegible]
Sta. A Tom	B Bob	Sta. A Tom	B Bob

Log True AB	
- Log Assumed AB**	
Log K	
Log Assumed QP	
+ Log K	
Log True QP	
Log Assumed AQ	
+ Log K	
Log True AQ	
Log Assumed BP	
+ Log K	
Log True BP	
Log Assumed (AP)(BQ)***	
+ Log K	
Log True (AP)(BQ)	

* USE STRONGEST TRIANGLE

** USE LOG DISTANCE OBTAINED FROM ANGLE (A OR B) NEAREST 90°

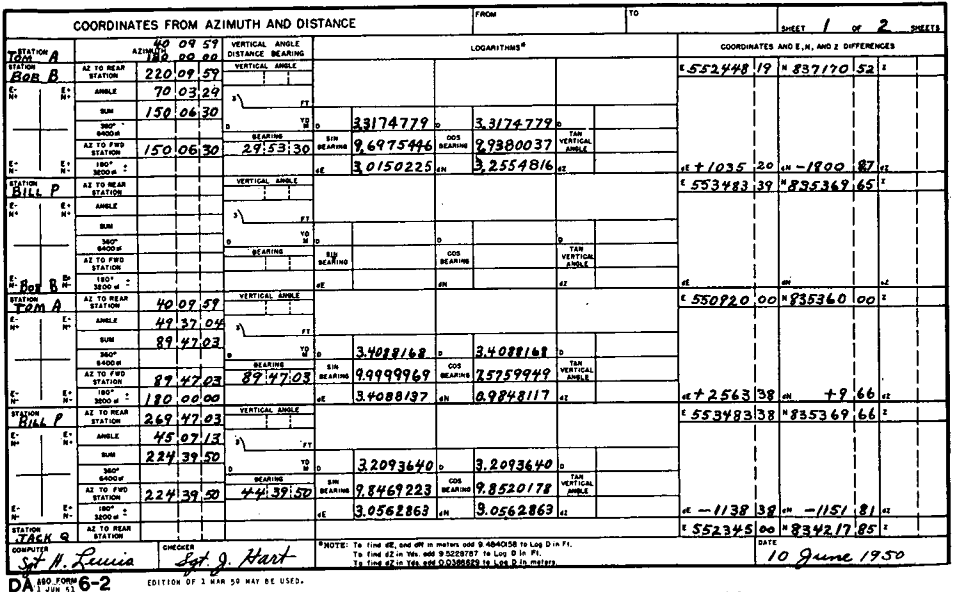
*** USE SHORTEST DIAGONAL

COMPUTER:	CHECKER:	DATE:
Sgt. H. Lewis	Sgt. J. Hart	10 July 1950

DA AGO FORM 1 JUN 51 6-18

Army-Ft. Sill, Okla.

Figure 40. Computing the azimuths and distances using the two-point resection form.



COORDINATES FROM AZIMUTH AND DISTANCE — FROM — TO — SHEET 1 OF 2 SHEETS

Station	Item	Azimuth	Vertical angle / Distance / Bearing	Logarithms*		Coordinates and E, N, and Z differences	
Tom A		40 09 59 / 180 00 00					
Bob B	AZ TO REAR STATION	220 09 59				E 552448.19	N 837170.52
	ANGLE	70 03 29					
	SUM	150 06 30		D 3.3174779	D 3.3174779		
	AZ TO FWD STATION	150 06 30	BEARING 29 53 30	SIN BEARING 9.6975446	COS BEARING 9.9380037		
	180° ±			dE 3.0150225	dN 3.2554816	dE +1035.20	dN −1900.87
Bill P	AZ TO REAR STATION					E 553483.39	N 835369.65
Bob B	180° ±						
Tom A	AZ TO REAR STATION	40 09 59				E 550920.00	N 835360.00
	ANGLE	49 37 04					
	SUM	89 47 03		D 3.4088168	D 3.4088168		
	AZ TO FWD STATION	89 47 03	BEARING 89 47 03	SIN BEARING 9.9999969	COS BEARING 7.5759949		
	180° ±	180 00 00		dE 3.4088137	dN 0.9848117	dE +2563.38	dN +9.66
Bill P	AZ TO REAR STATION	269 47 03				E 553483.38	N 835369.66
	ANGLE	45 07 13					
	SUM	224 39 50		D 3.2093640	D 3.2093640		
	AZ TO FWD STATION	224 39 50	BEARING 44 39 50	SIN BEARING 9.8469223	COS BEARING 9.8520178		
	180° ±			dE 3.0562863	dN 3.0562863	dE −1138.38	dN −1151.81
Jack Q	AZ TO REAR STATION					E 552345.00	N 834217.85

COMPUTER Sgt H. Lucia — CHECKER Sgt J. Hart — DATE 10 June 1950

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft. To find dZ in Yds. add 9.5228787 to Log D in Ft. To find dZ in Yds. add 0.0388629 to Log D in meters.

DA AGO FORM 1 JUN 51 6-2 — EDITION OF 1 MAR 50 MAY BE USED.

Figure 41. Computing coordinates using DA AGO Form 6–2.

COORDINATES FROM AZIMUTH AND DISTANCE

FROM | TO | SHEET 2 OF 2 SHEETS

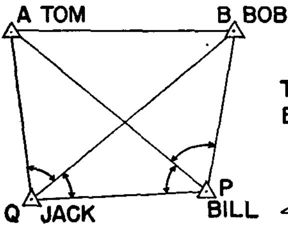
STATION		AZIMUTH			VERTICAL ANGLE / DISTANCE / BEARING	LOGARITHMS*			COORDINATES AND E, N, AND Z DIFFERENCES		
STATION Bob B											
STATION Tom A	AZ TO REAR STATION	40	09	57	VERTICAL ANGLE				E 550920.00	N 835360.00	Z
E- N+ / E+ N+	ANGLE	88	32	46	S FT						
	SUM	128	42	45							
	360° 6400 mil				D YD M	D 3.2615587	D 3.2615587	D			
	AZ TO FWD STATION	128	42	45	BEARING 51 17 15	SIN BEARING 9.8922582	COS BEARING 9.7961668	TAN VERTICAL ANGLE			
E- N- / E+ N-	180° 3200 mil ±					dE 3.1538169	dN 3.0577255	dZ	dE +1425.01	dN −1142.16	dZ
STATION Jack Q	AZ TO REAR STATION				VERTICAL ANGLE				E 552345.01	N 834217.84	Z
E- N+ / E+ N+	ANGLE				S FT						
	SUM										
	360° 6400 mil				D YD M	D	D	D			
	AZ TO FWD STATION				BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE			
E- N- / E+ N-	180° 3200 mil ±					dE	dN	dZ	dE	dN	dZ
STATION	AZ TO REAR STATION				VERTICAL ANGLE				E	N	Z
E- N+ / E+ N+	ANGLE				S FT						
	SUM										
	360° 6400 mil				D YD M	D	D	D			
	AZ TO FWD STATION				BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE			
E- N- / E+ N-	180° 3200 mil ±					dE	dN	dZ	dE	dN	dZ
STATION	AZ TO REAR STATION				VERTICAL ANGLE				E	N	Z
E- N+ / E+ N+	ANGLE				S FT						
	SUM										
	360° 6400 mil				D YD M	D	D	D			
	AZ TO FWD STATION				BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE			
E- N- / E+ N-	180° 3200 mil ±					dE	dN	dZ	dE	dN	dZ
STATION	AZ TO REAR STATION								E	N	Z

COMPUTER Sgt. H. Lewis | CHECKER Sgt. J. Hart | DATE 10 June 1950

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft.
To find dZ in Yds. add 9.5228787 to Log D in Ft.
To find dZ in Yds. add 0.03[illegible] to Log D in meters.

DA AGO FORM 6-2, 1 JUN 53 — EDITION OF 1 MAR 50 MAY BE USED.

Figure 41—Continued.



KNOWN COORDINATES

TOM (A) 550920.00 - 835360.00
BOB (B) 552448.19 - 837170.52

MEASURED ANGLES

∡ AQB	53°	17'	20"
∡ BQP	42°	39'	45"
∡ QPA	45°	07'	13"
∡ APB	60°	19'	27"

VERTICAL CONTROL OMITTED

ASSUMED DISTANCE = 1000 METERS MAP DISTANCE (INCLUDES SCALE FACTOR)

Figure 42. Initial data for a two-point resection problem using an assumed base.

Section VIII. VERTICAL CONTROL

90. GENERAL

a. Purpose. Elevations of points are determined in the artillery primarily for use in computing firing data. In order to accomplish this, the observation battalion normally carries elevation above sea level or an assumed datum plane to the division artillery survey control points, to the survey control points for corps artillery battalions, to the flash observation posts, and to the radar positions by trigonometric leveling. This vertical control is then extended into the target area.

b. Accuracy. The survey parties of a field artil-

AZIMUTH AND DISTANCE FROM COORDINATES

STATIONS	E	N
FROM Tom (A)	(−) 550920.00	(−) 835360.00
TO Bob (B)	(+) 552448.19	(+) 837170.52
	dE + 1528.19	dN + 1810.52
LOG dE 3.1841774	TAN BEARING = $\frac{dE}{dN}$ D = $\frac{dE}{\text{SIN BEARING}}$ = $\frac{dN}{\text{COS BEARING}}$	
−LOG dN 3.2578033		SKETCH 0°-360° 0-6400 mil; E− N+; E+ N+
LOG TAN BEARING 9.9263741	BEARING 40° 09′ 59″	
LOG dE¹ 3.1841774	AZIMUTH 40° 09′ 59″	270° 4800 mil; 90° 1600 mil
−LOG SIN BEARING¹ 9.8095661		
LOG D 3.3746113	D YARDS METERS	E− N−; 180° 3200 mil; E+ N−

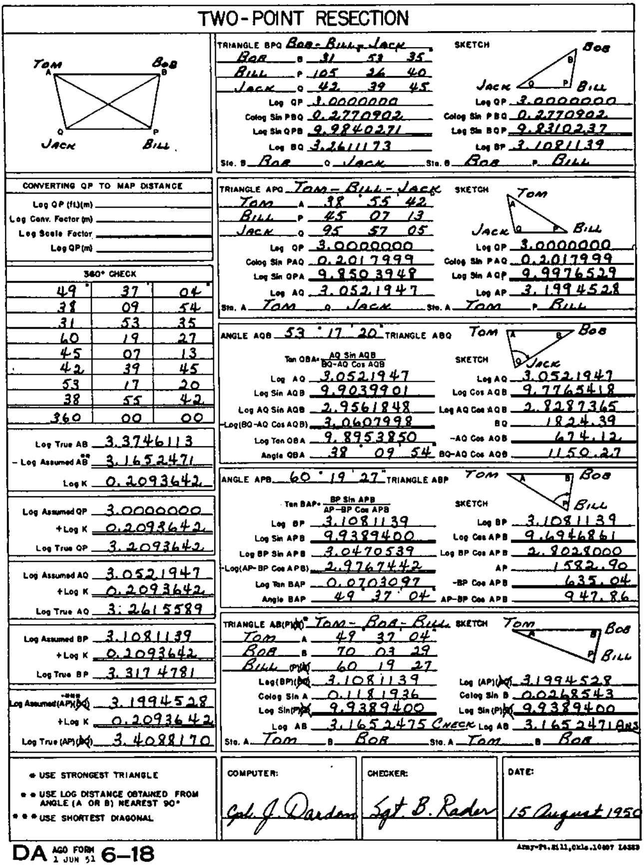
STATIONS	E	N
FROM	(−)	(−)
TO	(+)	(+)
	dE	dN
LOG dE	TAN BEARING = $\frac{dE}{dN}$ D = $\frac{dE}{\text{SIN BEARING}}$ = $\frac{dN}{\text{COS BEARING}}$	
−LOG dN		SKETCH 0°-360° 0-6400 mil; E− N+; E+ N+
LOG TAN BEARING	BEARING	
LOG dE¹	AZIMUTH	270° 4800 mil; 90° 1600 mil
−LOG SIN BEARING¹		
LOG D	D YARDS METERS	E− N−; 180° 3200 mil; E+ N−

¹If dE is less than ½dN, enter Log dN instead of Log dE and Log Cos Bearing instead of Log Sin Bearing in these spaces.

DA AGO FORM 1 JUN 51 6-1 EDITION OF 1 MAY 49 MAY BE USED. Army-Ft.Sill,Okla.12490 L4639

Figure 43. Computing azimuth and distance from coordinates using DA AGO Form 6-1.

lery observation battalion extend vertical control using methods that are precise enough to insure that the vertical coordinate is accurate to 1 yard.



TWO-POINT RESECTION

Tom A, Bob B, Jack Q, Bill P

TRIANGLE BPQ Bob - Bill - Jack SKETCH

Bob B	31	53	35
Bill P	105	26	40
Jack Q	42	39	45

Log QP 3.0000000 — Log QP 3.0000000
Colog Sin PBQ 0.2770902 — Colog Sin PBQ 0.2770902
Log Sin QPB 9.9840271 — Log Sin BQP 9.8310237
Log BQ 3.2611173 — Log BP 3.1081139
Sta. B Bob Q Jack — Sta. B Bob P Bill

TRIANGLE APQ Tom - Bill - Jack SKETCH

Tom A	38	55	42
Bill P	45	07	13
Jack Q	95	57	05

Log QP 3.0000000 — Log QP 3.0000000
Colog Sin PAQ 0.2017999 — Colog Sin PAQ 0.2017999
Log Sin QPA 9.8503948 — Log Sin AQP 9.9976529
Log AQ 3.0521947 — Log AP 3.1994528
Sta. A Tom Q Jack — Sta. A Tom P Bill

CONVERTING QP TO MAP DISTANCE
Log QP (ft)(m) ____
Log Conv. Factor (m) ____
Log Scale Factor ____
Log QP (m) ____

360° CHECK

49	37	04
38	09	54
31	53	35
60	19	27
45	07	13
42	39	45
53	17	20
38	55	42
360	00	00

ANGLE AQB 53° 17' 20" TRIANGLE ABQ SKETCH

Tan QBA = AQ Sin AQB / (BQ - AQ Cos AQB)

Log AQ 3.0521947 — Log AQ 3.0521947
Log Sin AQB 9.9039901 — Log Cos AQB 9.7765418
Log AQ Sin AQB 2.9561848 — Log AQ Cos AQB 2.8287365
-Log (BQ-AQ Cos AQB) 3.0607998 — BQ 1824.39
Log Tan QBA 9.8953850 — -AQ Cos AQB 674.12
Angle QBA 38° 09' 54" — BQ-AQ Cos AQB 1150.27

Log True AB 3.3746113
- Log Assumed AB** 3.1652471
Log K 0.2093642

ANGLE APB 60° 19' 27" TRIANGLE ABP SKETCH

Tan BAP = BP Sin APB / (AP - BP Cos APB)

Log BP 3.1081139 — Log BP 3.1081139
Log Sin APB 9.9389400 — Log Cos APB 9.6946861
Log BP Sin APB 3.0470539 — Log BP Cos APB 2.8028000
-Log (AP-BP Cos APB) 2.9767442 — AP 1582.90
Log Tan BAP 0.0703097 — -BP Cos APB 635.04
Angle BAP 49° 37' 04" — AP-BP Cos APB 947.86

Log Assumed QP 3.0000000
+Log K 0.2093642
Log True QP 3.2093642

Log Assumed AQ 3.0521947
+Log K 0.2093642
Log True AQ 3.2615589

TRIANGLE AB(P)(Q)* Tom - Bob - Bill SKETCH

Tom A	49	37	04
Bob B	70	03	29
Bill (P)(Q)	60	19	27

Log (BP)(BQ) 3.1081139 — Log (AP)(AQ) 3.1994528
Colog Sin A 0.1181936 — Colog Sin B 0.0268543
Log Sin (P)(Q) 9.9389400 — Log Sin (P)(Q) 9.9389400
Log AB 3.1652475 Check — Log AB 3.1652471 Ans
Sta. A Tom B Bob — Sta. A Tom B Bob

Log Assumed BP 3.1081139
+Log K 0.2093642
Log True BP 3.3174781

Log Assumed (AP)(BQ)*** 3.1994528
+Log K 0.2093642
Log True (AP)(BQ) 3.4088170

* USE STRONGEST TRIANGLE
** USE LOG DISTANCE OBTAINED FROM ANGLE (A OR B) NEAREST 90°
*** USE SHORTEST DIAGONAL

COMPUTER: Cpl. J. Dardon — CHECKER: Sgt B. Rader — DATE: 15 August 1950

DA AGO FORM 1 JUN 51 6–18

Army-Ft. Sill, Okla.

Figure 44. Computing the azimuths and distances using the two-point resection form.

It is desirable to have all corps artillery on common vertical control datum, either true or assumed, as soon as possible.

COORDINATES FROM AZIMUTH AND DISTANCE FROM TO SHEET 1 OF 2 SHEETS

STATION		AZIMUTH			VERTICAL ANGLE / DISTANCE / BEARING	LOGARITHMS*						COORDINATES AND E, N, AND Z DIFFERENCES		
Tom A		40 / 180	09 / 00	59 / 00										
STATION Bob B	AZ TO REAR STATION	220	09	59	VERTICAL ANGLE							E 552448.19	N 837170.52	Z
E- N+ / E+ N+	ANGLE	70	03	29										
	DIFF	150	06	30	S FT									
	360° 6400 mil				D YD M	D	3.3174781	D	3.3174781	D				
	AZ TO FWD STATION	150	06	30	BEARING 29 53 30	SIN BEARING	9.6975446	COS BEARING	9.9380037	TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±					dE	3.0150227	dN	3.2554818	dZ		dE +1035.20	dN −1800.87	dZ
STATION Bill P	AZ TO REAR STATION				VERTICAL ANGLE							E 553483.39	N 835369.65	Z
E- N+ / E+ N+	ANGLE													
	SUM				S FT									
	360° 6400 mil				D YD M	D		D		D				
	AZ TO FWD STATION				BEARING	SIN BEARING		COS BEARING		TAN VERTICAL ANGLE				
E- N- Bob B E+ N-	180° 3200 mil ±					dE		dN		dZ		dE	dN	dZ
STATION Tom A	AZ TO REAR STATION	40	09	59	VERTICAL ANGLE							E 550920.00	N 835360.00	Z
E- N+ / E+ N+	ANGLE	49	37	04										
	SUM	89	47	03	S FT									
	360° 6400 mil				D YD M	D	3.4088170	D	3.4088170	D				
	AZ TO FWD STATION	89	47	03	BEARING 89 47 03	SIN BEARING	9.9999969	COS BEARING	7.5759949	TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±	180	00	00		dE	3.4088139	dN	0.9848119	dZ		dE +2563.39	dN +9.66	dZ
STATION	AZ TO REAR STATION	269	47	03	VERTICAL ANGLE							E 553483.39	N 835369.'6	Z
E- N+ / E+ N+	ANGLE	45	07	13										
	DIFF	224	39	50	S FT									
	360° 6400 mil				D YD M	D	3.2093642	D	3.2093642	D				
	AZ TO FWD STATION	224	39	50	BEARING 44 39 50	SIN BEARING	9.8469223	COS BEARING	9.8520178	TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±					dE	3.0562865	dN	3.0613820	dZ		dE −1138.38	dN −1151.81	dZ
STATION	AZ TO REAR STATION											E 552345.01	N 834217.85	Z

COMPUTER Cpl. J. Darden — CHECKER Sgt. Rader — DATE 15 June 1950

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft.
To find dZ in Yds. add 9.5228787 to Log D in Ft.
To find dZ in Yds. add 0.0388629 to Log D in meters.

DA AGO FORM 6-2, 1 JUN 51 — EDITION OF 1 MAR 50 MAY BE USED.

Figure 45. Computing coordinates using DA AGO Form 6-2.

COORDINATES FROM AZIMUTH AND DISTANCE

FROM | TO | SHEET 2 OF 2 SHEETS

STATION	AZIMUTH		VERTICAL ANGLE / DISTANCE / BEARING	LOGARITHMS*			COORDINATES AND E, N, AND Z DIFFERENCES		
STATION Bob B									
STATION Tom A	AZ TO REAR STATION	40 09 57	VERTICAL ANGLE				E 550920 00	N 835360 00	Z
E- N+ / E+ N+	ANGLE	88 32 46	S FT						
	SUM	128 42 45	D YD M	D 3.2615589	D 3.2615589	D			
	360° 6400 mil		BEARING	SIN BEARING 9.8922582	COS BEARING 9.7961668	TAN VERTICAL ANGLE			
	AZ TO FWD STATION	128 42 45	51 17 15						
E- N- / E+ N-	180° 3200 mil ±			dE 3.1538171	dN 3.0577257	dZ	dE +1425 01	dN −1142 16	dZ
STATION Jack Q	AZ TO REAR STATION		VERTICAL ANGLE				E 552345 09	N 834217 84	Z
E- N+ / E+ N+	ANGLE		S FT						
	SUM		D YD M	D	D	D			
	360° 6400 mil		BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE			
	AZ TO FWD STATION								
E- N- / E+ N-	180° 3200 mil ±			dE	dN	dZ	dE	dN	dZ
STATION	AZ TO REAR STATION		VERTICAL ANGLE				E	N	Z
E- N+ / E+ N+	ANGLE		S FT						
	SUM		D YD M	D	D	D			
	360° 6400 mil		BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE			
	AZ TO FWD STATION								
E- N- / E+ N-	180° 3200 mil ±			dE	dN	dZ	dE	dN	dZ
STATION	AZ TO REAR STATION		VERTICAL ANGLE				E	N	Z
E- N+ / E+ N+	ANGLE		S FT						
	SUM		D YD M	D	D	D			
	360° 6400 mil		BEARING	SIN BEARING	COS BEARING	TAN VERTICAL ANGLE			
	AZ TO FWD STATION								
E- N- / E+ N-	180° 3200 mil ±			dE	dN	dZ	dE	dN	dZ
STATION	AZ TO REAR STATION						E	N	Z

COMPUTER Cpl. J. Darden | CHECKER Sgt. Rader | DATE 15 June 1950

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft.
To find dZ in Yds. add 9.5228787 to Log D in Ft.
To find dZ in Yds. add 0.0388629 to Log D in meters.

DA AGO FORM 6-2, 1 JUN 52. EDITION OF 1 MAR 50 MAY BE USED.

Figure 45—Continued.

a. Trigonometric Leveling.

(1) *Procedure.* The angle of site may be measured either with the transit or with one of the flash-observing instruments. The distance is obtained by any survey method or is scaled from a map and the difference of elevation obtained by solving the vertical triangle. For the best results, simultaneous, reciprocal observations should be made. These will cancel out the effects of curvature and refraction. If the vertical angle is measured in only one direction, a correction must be applied for curvature and refraction for a more accurate determination of the elevation. This correction may be neglected when the range is less than 2,000 yards. Curvature and refraction correction tables are given in appendix V. When the transit is used vertical angles must be measured at least once with the telescope direct and once with the telescope reversed.

(2) *Computation (fig. 46).*

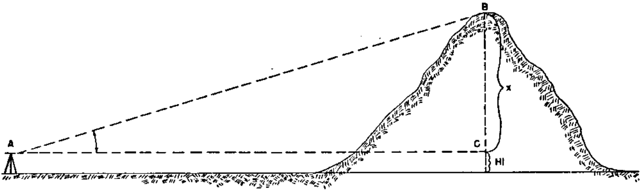


Figure 46. Trigonometric leveling.

(*a*) X = horizontal distance x tangent BAC.

(*b*) $X + HI$ = difference in elevation between A and B.

(*c*) In the example shown below, the vertical angle is measured in only one direction; the readings are recorded as follows:

Direct	=	$+1°$	$08'$
Reverse	=	$+1°$	$06'$
Mean	=	$+1°$	$07'$

(*d*) Horizontal distance = 5026 yards.

(*e*) Altitude of A = 576 feet.

(*f*) Height of instrument (HI) = 5 feet.

(*g*) Difference in altitude (X) = 5026 x tan $1° 07'$

$$\text{Log } 5026 = 3.7012225$$
$$\text{Log tan } 1° 07' = 8.2898559$$
$$\text{Log } 5026 \times \tan 1° 7' = 1.9910784 = 97.97 \text{ yds.} = 294 \text{ ft.}$$

(*h*)

Altitude of A	=	576 feet
Difference in altitude	=	+294 feet
Height of instrument	=	+ 5 feet
Curvature and refraction correction (app. V)	=	+ 5 feet
Altitude of B	=	880 feet

b. Surveying Altimeter. Since atmospheric pressure and elevation above sea level are closely related, the altimeter is used to determine the difference of elevation between two points which are not over 6 to 8 miles apart. Figure 47 shows DA AGO Form 6–9 which is used to record the data taken and compute the altitudes.

LEVELING WITH ALTIMETERS—FIELD OBSERVATIONS AND COMPUTATIONS

Instrument No. 6-44 Weather Clear Cool Observer G. R. Jones Recorder G. R. Jones Date 10 Feb 50

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Field Station Data				Mean Temp.	Index Diff. ±	Field Alt. Indexed (3+6)	Base Sta. Altimeter Reading	Indicated Diff. (7−8) ±	Temp. Corr. ±	Diff. Corrected (9+10) ±	Unadj. Altitude	Clos. Adj. ±	Adjusted Altitude	Known Altitude
Station	Time	Altimeter Reading	Temp.											
BM 850	0530	2100	35	35	+20	2120	2120	0	0	0	—	—	—	850R
Sta. A	0640	3606	32	34	+20	3626	2124	+1502	-48	+1454	2304	-2	2302	—
Sta. B	0740	2172	49	50	+20	2192	2130	+62	±0	+62	912	-3	909	—
Sta. C	0930	2304	54	55	+20	2324	2132	+192	+2	+194	1044	-6	1038	—
Sta. D	1040	2180	63	64	+20	2200	2140	+60	+2	+62	912	-8	904	—
BM 850	1100	2133	65	65	+20	2153	2145	+8	—	+8	858	-8	850	850

Computed by G. R. Jones Checked by G. H. Wenzel Date 10 Feb 50

DA AGO FORM 1 JUN 51 6–9 REPLACES FAS FORM 9, 12 JUN 44 WHICH MAY BE USED.

Figure 47. Example of recording and computing for leveling with the altimeter using DA AGO Form 6–9.

Section IX. ASTRONOMIC OBSERVATIONS

92. GENERAL

a. Purpose. The observation battalion employs astronomic observations to determine direction (azimuth) upon the ground. The artillery has four principal uses for azimuths obtained by astronomic means:

(1) To obtain a starting azimuth when no line of direction is known or when no established and intervisible points exist.

(2) To check the azimuth of a traverse leg which has been brought forward through a succession of traverse stations.

(3) To establish declination stations.

(4) To determine the direction of the orienting lines of individual artillery firing units.

b. Methods. The two standard methods used are the *altitude method* and the *hour angle method.* The hour angle method generally produces the best results; however, the choice of method is dependent upon existing conditions. Most important of these conditions is the position of a selected celestial body at the time of observation. The altitude method requires the celestial body to be between 20° and 45° in altitude and at least 2 hours from the observer's meridian. When the hour angle method is used, the heavenly body should be near the observer's prime vertical, or in the case of circumpolar stars, near elongation (TM 5–235).

93. BASIC ASTRONOMIC CONCEPTS

a. Definitions.

(1) Refer to figure 48 for illustration of the following definitions.

(*a*) *Celestial sphere.* An imaginary sphere of infinite radius with its center at the center of the earth and upon which all celestial bodies appear to be fixed.

(*b*) *Celestial equator.* The great circle on the celestial sphere cut by a plane through the center of the earth perpendicular to the earth's axis.

(*c*) *North and south celestial poles* (*N* and *S*). Points where the prolonged polar axis of the earth intersects the celes-

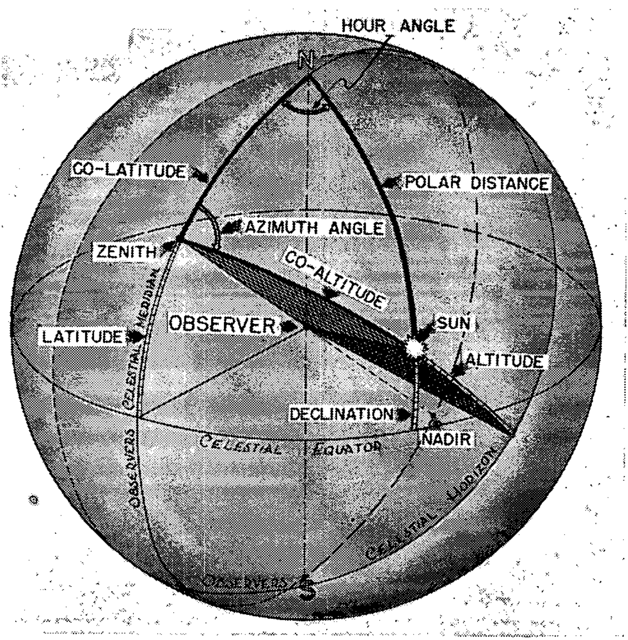


Figure 48. The celestial sphere showing the celestial triangle (North celestial pole-Zenith-Sun) outlined with a heavy black line.

tial sphere.

(*d*) *Observer's celestial horizon.* A great circle cut on the celestial sphere by a plane perpendicular to the plumb line at the observer's position.

(*e*) *Zenith and Nadir.* The points where the prolonged plumb line intersects the celestial sphere directly overhead and underneath.

(*f*) *Celestial meridian.* The great circle on the celestial sphere which passes through the celestial poles and the observer's zenith.

(*g*) *Latitude.* The angular distance on the earth's surface measured from 0° to 90°, north or south of the equator. It is also the angular distance on the celestial sphere measured north or south from the celestial equator to the observer's zenith.

(*h*) *Declination.* The angular distance from the celestial equator to a celestial body, measured along the hour circle through the body. Declination is positive when a body is north of the celestial equator and negative when it is south.

(*i*) *Altitude* (*h*). The observed vertical angle at the observer's station between the horizon and a celestial body corrected for refraction and also for parallax when the sun or planets are used.

(*j*) *Hour angle.* The angle between the plane of the observer's meridian and the hour circle through a celestial body.

(2) The following definitions are pertinent but are not illustrated.

(*a*) *Prime vertical.* The great circle passing through the zenith and nadir and perpendicular to the observer's meridian. It intersects the horizon at points directly east and west.

(*b*) *Hour circle.* Any great circle through the celestial poles.

(*c*) *Refraction.* The apparent displacement of a celestial body due to the downward bending of the rays of light passing through the earth's atmosphere.

(*d*) *Parallax.* The difference in direction of a celestial body as seen from the center of the earth and from a station on the earth's surface.

b. The Celestial Triangle. Figure 48 illustrates the celestial triangle (North celestial pole – Zenith – Sun) which must be solved to determine the azimuth of a celestial body.

94. PROCEDURE

a. Identification. To obtain an astronomic azimuth, it is necessary to identify the heavenly body on which the observations are made. This can be done by the use of star charts or the use of a star finder which is entered with certain observed data after the observing is completed. There are a number of star charts which can be used. The star finder and identifier, which is available through the United States Navy Hydrographic Office, is an excellent mechanical device for identifying the stars.

b. Observing.

(1) *Altitude method.* The field work consists essentially of measuring the vertical angle of the celestial body, the horizontal angle from a terrestrial mark to

the heavenly body, and determining the time of observation. Angles are measured to celestial bodies in the same manner as to points on the earth except in the case of the sun which requires a special technique. Unlike other celestial bodies, except the moon, which appear as pin points of light, the sun appears as a disc in the sky with an angular diameter of approximately 32 minutes. All measurements must be made to the sun's center so readings are taken to the right and left and upper and lower edges of the sun, and the mean is determined to the center both horizontally and vertically. The time is recorded and averaged to determine the corresponding time for the mean horizontal and vertical angles. The air temperature is taken and recorded. The observer's latitude, longitude, time zone, and watch correction must be known. The latitude and longitude can be scaled from a map of a scale no smaller than 1/50,000. For greater accuracy and a check, three sets of observations should be taken.

(2) *Hour angle method.* Field work consists of measuring the horizontal angle from a terrestrial mark to the celestial body and determining the exact time of observation. The horizontal angle is measured as in triangulation, except that when the sun is observed, readings must

948797°—51—10

be taken to the right and left edges to obtain the horizontal angle to the sun's center. The latitude, longitude, and watch correction (TM 5–235) must be known. The watch correction can be obtained from radio time signals. Time is the critical element in this method, and it must be correct to within 5 seconds to obtain the required accuracy. Three separate sets of observations should be made. If these do not provide at least two sets having nearly identical values, the observations should be repeated.

c. Computation. DA AGO Form 6–11 is provided for azimuth computation by the altitude method and DA AGO Form 6–10 is provided for use with the hour angle method (figs. 49 and 50). An ephemeris or nautical almanac for the current year and a table of logarithms are needed for the computation. The computation is based on the solution of a spherical triangle, the vertices of which are the celestial pole, the zenith, and the celestial body. The sides of the astronomical triangle are arcs of great circles passing through each pair of vertices mentioned above.

(1) *Altitude method* (fig. 49). Any observed altitude angle, whether of the sun or a star, must be corrected for refraction. The observed altitude angle of the sun is also corrected for parallax. The corrected altitude angle is then subtracted from 90° to determine one side of the

AZIMUTH DETERMINATION — ALTITUDE METHOD

SET UP AT	STATION JIGG
MARK	STATION TOWER
DATE	25 APRIL 1950
LOCALITY	FORT SILL, OKLA.

CELESTIAL BODY	SUN	
WEATHER	CLEAR & COOL	
TEMPERATURE	50° F.	
WATCH F(−) OR S(+)	14	SECONDS
WATCH CHECKED AGAINST	RADIO	

LATITUDE (Lat)	34° 39' 34" N
LONGITUDE	98° 24' 18" W
TIME ZONE	90TH MERIDIAN
INSTRUMENT NUMBER	12438

SET NO. 1*

TEL.	OBJECT	TIME HR.	TIME MIN.	TIME SEC.	HORIZONTAL ANGLE °	'	"	VERTICAL ANGLE °	'	"
D	MARK	—	—	—	0	00	00	—	—	—
D	APPARENT SUN POSITION	08	34	23	251	44	40	32	22	—
D		08	34	58	251	50	00	32	28	—
D		08	35	31	251	55	40	32	36	—
R		08	37	21	71	35	40	33	27	—
R		08	38	03	71	42	20	33	36	—
R		08	38	43	71	48	20	33	43	—
R	MARK	—	—	—	180	00	20	—	—	—
MEAN		08	36	30	251	45	57	33	02	00
WATCH CORRECTION			+	14	PARALLAX + (sun only)					07
TIME ZONE CORRECTION		06	00	00	REFRACTION −				1	29
GCT		14	36	44	ALTITUDE h			33	00	38
GREENWICH DATE	25 APRIL 1950									
DECLINATION d AT 0^h GCT							±	12°	55'	59.0
GCT X d VARIATION PER HOUR							±		11	56.5
CORRECTED DECLINATION d							±	13	07	56

SET NO. 2

TEL.	OBJECT	TIME HR.	TIME MIN.	TIME SEC.	HORIZONTAL ANGLE °	'	"	VERTICAL ANGLE °	'	"
D	MARK	—	—	—	0	00	00	—	—	—
D	APPARENT SUN POSITION	08	42	54	253	07	00	34	06	—
D		08	43	23	253	11	20	34	11	—
D		08	43	48	253	15	20	34	16	—
R		08	44	49	72	47	00	35	00	—
R		08	45	26	72	52	40	35	07	—
R		08	46	02	72	58	40	35	14	—
R	MARK	—	—	—	180	00	00	—	—	—
MEAN		08	44	24	253	02	00	34	39	00
WATCH CORRECTION			+	14	PARALLAX + (sun only)					07
TIME ZONE CORRECTION		06	00	00	REFRACTION −				1	24
GCT		14	44	38	ALTITUDE h			34	37	43
GREENWICH DATE	—									
DECLINATION d AT 0^h GCT								12°	55'	59.0
GCT X d VARIATION PER HOUR									12	02.9
CORRECTED DECLINATION d								13	08	02

SET NO. 3

TEL.	OBJECT	TIME HR.	TIME MIN.	TIME SEC.	HORIZONTAL ANGLE °	'	"	VERTICAL ANGLE °	'	"
D	MARK	—	—	—	0	00	00	—	—	—
D	APPARENT SUN POSITION	08	49	38	254	13	00	35	26	—
D		08	50	15	254	18	40	35	35	—
D		08	50	44	254	23	40	35	41	—
R		08	51	55	73	56	40	36	25	—
R		08	52	41	74	04	20	36	35	—
R		08	53	20	74	10	20	36	43	—
R	MARK	—	—	—	180	00	20	—	—	—
MEAN		08	51	26	254	10	57	36	04	10
WATCH CORRECTION			+	14	PARALLAX + (sun only)					07
TIME ZONE CORRECTION		06	00	00	REFRACTION −				1	20
GCT		14	51	40	ALTITUDE h			36	02	57
GREENWICH DATE	—									
DECLINATION d AT 0^h GCT								12°	55'	59.0
GCT X d VARIATION PER HOUR									12	08.7
CORRECTED DECLINATION d								13	08	08

* A minimum of two sets should be taken to afford a check. Three sets are preferred for maximum required accuracy.

OBSERVER: SGT. LAUR

RECORDER: SGT McGEE

DA AGO FORM 1 JUN 52 6-11 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

Figure 49. Computation of the azimuth of the sun by the altitude method using DA AGO Form 6–11.

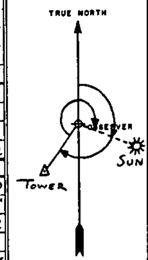
celestial triangle. Using the time and date of observation, the corrected declination of the observed body is obtained from the ephemeris or nautical almanac. A second side of the triangle is determined by subtracting the corrected declination from 90° when it is positive or adding the corrected declination to 90° when it is negative. The third side of the triangle is found by subtracting the observer's latitude from 90°. Knowing the values of the three sides, the triangle can be solved for the angle at the zenith. When the declination of a celestial body is more than the latitude of the observer's position the bearing of the body will always be less than 90°. When the declination of a celestial body is less than the observer's latitude, *and* both are in the same hemisphere, the altitude of the body determines the bearing in some cases (TM 44–225). When the celestial body is east of the observer's meridian, this angle is the true azimuth to the celestial body; when west, the zenith angle must be subtracted from 360° to obtain the true azimuth. By applying the horizontal angle from the mark on the ground to the celestial body, the true north azimuth is determined to the mark.

(2) *Hour angle method* (fig. 50). At the completion of an hour angle observation,

$s = \frac{1}{2}(p + Lat + h)$	$\text{Tan } \frac{1}{2}A = \sqrt{\frac{\text{Sin }(s-Lat)\ \text{Sin }(s-h)}{\text{Cos } s\ \text{Cos }(s-p)}}$	A = Bearing of Celestial Body East or West of True North
	Polar Distance (p) = 90° − Declination	

	SET NO. 1					SET NO. 2					SET NO. 3				
	90°	00'	00"			90°	00'	00"			90°	00'	00"		
DECLINATION ⊕	13	07	56			13	08	02			13	08	08		
POLAR DISTANCE (p)	76	52	04			76	51	58			76	51	52		
LATITUDE (Lat)	34	39	34			34	39	34			34	39	34		
ALTITUDE (h)	33	00	38			34	37	43			36	02	57		
SUM 2)	143	91	76			144	127	135			146	92	143		
s	72	16	08	Colog Cos	0.5163409	73	04	38	Colog Cos	0.5359839	73	47	12	Colog Cos	0.5540619
s − p	4	35	56	Colog Cos	0.0014005	03	47	20	Colog Cos	0.0009503	03	04	40	Colog Cos	0.0006269
s − Lat	37	36	34	Log Sin	9.7855261	38	25	04	Log Sin	9.7933649	39	07	38	Log Sin	9.8000599
s − h	39	15	30	Log Sin	9.8012788	38	26	55	Log Sin	9.7936594	37	44	15	Log Sin	9.7867832
SUM				2)	0.1045463					0.1239585					0.1415319
LOG TAN ½A					0.0522732					0.0619792					0.0707660
½A					48° 26' 24"					49° 04' 29"					49° 38' 51"
A (E or W of North)					96 52 48					98 08 58					99 17 42
AZIMUTH TO CELESTIAL BODY					456 96 52 48					458 98 08 58					459 99 16 17 102 42
MINUS ANGLE, MARK TO BODY					251 45 57					253 02 00					254 10 57
TRUE AZIMUTH TO MARK					205 06 51					205 06 58					205 06 45

SKETCH



GRID CONVERGENCE *(GC) = Difference in Longitude between Observer's meridian and central meridian of Grid zone x sin Observer's Latitude

Longitude, Observer's Meridian	98°	24'	18"	Log Difference Longitude in minutes	1.5526682
Longitude, Central Meridian	98	59	60	Log Sin Latitude	9.7548813
Difference Longitude (E) W		35	42	Log GC	1.3075495
* May also be taken from map or computed using tables in FM 6-120				Grid Convergence	° 20' 18"
** In Southern Hemisphere use REVERSE signs					

TRUE AZIMUTH TO MARK, SET 1	205°	06'	51"
" " " " " 2	205	06	58
" " " " " 3	205	06	45
SUM 3)	615	18	154
MEAN	205	06	51
GRID CONVERGENCE ** EAST − WEST +		20	18
GRID AZIMUTH TO MARK	204	46	33

Computer *Cpl. Jackson* Checker *Cpl. Johnson* Date *25 April 1950*

Figure 49—Continued.

AZIMUTH DETERMINATION—HOUR ANGLE METHOD

Set up at STATION JIGG
Celestial Body POLARIS
Mark STATION TOWER
Date 3 MAY 1950
Latitude 34° 39' 34" N
Longitude 98° 24' 18" W
Time Zone 90th MERIDIAN
Watch F (−) or S (+) 09 Seconds
Watch Checked Against RADIO
Locality FORT SILL, OKLA
Weather CLEAR, WARM
Observer SGT. ROSIER
Recorder SGT. MANNS
Instrument No. 12438

		SET NO. 1								SET NO. 2								SET NO. 3							
		Time			Horizontal Angle					Time			Horizontal Angle					Time			Horizontal Angle				
							Verniers (")								Verniers (")								Verniers (")		
Tel.	Rep.	hr	min	sec	°	'	A	B	Mn	hr	min	sec	°	'	A	B	Mn	hr	min	sec	°	'	A	B	Mn
D	0	—	—	—	0	00	00	00	00	—	—	—	0	00	00	20	10	—	—	—	0	00	00	20	10
D	1	20	27	50	154	01	20	—	—	20	34	17	154	03	20	—	—	20	40	26	154	04	40	—	—
D	2	20	28	57	—	—	—	—	—	20	35	23	—	—	—	—	—	20	41	28	—	—	—	—	—
D	3	20	29	38	102	06	40	—	—	20	36	09	102	11	20	—	—	20	42	15	102	14	00	—	—
R	4	20	30	35	—	—	—	—	—	20	37	14	—	—	—	—	—	20	43	27	—	—	—	—	—
R	5	20	31	14	—	—	—	—	—	20	38	01	—	—	—	—	—	20	44	31	—	—	—	—	—
R	6	20	32	13	204	16	00	00	00	20	38	56	204	24	00	20	10	20	45	19	204	31	20	20	20
Sum	6	120	177	207	924	16	—	—		120	218	120	924	24	—	—	00	120	255	146	924	31	—	—	10
Mean		20	30	04	154	02	—	—	40	20	36	40	154	04	—	—	00	20	42	54	154	05	—	—	12

		Set No. 1			Set No. 2			Set No. 3		
		hr	min	sec	hr	min	sec	hr	min	sec
	Watch Corr		+	09		+	09		+	09
	Time Zone Corr	6	00	00	6	00	00	6	00	00
(1) Greenwich Date 4 MAY 1950	(1) GCT	~~26~~ 02	30	13	~~26~~ 02	36	49	~~26~~ 02	43	03
(2) * Equation of Time at 0^h GCT / Greenwich Sidereal Time at 0^h GCT		14	45	14.3	14	45	14.3	14	45	14.3
(3) * Correction, Equation of Time / Correction, Mean Solar to Sidereal				24.1			25.8			26.8
(4) * Greenwich Apparent Time of Obsn / Greenwich Sidereal Time of Obsn	(1) + (2) + (3)	17	15	52	17	22	29	17	28	44
(5) Longitude W (−) E (+)	(in hr., min., sec.)	6	33	37	6	33	[illegible]	6	33	37
(6) * Local Apparent Time / Local Sidereal Time	(4) + (5)	10	42	15	10	48	52	10	55	07
(7) * Apparent Noon = 12 hr 00 min 00 sec / Right Ascension of Star		1	47	15	1	47	15	1	47	15
Local Hour Angle of Body	* (6) ± (7) / (6) − (7)	8	55	00	9	01	37	9	07	52

		Set No. 1				Set No. 2				Set No. 3			
		±	°	'	"	±	°	'	"	±	°	'	"
* Declination at 0^h GCT		+ −				+ −				+ −			
* GCT x Variation per Hour		+ −				+ −				+ −			
Corrected Declination		+	89	01	47	+	89	01	47	+	89	01	47

* USE FOR SUN OBSERVATIONS ONLY

DA AGO FORM 1 JUN 51 6-10 REPLACES FAS FORM 10, 6 JUL 49, WHICH IS OBSOLETE.

Figure 50. Computation of the azimuth of Polaris by the hour angle method using DA AGO Form 6-10.

$\text{TAN } A = \dfrac{\text{Sin } t}{\text{Cos Lat} \times \text{Tan Decl.} - \text{Sin Lat} \times \text{Cos } t} = \dfrac{\text{Sin } t}{a - b}$, A = bearing of Celestial Body, E or W of True North depending on value of LHA. 0^h to 12^h = W; 12^h to 24^h = E

SET NO. 1

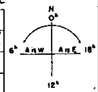
LATITUDE		34°	39′	34″
DECLINATION		89	01	47
LHA in Arc (t)		133	45	00
Log Cos Lat 9.9151606	Log Sin Lat	9.7548813		
Log Tan Decl 1.7711850	Log (W) Cos t	9.8398004		
Sum = Log a 1.6863456	Sum (W) Log b	9.5946817		
	a =	48.5675		
	b =	(–) .3933		
a – b = (+), –		48.9608		
Log Sin t		9.858 7561		
Minus Log (a – b)		1.689 8485		
Diff = Log Tan A		8.168 9076		
If A is W subtract from 360°		359°	59′	60″
A E, (W)		0	50	43
Azimuth to Body		359	09	17
Minus Angle, Mark to Body		154	02	40
True Azimuth to Mark		205	06	37

SET NO. 2

LATITUDE		34	39	34
DECLINATION		89	01	47
LHA in Arc (t)		135	24	15
Log Cos Lat 9.9151606	Log Sin Lat	9.7548813		
Log Tan Decl 1.7711850	Log (W) Cos t	9.8525270		
Sum = Log a 1.6863456	Sum (W) Log b	9.6074083		
	a =	48.5675		
	b =	(–) .4050		
a – b = (+), –		48.9725		
Log Sin t		9.846 3998		
Minus Log (a – b)		1.6899522		
Diff = Log Tan A		8.1564476		
If A is W subtract from 360°		359°	59′	60″
A E, (W)		0	49	17
Azimuth to Body		359	10	43
Minus Angle, Mark to Body		154	04	00
True Azimuth to Mark		205	06	43

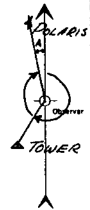
SET NO. 3

LATITUDE		34°	39′	34″
DECLINATION		89	01	47
LHA in Arc (t)		136	58	00
Log Cos Lat 9.9151606	Log Sin Lat	9.754881 3		
Log Tan Decl 1.7711850	Log (W) Cos t	9.8638917		
Sum = Log a 1.6863456	Sum (W) Log b	9.6187730		
	a =	48.5675		
	b =	(–) .4157		
a – b = (+), –		48.9832		
Log Sin t		9.8340541		
Minus Log (a – b)		1.6900472		
Diff = Log Tan A		8.1440069		
If A is W subtract from 360°		359°	59′	60″
A E, (W)		0	47	53
Azimuth to Body		359	12	07
Minus Angle, Mark to Body		154	05	12
True Azimuth to Mark		205	06	55



CELESTIAL BEARING

SKETCH



GRID CONVERGENCE *(GC) = Difference in Longitude between Observer's meridian and central meridian of Grid zone x sin Observer's Latitude.

Longitude, Observer's Meridian	98°	24′	18″
Longitude, Central Meridian	98	59	60
Difference Longitude (E), W		35	42

Log Diff Long. in minutes	1.5526682		
Log Sin Latitude	9.7548813		
Log GC	1.3075495		
Grid Convergence	°	20′	18″

TRUE AZIMUTH TO MARK	SET 1	205°	06′	37″
" " " "	SET 2	205	06	43
" " " "	SET 3	205	06	55
SUM	3)	615	18	135
MEAN		205	06	45
GRID CONVERGENCE	** EAST (–) WEST +		20	18
GRID AZIMUTH TO MARK		204	46	27

* May also be taken from map or Computed using tables in FM 6-120.
** In Southern Hemisphere, REVERSE signs.

Computer Cpl Smith   Checker Cpl Jones   Date 3 May 1950

Figure 50—Continued.

two sides and the included angle of the celestial triangle can be determined. The two sides are the co-latitude and the polar distance. The angle between these two sides, or the angle between the observer's meridian and the hour circle through the celestial body, is called the local hour angle. It can be computed by using the local time of observation. With these values known, the triangle can be solved for the angle at the zenith, and the true azimuth of the body determined. By applying the measured horizontal angle, the true north azimuth to the mark is obtained.

(3) *Grid correction.* Since the artillery is always oriented with respect to grid north, all true north azimuths must be converted to grid azimuths before they can be used.

CHAPTER 7

SOUND RANGING

Section I. GENERAL

95. DEFINITIONS

a. Sound Ranging. The procedure of locating the source of a sound, such as a gun report or a shell burst, by calculations based upon observations of the propagated sound wave is called sound ranging. It normally is employed to locate hostile guns in position and firing, and to adjust the fire of friendly artillery under certain conditions.

b. Gun Wave. The gun wave, or muzzle wave, is the impulse wave produced by the piece when it fires.

c. Ballistic Wave. A projectile whose velocity in flight is greater than the velocity of sound gives rise to a ballistic wave audible to an observer near the trajectory as a sharp crack.

d. Burst Wave. The burst wave is an impulse wave which originates in the detonation of a high explosive shell.

e. Whistling. This is a whistling, rustling, or hissing sound associated with the shell in its flight, caused by interference of sound waves within the ballistic wave cone. Microphones do not record this sound.

f. Splinter Waves. These are ballistic waves of small amplitude, produced by shell fragments, or splinters, moving faster than the speed of sound.

96. GENERAL DESCRIPTION

a. Installation. A typical sound ranging installation is shown in figure 51.

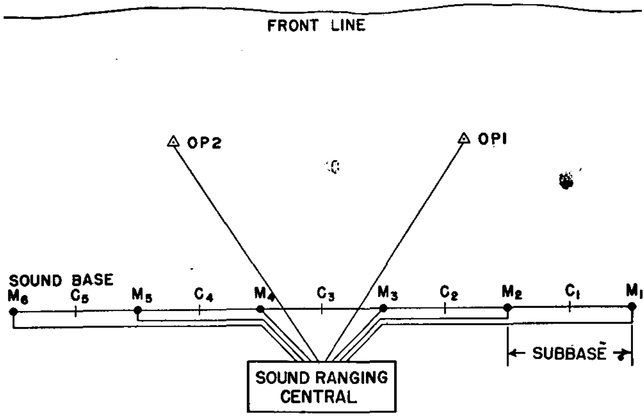


Figure 51. A typical sound ranging installation.

b. Basic Theory of Sound Ranging. The discharge of a gun or burst of a shell causes a sound disturbance or pressure vibration of the air, lasting for only a fraction of a second. The impulse so produced travels outward through the air in all directions at speeds which are dependent upon weather conditions. The speed of sound varies from 330 to 350 meters per second at average air temperatures. If there is no wind and the entire mass of air has a uniform temperature of 50° Fahrenheit, the velocity of the advancing wave front is 337.6 meters per second. These are the assumed standard conditions used in sound ranging. In still air, the sound wave will arrive at two given points at the same time if their distances from the source are equal, that is, if the source of the sound lies on the perpendicular bisector of the line connecting the two points. For a source in any other position, the arrival times at the points of observation will be different. This time difference increases as the distance of the sound source from the perpendicular bisector increases. It provides a measure of the angle between the perpendicular bisector and a ray through the sound source extending from the midpoint of the line connecting the two observation points. If two microphones are placed some distance apart and the difference in arrival time of a sound at each microphone is recorded, the direction of a ray which passes very close to the origin of the sound may be determined. Other combinations of two microphones will provide similar rays, and from the intersection of these rays the source of sound may be located.

c. Sound Base. In practice, a sound wave is detected by an array of four to six microphones, normally spaced at equal intervals (700 to 2,000 or more meters) along a straight line or, under certain conditions, along the arc of a circle. In some cases the microphones may be spaced at unequal intervals along a straight or broken line. Such an array is termed a *sound ranging base* or *sound base.* A straight line segment connecting a pair of adjacent microphones constitutes a *subbase.*

d. Recording. Each microphone is connected by a wire or radio circuit to the sound recording set located at the *sound ranging central (SRC).* The sound impulse received at each microphone is recorded by this equipment on a moving paper tape. Recorded sound impulses are called *breaks.* In front of the sound base, at distances of 1,000 or more meters, one or two outpost observers are stationed. Either observer, upon hearing a sound of a gun or shell burst, must activate the sound ranging apparatus in time to record the sound.

e. Sound Record. The sound record is a paper tape upon which a time scale (1/100-second graduations) and the arrivals of the sound impulse at each microphone are recorded. The time of arrival at each microphone, as measured from an arbitrary zero time, is read from the record, and the difference between arrival times is computed for each pair of adjacent microphones.

f. Plotting. The midpoint and reference line of each microphone subbase are plotted on the plotting board or plotting chart. The reference line is initially the perpendicular bisector of the subbase. It may be adjusted for direction (par. 116). Draw a ray from each midpoint at the angular displacement (D) from the corresponding reference line. The angular displacement (D) is given by the relation:

$D = \text{arc sin } \frac{t}{s}$ in which

t = time difference of arrival of a sound wave at the two ends of the subbase.

s = length of subbase in sound-seconds. (One sound-second, or the distance sound travels in one second, is 337.6 meters under standard atmospheric conditions.)

The intersection of the rays from the midpoints (or geometrical center of a polygon of error) gives the location of the sound source. The accuracy of the location is increased by application of certain corrections to the computed time differences (par. 115).

g. Rapid and Deliberate Methods. Normally, sound ranging installations are accurately surveyed by precise methods. Initially, a sound base may be rapidly installed by hasty survey methods. Such an installation is limited in application by lack of accuracy of the hasty survey and restricted connecting survey. For a discussion of rapid survey methods, see paragraph 104.

Section II. SELECTION OF A SOUND POSITION

97. TYPES OF BASES

a. Number of Microphones. The number of microphones installed in a sound base depends on the time available and the terrain (par. 101). A complete installation normally employs five or six microphones. A minimum of four microphones should always be installed to permit three-ray intersection at the target. Increasing the number of microphones increases the number of intersecting rays and improves the reliability of locations.

b. Arrangement of Microphones.

(1) *Spacing and alinement in a regular base.* The microphones are spaced at uniform intervals along a straight line (*straight*

base) or along the arc of a circle concave toward the front (*curved base*). The base is *irregular* if either the spacing or alinement of the microphones is irregular.

(2) *Numbering of microphones* (fig. 51). Microphones are numbered consecutively from the right when facing the front. They are designated by the symbols, M_1, M_2, etc. The midpoints of the subbases are numbered C_1, C_2, etc., consecutively from the right.

(3) *Azimuth of base.* The azimuth of a subbase is the direction from the lower-numbered to the higher-numbered microphone, (from M_1 to M_2, M_3 *to* M_4, etc.). The azimuth of a straight base is the azimuth of any subbase. *The azimuth of a curved base* is the azimuth of the *long chord,* or line joining the two extreme flank microphones.

98. COMPARISON OF BASES

a. Regular Base.

(1) *General.* The most important advantage of a regular base is that the recorded arrivals of sound at the microphones form an easily recognized pattern on the record. Anyone accustomed to reading records (par. 114) on one regular base can read them with equal facility on any regular base; whereas, when there is a change in an irregular base, the record reader must learn the characteristic pat-

terns of breaks for the new base. Another advantage of a regular base is that standard plotting equipment with previously prepared time scales may be used.

(2) *Curved and straight bases.* The curved base avoids the possible error of plotting a sound source to the front when it is actually to the rear; it also facilitates record reading because the recorded sound arrivals are grouped more closely together than for a comparable straight base. The curved base requires more computations in survey than does a straight base. A curved base covers a somewhat narrower frontage of target area than does a straight base.

b. Irregular Base. The irregular base is used when the terrain or time available for survey does not permit the installation of a regular base. It results in irregularity in the sequence of breaks, which, when there is considerable artillery activity, may render the records unreadable. To reduce this effect, microphone positions should be selected to bring the microphones as nearly as possible into alinement, since alinement is more critical than regularity of spacing. The irregular base has the advantage that acoustically favorable locations may be selected for each microphone, which may, under certain conditions of terrain (par. 101), be the determining factor in choosing the type of base to be used.

99. LENGTH OF BASE

a. The unit of measure for subbases is the *sound-second*—337.6 meters (par. 96). Convenient subbase lengths for rapid installations are 2 and 4 sound-seconds. Other values, preferably multiples of a standard length, may be used. Subbases of 4.0, 4.5, 5.0, and 5.5 sound-seconds generally are accepted as standard regular bases. Selections of subbase length is based upon the front to be covered, range to enemy artillery, available terrain, survey, wire laying, and available time.

b. The 2-sound-second (2-second) base may be used when time is very limited and the difficulties of surveying or laying wire render a longer base impracticable, or when terrain or situation prevents the use of a longer base. The 2-second base is expanded at the first opportunity, usually to a 4-second base, by removing alternate microphones and adding additional microphones at the ends of the base.

c. To attain maximum plotting accuracy the base length should be not less than two-thirds the distances to the sound source. Satisfactory results may be obtained if the base length is not less than one-third of the distance. An existing base may be lengthened by using longer subbases or by adding microphones.

100. RADIUS OF CURVED BASE

The radius of a curved sound base is the distance in sound-seconds from the center of curvature to the arc through the midpoints. The radius to the arc through the microphones is slightly greater (fig. 52). The radius is selected so that it will place the center of curvature near the center of the area to be observed and will fit the base to the available terrain. Values of subbase, radius of base, and other elements of standard curved bases for which the mechanical plotting board may be used are given in appendix X.

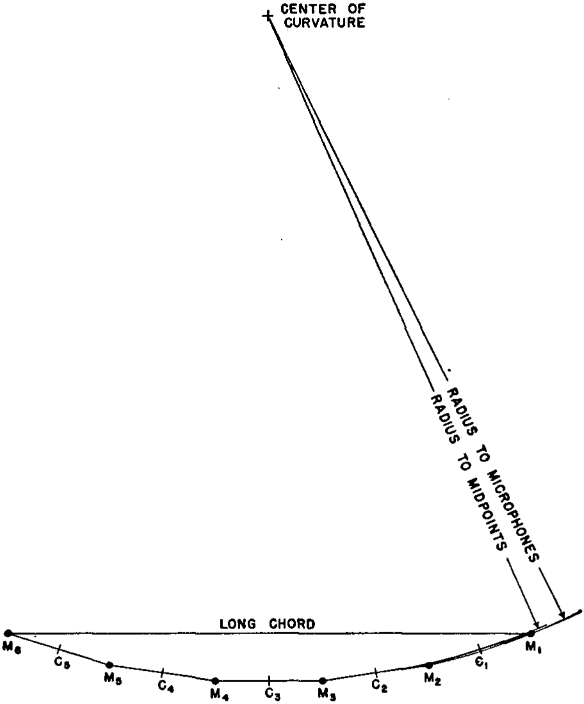


Figure 52. Curved sound bases.

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101. LOCATION OF SOUND BASE

a. Location with Respect to Enemy Artillery. The base should be as close as possible (consistent with the proper location of the outpost observer) to the area to be observed, and so oriented that the perpendicular bisector of the base passes through the approximate center of the area (fig. 53). To improve sound ranging when a strong flank wind interferes with reception of sound, the sound base should be shifted downwind with respect to the target area. This may be done by adding one or more microphones on the downwind end of the base. Crossed bases may be used to increase the width of the sector of observation. The cross-base switching device permits utilization of two bases by affording the operator a means whereby he can switch from one to the other as desired.

b. Location with Respect to Front Lines. The base should be sufficiently far behind the front lines to enable the outpost observers, upon hearing a sound, to activate the sound recording set before the sound reaches any microphone (par. 102).

c. Location of Microphones.

(1) Microphones should be located in such positions that they will detect the desired sounds without excessive interference from undesired sounds such as heavy shelling, our own artillery batteries, or heavy motor traffic. Interference from ballistic waves of shells from friendly batteries may be avoided by locating microphones to the rear of these

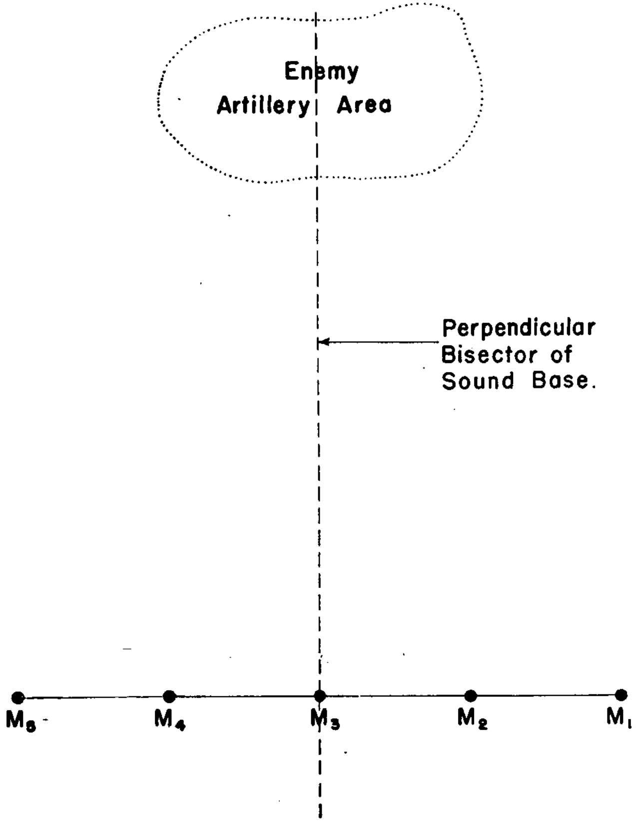

Figure 53. Location of sound base in relation to area of probable location of enemy artillery.

batteries.

(2) Local obstacles, such as low buildings, woods, low banks, or rolling hills, do not materially affect the travel of a low-frequency sound wave. High hills in the di-

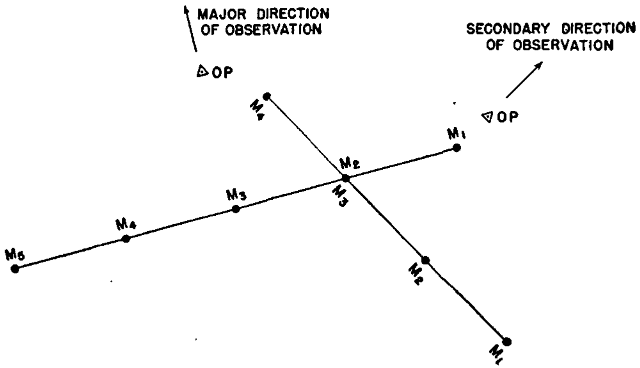

Figure 54. Crossed sound bases.

rect path between a sound source and microphone may impair the effectiveness of the microphone position or render the microphone totally insensitive. Cliffs, large steep hills, and large buildings near a microphone position may cause a time error as well as disturbing echoes.

(3) If one or more microphones fall in unsuitable locations, the entire base may be displaced a short distance or the unsuitable locations may be eliminated by moving individual microphones.

d. Survey and Communication Considerations. When possible, the base should be located to provide favorable routes for wire laying and favorable terrain for survey. To reduce line maintenance, wire routes should avoid use of heavily traveled roads (FM 24–20).

e. Map Reconnaissance. If suitable maps are available, a map reconnaissance will facilitate selection of the sound base relative to the target area, combat lines, friendly installations, and terrain features. Transparent templates of standard sound bases to the scale of the map are an aid in determining a suitable position of the base on the ground. The template is laid on the map and shifted until all microphones fall into satisfactory positions. To take account of terrain conditions which may be at variance with, or not shown on, available maps, a ground reconnaissance must be made before final selection of microphone positions is made.

102. OUTPOST POSITIONS

a. An outpost position should be at least 2 sound-seconds (approximately 675 meters) closer to a sound source than any microphone. After the outpost observer detects the sound, some delay (observer's reaction time) occurs before he presses the outpost switch, and after he presses the switch, a further delay occurs before the sound set begins recording. Figure 55 shows the areas that can be covered from several outpost positions for certain standard bases. If the front is narrow, one outpost position may be sufficient. Two outposts, one toward either flank of the base, are necessary for complete coverage of a wide front unless a single observer can be placed well forward.

b. The outpost position should be as free as possible from the disturbing noises of friendly artillery firing and small arms fire. It should provide cover and concealment for the observers and a covered route of approach. It should be located on a vantage point to provide good visual observa-

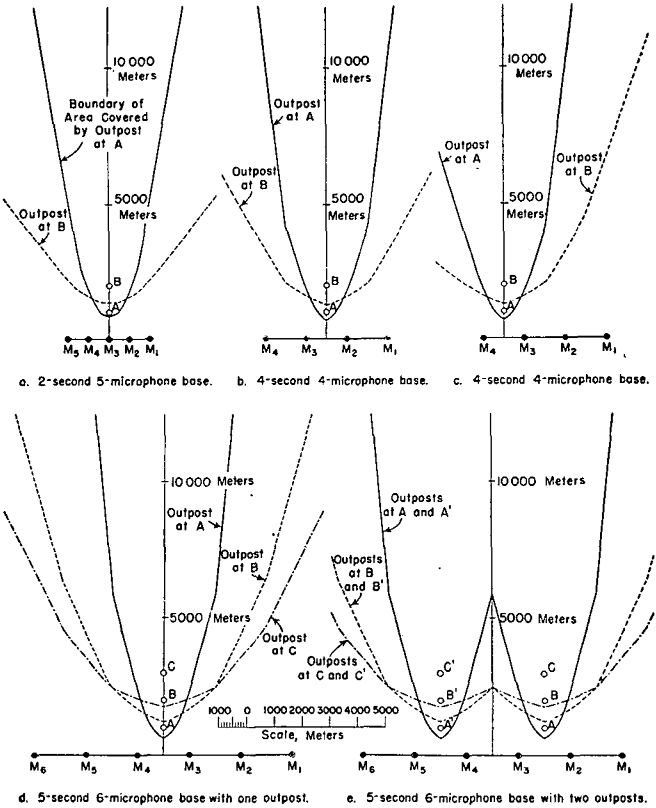

Figure 55: Area of target locations from which a sound is heard by the outpost observer at least 2 seconds before its arrival at any microphone.

tion into the enemy area to permit the observer to estimate accurately the direction to the sound source.

103. SOUND RANGING CENTRAL

To reduce the amount of wire necessary, the sound ranging central should be as near the center of the sound base as is consistent with security. It should provide cover and concealment for the personnel at the sound ranging central and a covered route of approach. Normally it is as close to the base as possible.

Section III. INSTALLATION OF A BASE

104. SURVEY OF SOUND BASE BY RAPID METHODS

a. Internal Survey. The internal survey of a sound base consists of locating and marking the microphone positions on the ground in their correct relative positions independently of common survey control. It may be performed by either hasty or precise methods. Survey of sound bases by precise methods is covered in paragraph 105.

(1) *Calibrated wire method.* The starting point for the survey normally is either, the center of the base or a microphone position. It should be marked on the ground with a range pole or a flag. The direction of the base is marked with another range pole or flag 100 to 200 meters distant. Two taping parties, working in opposite directions from the starting point and maintaining alinement by eye, measure the distance between microphones with fixed lengths of field wire. A single strand of field wire, ¼ sound-second (84.4 meters) in length, is satis-

factory. No attempt is made to keep the wire horizontal. Alinement is easily maintained by use of range poles or by placing the base on line between two distant terrain features. To avoid errors in total number of tape lengths, the tapemen count the number of taping pins or use a counter. Tapemen should move at double time between tape lengths. This method is best adapted to open terrain; it is rapid, and it usually is the most accurate hasty method of internal survey.

(2) *Inspection and short traverse.* A base may be located by inspection from a map or photomap and by scaling from the map the distances and directions to each microphone from nearby terrain features which can be identified on both the map and on the ground. A short traverse is run from the terrain feature to the microphone position. The scale of a photomap is determined as described in FM 6–40. This method is rapid and is accurate if the map or photomap is accurate and if sufficient recognizable features exist on the map or photomap. It is particularly valuable in rough terrain. It is applicable to either regular or irregular bases. The microphone positions may be located on the sound plotting board by affixing the map or photomap to the plotting board.

(3) *"Shot in" base.* The base may be "shot

in" when satisfactory maps or photomaps are not available, or when rugged or heavily wooded terrain makes other survey methods difficult or impossible. Microphone positions are selected arbitrarily on the ground, approximating a straight, regular base. Relative positions of the microphones are determined by the method described below.

(*a*) *Determining the distances from the microphones to the outpost position.* A "shot point" (position at which an explosive charge is detonated) is selected near the outpost. The outpost observer makes electrical connections to the outpost line as shown in figure 56. At the sound recording set, the outpost circuit is temporarily connected to a recording channel. When the charge is set and the outpost operator has returned to his telephone at a safe distance (30 to 50 meters) from the charge, he signals the operator of the sound recording set READY. The operator signals FIRE and starts the sound set. The outpost operator waits 5 to 10 seconds and detonates the explosive. A sound record is obtained indicating the instant the charge was fired and the instant of the sound arrival at each microphone. The time interval required for the sound to travel

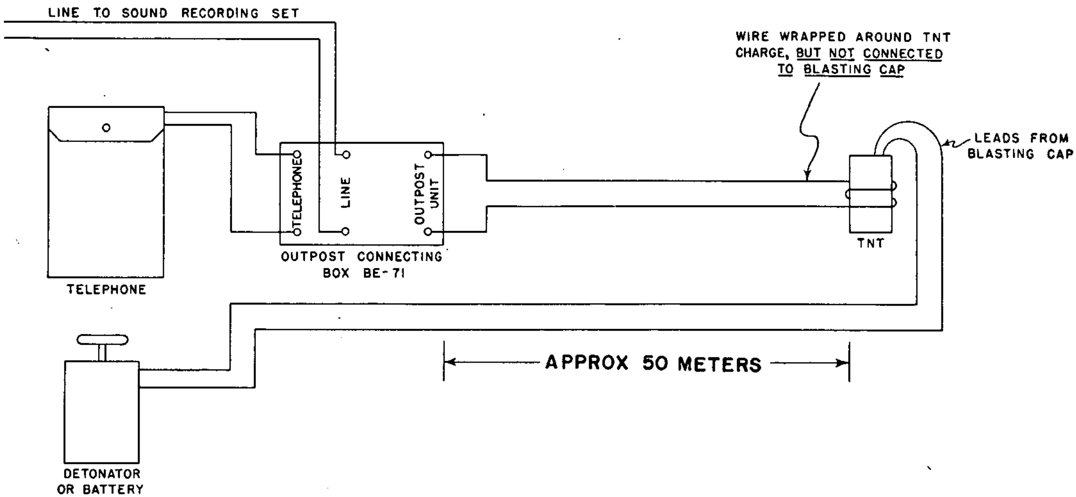

Figure 56. Electrical connections for "shooting in" a sound base.

TNT FIRED AT "A"

SOUND PLOTTING RECORD

Base: Location S. ARBUCKLE Type 5 MIC. APPROX. 3 SECS. IRREG. Azimuth .... Date 5 JUNE 1950

Record No. .... Time 1420 Temperature 82 °F. Wind: Direction 800 mils. Speed 16 m.p.h.

TIME READINGS

	1		2		3		4		5	
Results to (−)										
1	2 M_1 5.806		3 M_2 4.165		4 M_3 4.122		5 M_4 5.809		6 M_5 7.887	
Results to (+)	A 0.126		A 0.126		A 0.126		A 0.126		A 0.126	
	+	−	+	−	+	−	+	−	+	−
Time Interval	5.680		4.039		3.996		5.683		7.761	
Temperature Correction	0.182		0.129		0.128		0.182		0.248	
Wind Correction	0.000		0.032		0.078		0.121		0.161	
Sub-Totals										
Subtract										
Weather Corrected Time Interval										
Curvature Correction										
Final Time Interval	5.862		4.200		4.202		5.986		8.170	
Approximate Distance	1975		1418		1419		2020		2760	

Coordinates: E .... N .... Accuracy .... Meters. Caliber .... File No. ....

Area Shelled .... Number of Pieces .... Time Reported .... Conc. No. ....

DA FORM 6-4 1 JUN 51 REPLACES FAS FORM 4, 10 JUN 44, WHICH IS OBSOLETE.

Figure 57. Computations for a "shot in base with TNT" fired at "A" using the sound plotting record form.

from the "shot point" to each microphone is computed (par. 115) on the sound plotting record (fig. 57), corrected for temperature and wind as described in (*d*) below, and multiplied by 337.6 to obtain the corresponding distance in meters.

(*b*) *Determining distances between microphones.* A second "shot point" is selected at one of the interior microphone positions. The microphone is disconnected and removed to a safe distance and connections made as in figure 56. A sound record is made of an explosive charge fired from within a meter or two of the microphone position by the same procedure as

TNT FIRED AT M_3 **SOUND PLOTTING RECORD**

Base: Location S. ARBUCKLE Type 5 MIC Approx 3 SEC IRREG Azimuth .... Date 5 JUNE 1950

Record No .... Time 1425 Temperature 82 °F Wind: Direction 200 mils. Speed 16 m.p.h.

TIME READINGS

	1	2	3	4	5
Results to (−)					
1	M_1 2 5.936	M_2 3 3.163	M_4 4 3.131	M_5 5 5.669	6
Results to (+)	M_3 0.230	M_3 0.230	M_3 0.230	M_3 0.230	

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval	5.706		2.933		2.901		5.439			
Temperature Correction	0.188		0.094		0.093		0.174			
Wind Correction		0.086		0.044	0.044		0.082			
Sub-Totals	5.894	0.086	3.027	0.044						
Subtract	0.086		0.044							
Weather Corrected Time Interval	5.808		2.983							
Curvature Correction										
Final Time Interval	5.808		2.983		3038		5.695			
Approximate Distance	1960		1001		1020		1920			

Coordinates: E .... N .... Accuracy .... Meters, Caliber .... File No. ....

Area Shelled .... Number of Pieces .... Time Reported .... Conc. No. ....

DA AGO FORM 1 JUN 51 6–4 REPLACES FAS FORM 4, 10 JUN 44, WHICH IS OBSOLETE.

Figure 58. Computations for a "shot in" base with TNT fired at "M_3" using DA AGO Form 6–4.

when firing at the outpost position. Distances from the "shot point" to the other microphones are computed as in (*a*) above (fig. 58).

(*c*) *Plotting.* The positions of the microphones are plotted as illustrated by the example in (*e*) below.

(*d*) *Weather corrections.* The temperature correction for each time interval is determined by using the temperature correction chart in the normal manner (par. 115). The wind corrector M_1, which may be set up for any standard length of subbase, is used in the normal way (par. 115), except that each subbase marker is set at the estimated azimuth *from* a microphone *to* the "shot point." When difficult terrain makes an estimate of azimuth (to the nearest 200 mils) difficult, it is measured from an uncorrected plot of the microphone positions. The wind corrections are read from the corrector and multiplied by the ratio t/s, in which t is the measured time interval in seconds for the microphone in question, and s is the length in sound seconds of the subbase for which the corrector is set up.

(*e*) *Illustrative example.* Microphone positions were selected on the ground approximating a 3-second, five-microphone sound base. TNT was fired at point A near the outpost position, and at the position of M_3. Time readings for each detonation were recorded (figs. 57 and 58). Time intervals were computed, and temperatures and wind corrections were

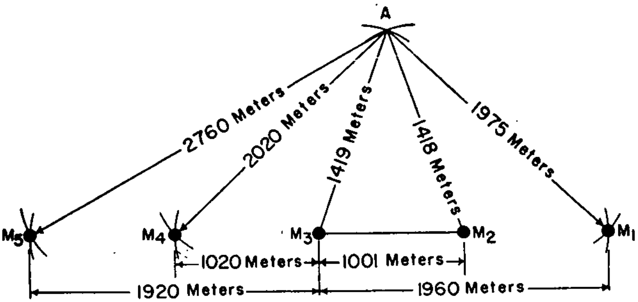

Figure 59. Graphical construction of a "shot in" base.

applied as shown. The wind corrections were computed as follows: (The azimuth from each microphone to the sound source was estimated to the nearest 200 mils, and the wind corrector was set up for a 4-second subbase.)

TNT FIRED AT *A*

Microphone	Estimated azimuth to TNT	Reading from corrector		Ratio t/s		Wind correction
M_1	5600	0.000	×	1.420	=	0.000
M_2	6000	+0.032	×	1.010	=	+0.032
M_3	400	+0.078	×	0.999	=	+0.078
M_4	800	+0.085	×	1.421	=	+0.121
M_5	1000	+0.083	×	1.940	=	+0.161
TNT FIRED AT M_3						
M_1	4800	—0.060	×	1.428	=	—0.086
M_2	4800	—0.060	×	0.733	=	—0.044
M_4	1600	+0.060	×	0.723	=	+0.044
M_5	1600	+0.060	×	1.360	=	+0.082

Each corrected time interval was multiplied by 337.6 to determine the distance from the "shot point" to the microphone; this distance was then recorded as shown in figures 57 and 58. A line was drawn near the lower edge of the sound plotting chart to represent the line of the subbase M_2—M_3 (fig. 59). A point on this line was arbitrarily selected as the position of M_3. A point on the line plotted to scale at the computed distance of 1,001 meters (fig. 58) to the right of M_3 located M_2. Point A was located by the intersection of arcs from M_3 and M_2 at radii of 1,419 and 1,418 meters, respectively. Each remaining microphone was located by the intersection of arcs of radii equal to the computed distances from M_3 and point A.

b. Connecting Survey. The connecting survey for a sound base is the survey performed to determine the orientation and position of the base relative to other installations on a common grid. In a hasty installation, survey control frequently is not completed until the internal survey of the base is improved. The azimuth of a hasty base usually is determined by means of a map or compass. The location of the base on the grid may be determined by resection, by inspection and short traverse from a known point, or by firing.

c. Improving Survey of a Sound Base. Internal survey performed by hasty methods is improved by using one or a combination of the precise methods described in chapter 6. In the process of improving the survey, the base may be expanded as desired, and an irregular base may be converted to a regular base. The sound base is placed on the common grid by connecting the internal survey of the base to established survey control.

105. SURVEY OF BASE BY PRECISE METHODS

a. General. The microphone positions of a sound base will be located, whenever possible, by survey methods described in chapter 6.

b. Regular Base. The coordinates of a point on the sound base (usually a microphone position or the center of the base) and the azimuth of the base, from which the coordinates of each microphone position are computed, may be determined from a map or photomap. The microphones are then located on the ground at their computed positions by survey. If survey control is available at a point on or near the base, the internal survey may start from this point. If survey control is not available, the internal survey is started from a convenient point assigned arbitrary coordinates. Conversion to common grid coordinates is made as soon as possible. If sufficient survey control points exist in the vicinity of the sound base, a short traverse may be run to each microphone

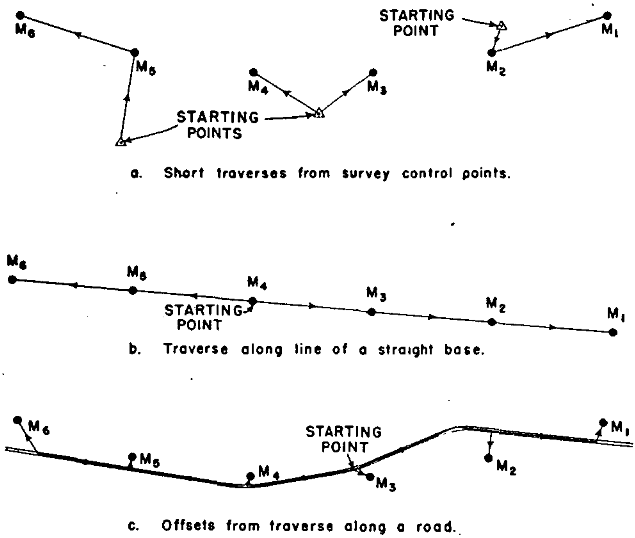

Figure 60. Methods of surveying sound bases.

position from the nearest control point (fig. 60).

c. Irregular Base. Microphone positions are selected by map inspection and reconnaissance. In an irregular base, selection of the final locations of microphones may precede the determination of their coordinates by survey. Microphones usually are located by traverse; on suitable terrain, however, survey may be accomplished by triangulation or a combination of triangulation and traverse.

106. COMPUTATION FOR SOUND BASE

a. Regular Base. Data necessary to compute the coordinates of each microphone position of a regular base are length of subbase; number of microphones; radius of base, if curved; coordinates of one point on the base; and the azimuth of the base. Computations should be made *independently* by two computers to provide a check. Computers should construct a rough sketch, showing the orientation of the base relative to the grid with microphones properly numbered, as an aid in avoiding gross errors. DA AGO Form 6–2 is used for the computations (fig. 61).

(1) *Straight base.* An example of the computations for a 4-second, six-microphone straight base (azimuth 278° 15′ 00″; coordinates of M_3, (284,044.00–182,385.60)) is shown in figure 61. The length of subbase (M_3 to M_4 is tabulated in appendix VI, as 1350.4 meters. With the completion of the computations indicated on the form, dE is determined as minus

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1336.42 meters and dN as plus 193.77 meters. Thus, in moving from M_3 to M_4, or from any microphone to the next higher-numbered microphone, the E coordinate is decreased by 1336.42 meters and the N coordinate is increased by 193.77 meters. Starting with the coordinates of M_3 increments are added for each microphone up to M_6, as follows:

	E	N
Coordinates of M_3.............	284,044.00	182,385.60
Difference, M_3 to M_4...........	—1,336.42	+193.77
Coordinates of M_4.............	282,707.58	182,579.37
Difference, M_4 to M_5...........	—1,336.42	+193.77
Coordinates of M_5.............	281,371.16	182,773.14
Difference, M_5 to M_6...........	—1,336.42	+193.77
Coordinates of M_6.............	280,034.74	182,966.91

In moving in the opposite direction, from M_3 to M_1, the same increments are applied with opposite signs.

	E	N
Coordinates of M_3.............	284,044.00	182,385.60
Difference, M_3 to M_2...........	+1,336.42	—193.77
Coordinates of M_2.............	285,380.42	182,191.83
Difference, M_2 to M_1...........	+1,336.42	—193.77
Coordinates of M_1...............	286,716.84	181,998.06

As a check, the difference between the E coordinates of M_1 and M_6 should be 5 times dE, and the difference between the N coordinates of M_1 and M_6 should be 5 times dN. If the computation begins with the coordinates of the midpoint of the base, C_3, the procedure is the same with the exception that the first increment, from C_3 to M_4,

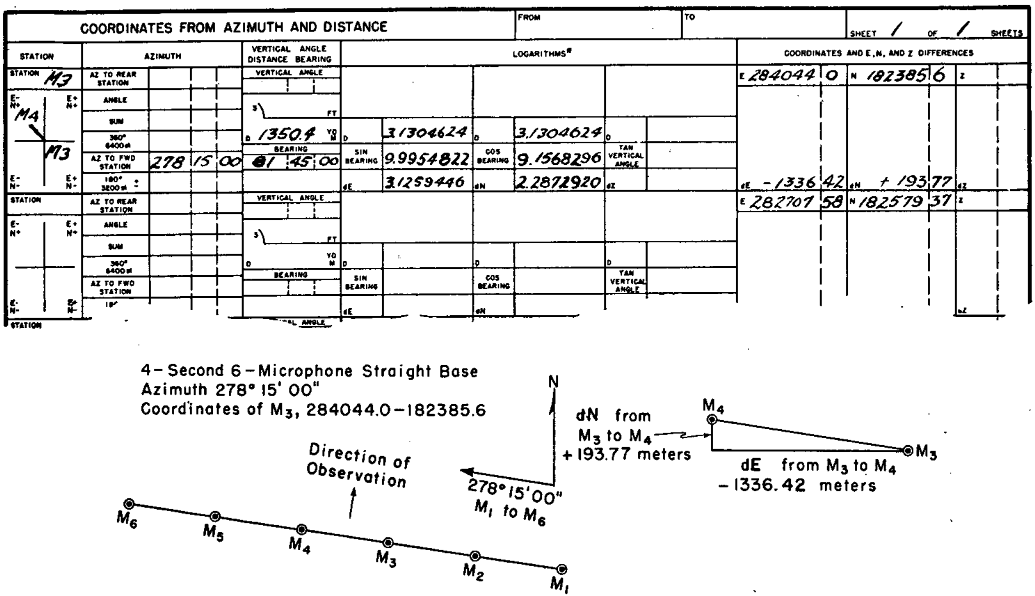


Figure 61. Sketch and computations for a straight sound base using DA AGO Form 6–2.

and from C_3 to M_3, is one-half that for the subbase of 1350.4 meters.

(2) *Curved base.* Since each subbase of a curved base has a different azimuth, the increments dE and dN must be computed for each subbase. The offset angle is the difference in azimuth between any two adjacent subbases. This angle, when added to the azimuth of any subbase, gives the azimuth of the next higher-numbered subbase; when subtracted, the result is the azimuth of the next lower-numbered subbase. For a 5-second curved base with a radius of 30 seconds, appendix X lists the offset angle B as 9° 31′ 38″. If the azimuth of the base (and of subbase M_3 to M_4) is 73° 14′ 12″, the azimuths of the other subbases are computed as follows:

$$
\begin{aligned}
\text{Azimuth } M_3 \text{ to } M_4 &= 73^\circ\ 14'\ 12'' \\
+B &= \underline{+9^\circ\ 31'\ 38''} \\
\text{Azimuth } M_4 \text{ to } M_5 &= 82^\circ\ 45'\ 50'' \\
+B &= \underline{+9^\circ\ 31'\ 38''} \\
\text{Azimuth } M_5 \text{ to } M_6 &= 92^\circ\ 17'\ 28'' \\
\text{Azimuth } M_3 \text{ to } M_4 &= 73^\circ\ 14'\ 12'' \\
-B &= \underline{-9^\circ\ 31'\ 38''} \\
\text{Azimuth } M_2 \text{ to } M_3 &= 63^\circ\ 42'\ 34'' \\
-B &= \underline{-9^\circ\ 31'\ 38''} \\
\text{Azimuth } M_1 \text{ to } M_2 &= 54^\circ\ 10'\ 56''
\end{aligned}
$$

As a check, the azimuth of subbase M_1 to M_2 plus 4 times B equals the azimuth of subbase M_5 to M_6. Computations for this base are shown in figure 62. The coordinates of M_3 are given as (277,740.50 — 192,713.20). Appendix X, lists the length of the 5-second subbase as 1687.99 meters. Note that in progressing from M_3 to M_6, as shown in the first three computing forms of figure 62, the azimuths used are as computed above. The azimuth used in proceeding from M_3 to M_2 (from the higher-numbered microphone) is the back azimuth of M_2 to M_3. Similarly, the azimuth from M_2 to M_1 is the back azimuth of that shown above for M_1 to M_2 (fig. 62). A check on the computations is also shown in figure 62. Starting with the computed coordinates of M_1, and the distance and azimuth to M_6, the coordinates of M_6 are computed. The distance from M_1 to M_6 (length of the long chord L) is listed in appendix X.

b. Irregular Base. The coordinates of the microphones of an irregular base are computed as the stations in a traverse.

107. INSTALLING WIRE

a. Complete sound ranging wire installations consist of a circuit from each microphone and each outpost to the sound recording set. For early effective operation of the base, one outpost circuit should be completed by the time four microphones are connected.

b. The technique of field wire installation is

COORDINATES FROM AZIMUTH AND DISTANCE

FROM | TO | SHEET 1 OF 2 SHEETS

STATION		AZIMUTH	VERTICAL ANGLE / DISTANCE / BEARING	LOGARITHMS*						COORDINATES AND E, N, AND Z DIFFERENCES		
STATION M_3	AZ TO REAR STATION		VERTICAL ANGLE							E 277740 5	N 192713 2	Z
E- N+ / -E+ N+	ANGLE											
M_4	SUM		FT									
	360° 6400 mil		D 1687.99 YD	D	3.2273698	D	3.2273698	D				
M_3	AZ TO FWD STATION	73 14 12	BEARING 73 14 12	SIN BEARING	9.9811408	COS BEARING	9.4600240	TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±			dE	3.2085106	dN	2.6873938	dZ		dE +1616 26	dN +486 85	dZ
STATION M_4	AZ TO REAR STATION		VERTICAL ANGLE							E 279356 76	N 193200 05	Z
E- N+ / E+ N+	ANGLE	9 31 38										
M_5	SUM	82 45 50	FT									
	360° 6400 mil		D 1687.99 YD	D	3.2273698	D	3.2273698	D				
M_4	AZ TO FWD STATION	82 45 50	BEARING 89 45 50	SIN BEARING	9.9965272	COS BEARING	9.1002275	TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±			dE	3.2238970	dN	2.3275973	dZ		dE +1674 55	dN +212 62	dZ
STATION	AZ TO REAR STATION		VERTICAL ANGLE							E 281031 31	N 193412 67	Z
E+ N+ / E- N+	ANGLE	9 31 38										
	SUM	92 17 28	FT									
M_5	360° 6400 mil		D 1687.99 YD	D	3.2273698	D	3.2273698	D				
M_6	AZ TO FWD STATION	92 17 28	BEARING 87 42 32	SIN BEARING	9.9996527	COS BEARING	8.6018077	TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±			dE	3.2270225	dN	1.8291775	dZ		dE +1686 64	dN −67 48	dZ
STATION M_6	AZ TO REAR STATION		VERTICAL ANGLE							E 282717 95	N 193345 19	Z
E- N+ / E+ N+	ANGLE											
	SUM		FT									
	360° 6400 mil		D YD M	D		D		D				
	AZ TO FWD STATION		BEARING	SIN BEARING		COS BEARING		TAN VERTICAL ANGLE				
E- N- / E+ N-	180° 3200 mil ±			dE		dN		dZ		dE	dN	dZ
STATION	AZ TO REAR STATION									E	N	Z

COMPUTER Cpl. B. Bain | CHECKER Sgt. R. Judge

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft.
To find dZ in Yds. add 9.5228787 to Log D in Ft.
To find dZ in Yds. add 0.0388629 to Log D in meters.

DATE 18 July 1950

DA AGO FORM 1 JUN 51 6-2 EDITION OF 1 MAR 50 MAY BE USED.

Figure 62. Computation for a curved sound base using DA AGO Form 6–2.

COORDINATES FROM AZIMUTH AND DISTANCE

FROM | TO | SHEET 2 OF 2 SHEETS

STATION	AZIMUTH		VERTICAL ANGLE / DISTANCE / BEARING	COORDINATES AND E, N, AND Z DIFFERENCES		
STATION M_3	AZ TO REAR STATION		VERTICAL ANGLE	E 277740.5	N 192713.2	Z
	ANGLE					
M_3	SUM		S FT			
	360° 6400 mil		D 1687.99 YD M			
M_2	AZ TO FWD STATION	243 42 34	BEARING 63 42 34			
	180° 3200 mil ±			dE −1513.38	dN −747.65	dZ
STATION M_2	AZ TO REAR STATION		VERTICAL ANGLE	E 276227.12	N 191965.55	Z
	ANGLE	−9 31 28				
M_2	SUM		S FT			
	360° 6400 mil		D 1687.99 YD M			
M_1	AZ TO FWD STATION	234 10 56	BEARING 54 10 56			
	180° 3200 mil ±			dE −1368.76	dN −987.83	dZ
STATION M_1	AZ TO REAR STATION		VERTICAL ANGLE	E 274858.36	N 190977.72	Z
	ANGLE					
	SUM		S FT			
	360° 6400 mil		D YD M			
	AZ TO FWD STATION		BEARING			
	180° 3200 mil ±			dE	dN	dZ
STATION M_1	AZ TO REAR STATION		VERTICAL ANGLE	E 274858.36	N 190977.72	Z
	ANGLE					
M_6	SUM		S FT			
M_1	360° 6400 mil		D 8208.38 YD M			
	AZ TO FWD STATION	73 14 12	BEARING 73 14 12			
	180° 3200 mil ±			dE +7859.58	dN +2867.46	dZ
STATION	AZ TO REAR STATION			E 282717.94	N 193345.18	Z

LOGARITHMS*: D, SIN BEARING, dE; D, COS BEARING, dN; D, TAN VERTICAL ANGLE, dZ (entries blank for every station)

COMPUTER: Col. B. Bain | CHECKER: Sgt. R. Judge | DATE: 18 July 1950

*NOTE: To find dE, and dN in meters add 9.4840158 to Log D in Ft.
To find dZ in Yds. add 9.5228787 to Log D in Ft.
To find dZ in Yds. add 0.0388629 to Log D in meters.

DA AGO FORM 6-2, 1 JUN 51 EDITION OF 1 MAR 50 MAY BE USED.

Figure 62—Continued.

discussed in FM 24–20. In laying microphone lines, care must be exercised to avoid damaging wire insulation. Splices must be made carefully to avoid excessive line resistance, and they must be well insulated to prevent excessive leakage or possible shorts. Lines which would operate satisfactorily as telephone circuits may be inoperative as microphone lines. The latter usually operate at a potential of 90 to 135 volts; hence, their efficiency is seriously impaired by low-insulation resistance. Leaking lines cause induced sound breaks on the traces; this multiplicity of breaks from one sound source destroys the arrival pattern and makes interpretation difficult.

c. Microphone lines are normally laid from the sound ranging central to the microphone positions. The approximate microphone locations of a regular base frequently can be spotted by a wire laying party before the survey party locates their exact positions. Appendix VI, lists the lengths of standard subbases expressed in miles to facilitate use of odometers by the wire parties in spotting microphone positions. Upon reaching the approximate microphone position, sufficient slack must be provided to allow enough line to move the microphone from its spotted position to its surveyed position. The microphone is installed after the survey has been completed.

108. INSTALLING MICROPHONES

a. Procedure. Microphones are serviced by sound ranging personnel, but they may be installed by communication personnel. Upon arrival of a wire laying vehicle at a microphone position, the wire is cut, tied in, and tested. Sufficient slack is coiled at the position. A microphone is then connected to the line and tested. If the line and microphone are both found to be operative, one wireman is left with a telephone and the necessary equipment to complete the installation; the wire party goes on laying other wire circuits.

b. Emplacing Microphones. The microphone should be installed so as to be shielded as much as possible from the direct effects of wind and other disturbances. A microphone may be suspended from a microphone shelter on the springs provided or by other appropriate means (fig. 63). The standard shelter is a flat canvas cover on a metal frame from which the microphone is suspended in a hole in the ground, as shown in figure a, 63, or, if the character of the ground is such that a hole cannot be dug, a support as shown in figure b, 63 may be built of stones, earth, brush, or similar material. Where terrain does not permit emplacement as indicated in either figure a, 63 or b, 63, the microphone may be suspended from a tripod (fig. 64). Regardless of the method of emplacement, the microphone must be sheltered from the wind.

c. Connecting Telephone to Microphone Circuit. A telephone may be connected to any microphone circuit as may be required for communication with the sound ranging central. It must be disconnected when the microphone is being tested since the microphone is inoperative when the telephone is connected unless the connection is made through an outpost connecting box or other capacitor unit.

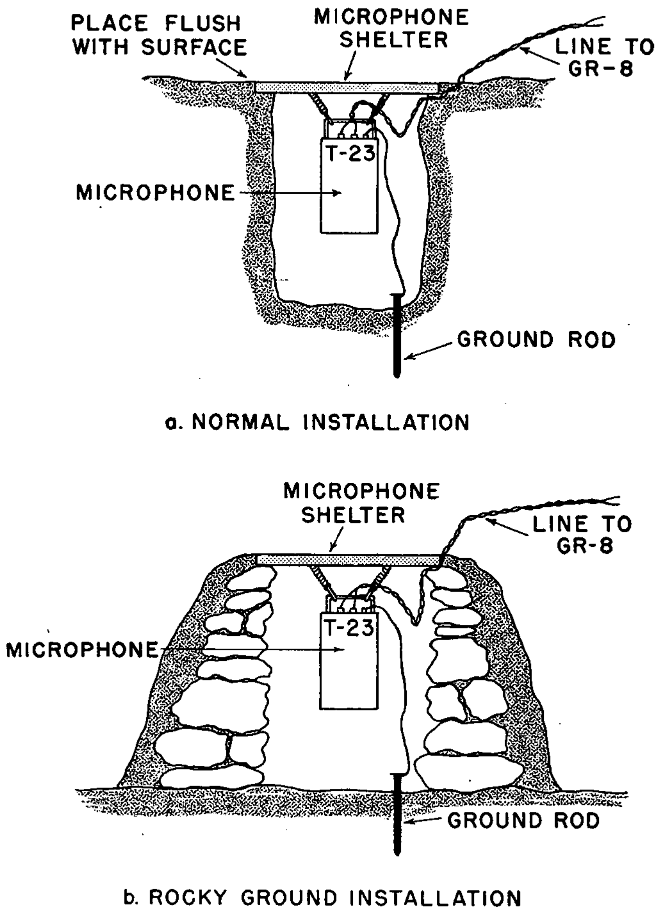


Figure 63. Emplacement of a microphone.

Telephones must not be connected to a microphone circuit when sound ranging is in progress.

d. Avoiding Shocks. When the circuit test key on the sound recording set is in other than the

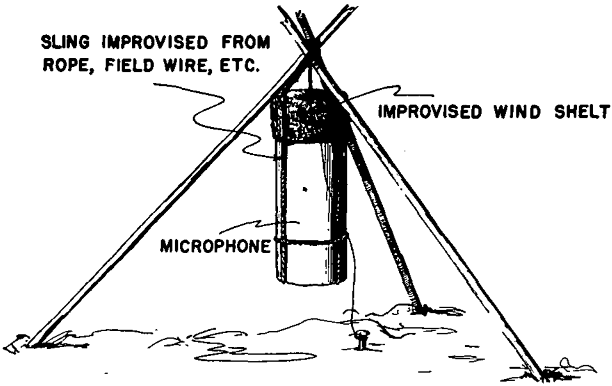


Figure 64. Improvised microphone shelter.

normal position, a high potential is applied to the microphone line. To avoid shocking the wireman, the key is left in the normal position until the wireman calls for a microphone test. It is then moved to the circuit test position *after* the wireman has had time to disconnect his telephone; it is left in that position for a short, prearranged period of time only.

e. Two Microphones On One Line. In an emergency, two microphones may be temporarily connected to a single microphone circuit. The first microphone is connected in the normal manner. When the second microphone is connected, a polarity test must be made at the sound recording set. If this test indicates that the polarity of the second microphone is reversed, the leads at the microphone must be changed.

f. Emplacing Microphones after Resurvey. The position of a microphone will not be changed without notifying the sound ranging central. It is preferable that all necessary shifting of microphone positions be made simultaneously to avoid as much as possible the interruption of sound ranging. If long moves are necessary, it is possible to install microphones at the new position and lay wire lines from them back to the old position. This permits the change-over to be made with a minimum loss of time; the lines from the microphones at the old position are disconnected and spliced into the new lines.

109. RADIO SOUND DATA TRANSMISSION SYSTEMS

a. General. It may be desirable to install a sound base in which some or all of the wire circuits are replaced by a radio sound data transmission system.

b. Employment. The radio sound data transmission system may serve as a means of communication. Under adverse conditions of weather or terrain, the installation of wire circuits may be delayed, or it may be impossible to install them. Also, sustained artillery fire or the operation of mechanized vehicles in the area may make maintenance of wire circuits difficult, if not impossible. Under such conditions, the system may provide communication between microphones and sound central, thereby permitting operation of a sound base which would otherwise be useless. The radio sound data transmission system facilitates rapid occupation of position and displacement.

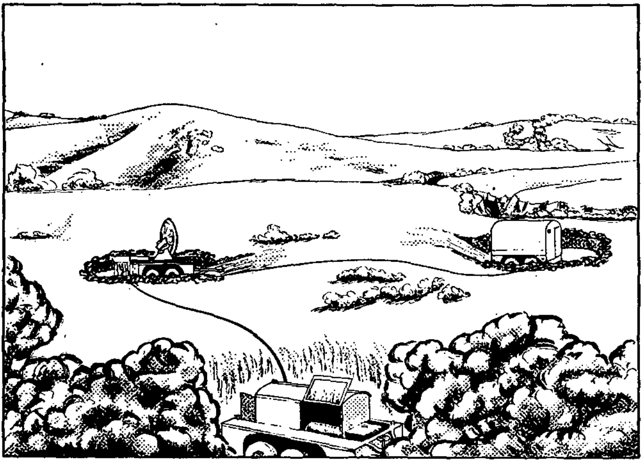
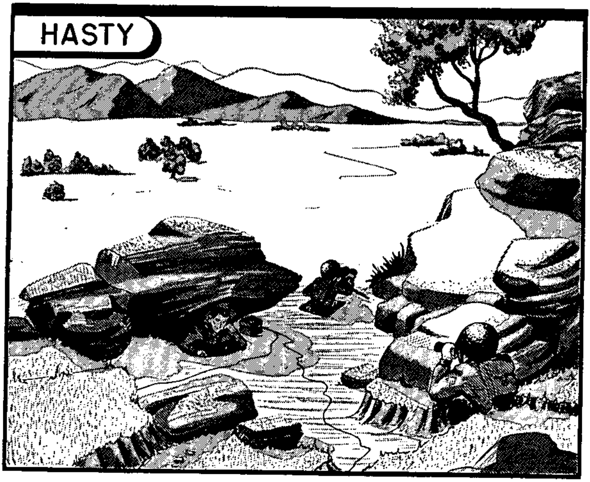
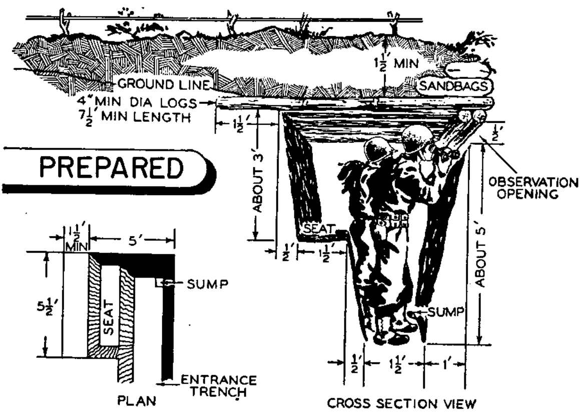


Figure 10. Type organization of a radar position (camouflage omitted).

d. Observation Posts. Observation posts are dug in and protected by overhead cover and camouflage to the greatest extent possible in the time available. Typical observation posts, both hasty and prepared, are shown in figure 11. The assistant observer or the recorder acts as a sentry at each observation post. Defense measures are *primarily* passive measures such as concealment, camouflage, and digging in. The observation post is of little or no value if the enemy discovers it. Extreme care must be taken to keep it hidden. Only as a last resort will the personnel engage in active defense with small arms fire. Vehicles and radio are kept well away from the observation post. They must be concealed, camouflaged, and defiladed.



1



2

Figure 11. Type organization of a flash observation post.

c. Installations. The number of microphones operated on the radio system depends upon the situation. It will usually be possible to lay at least one wire circuit to the microphone nearest the sound ranging central while radio communication is being established to the other microphones.

110. ORGANIZATION OF SOUND RANGING CENTRAL

The sound recording set (fig. 65) and the sound ranging plotting board (fig. 66) should be located near each other to permit the recorders and plotters to work together. In setting up the sound recording equipment, communication circuits should be connected and tested promptly. Sound plotting equipment is prepared for operation, and the sound ranging central is organized in the most expeditious manner consistent with the time available. In rapidly moving situations, the sound recording set may be installed in a small vehicle, trailer, or van.

Section IV. OPERATIONS

111. OPERATIONS OF OUTPOST OBSERVERS

In a rapid installation, the outpost observer may lay his own wire circuit from the recording set to his outpost position. If the base is to be "shot in," he must detonate an explosive at a point near the outpost, as described in paragraph 104. Immediately upon arrival at the out-

Figure 65. Sound recording set.

post position, the observer installs his equipment. He should be provided with a map and compass. He listens for the sounds of guns or shell bursts to be recorded, starts the sound recording set, and stops it when directed to do so by the sound recorder. He reports to the sound ranging central the apparent azimuth to, the estimated range to, and the suspected caliber of, specific enemy guns or batteries. He also reports the number, distribution, and activity of enemy guns in the general target area. He reports all other activity he observes. The outpost observer must be carefully trained and must have extensive experience. The effectiveness of sound ranging is directly proportional to his ability.

112. RECORDING

a. General. The technique of operating and maintaining the sound recording equipment is described in TM 11–2568.

b. Sound Ranging Adjustment. To record the shell bursts in a sound ranging adjustment, the sound recording set should be started by the operator, not by the outpost observer. To reduce wastage of recording paper, allowance should be made for the time of flight of the projectile and the estimated time of travel of the sound from the point of burst to the nearest microphone.

113. RECORDS

a. General. Records are obtained by recording sound arrivals either electrically (dry process)

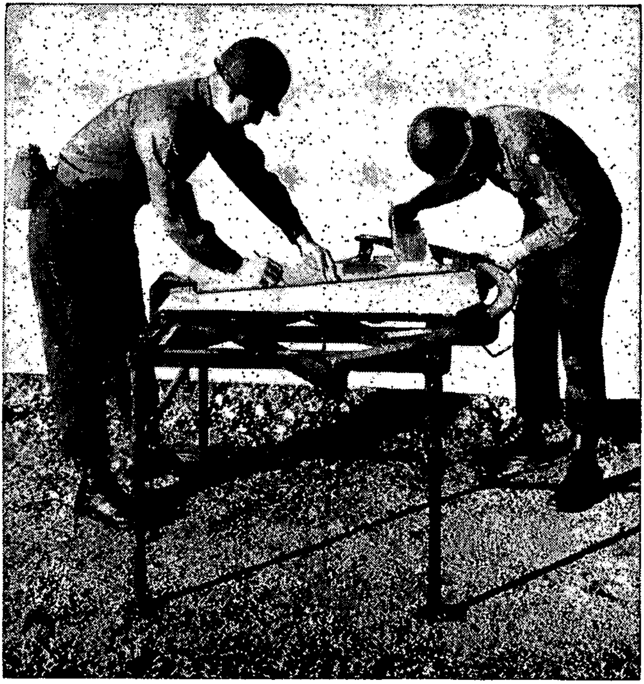


Figure 66. Sound ranging plotting board.

or photographically on a paper tape, at a rate of approximately 6 inches per second (fig. 67).

b. Galvanometer Traces.

(1) A number of horizontal lines are traced on the record—one corresponding to each microphone installed. Normally, the upper line is traced by the galvanometer connected to microphone number 1, the second by that connected to microphone number 2, et cetera.

(2) When no sound or wind strikes a micro-

phone, the corresponding galvanometer trace is recorded as a straight line. Wind causes the line to waver from its normal position in an irregular manner (fig. 68). When the sound of a gun reaches a microphone, an electric impulse is communicated to a galvanometer producing a wavy line or break (fig. 67). The point at which the trace first departs from its straight line part, or *zero line,* is the *initial break.* With sound ranging equipment now in use, the initial break is always downward for a sound, beginning with a compressional wave, produced by a gun or bursting shell. The low and high points on the trace are termed respectively *valleys* and *peaks.* The total elapsed time from the initial break until the trace has made one excursion downward and back and one excursion upward and back to the zero line (one cycle of oscillation) is the *period* of the sound wave. The configuration on the record of the breaks produced on the several traces by one sound wave, as it arrives in turn at the various microphones, is the *pattern of arrivals.* The pattern may be made more apparent if a smooth curve, connecting the initial breaks, is drawn on the record.

c. Dry Recording Process. A sound recording set which utilizes a dry recording process is shown in figure 65. Galvanometer traces are recorded on the record (fig. 67) by electric styli.

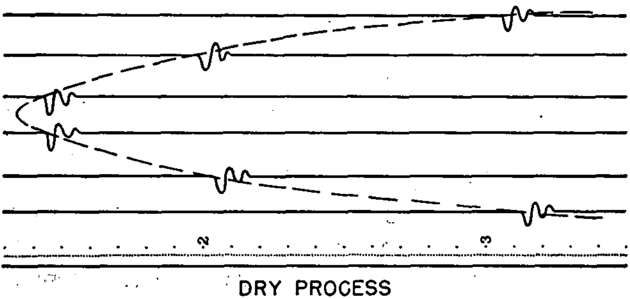
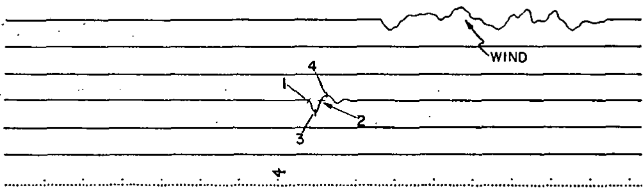


Figure 67. Sound ranging record.



NO. 1 : INITIAL BREAK, FIRST CHOICE, READ WHENEVER POSSIBLE.
NO. 2 ZERO LINE, SECOND CHOICE, READ WHEN INITIAL BREAK IS OBSCURED ON ONE OR MORE STRINGS.
NO. 3 : FIRST VALLEY, THIRD CHOICE, READ WHEN INITIAL BREAK AND ZERO LINE ARE OBSCURED ON ONE OR MORE STRINGS.
NO. 4 : FIRST PEAK, FOURTH CHOICE, READ WHEN NO'S 1,2,& 3 ARE OBSCURED ON ONE OR MORE STRINGS.

Figure 68. Reading indistinct breaks.

Time scales are recorded by two additional styli and a timing stamp. A row of dots, at intervals of 0.010 second, is marked near and parallel to the lower edge of the strip. Just above and synchronized with the row of 0.010-second dots is a similar row of dots at 0.100-second intervals. The timing stamp, which is synchronized with the 0.100-second stylus, prints consecutive numbers at 1-second intervals above the time dots. Since no identification data are recorded, a serial number and the time the record was made, along with any additional identification data and any information reported by the outpost observer, should be noted on the back of the record.

114. RECORD READING

a. Procedure. Selection of the desired pattern of breaks is the first step in reading a record. If there is only one pattern, this is a simple operation. When there are several patterns, which is frequently the case in combat, the reader must have a mental picture of the desired pattern in order to isolate it from the others. The record should be laid out carefully on a table or flat surface, with the end first emerging from the recording set to the left. With the time scale as a basis, the reader determines the time of the initial break for each trace with the aid of a special plastic record reader (dry recording process). Whole seconds, tenths, and hundredths are read directly, and thousandths are estimated by interpolating between the dots or lines. Thus in figure 67, the times are read as follows:

M_1: 3.070
M_2: 2.000
M_3: 1.450
M_4: 1.460
M_5: 2.030
M_6: 3.130

b. Indistinct Breaks.

(1) It is preferable to read each trace at the initial break when it can be identified. In some cases, the trace may break

so gradually from the zero line that the initial break is difficult to determine. This condition is aggravated if wind interference or other disturbances are superimposed on the trace.

(2) When it is impossible to locate the initial break accurately, other points along the trace may be read provided that the corresponding points on all breaks of the pattern are read (fig. 68).

c. Typical Patterns.

(1) An experienced reader associates the location of a sound source, in relation to the base, with a corresponding pattern of breaks produced on the record. Several typical patterns for a regular straight sound base and the corresponding locations of the sound source are shown in figure 69. For each pattern, a smooth curve can be drawn connecting the initial breaks. In each case, the curve is concave to the right. It is symmetrical if the sound source is to the direct front, skewed in one direction with its lower branch elongated when the sound source is to the right front, and skewed in the other direction with its upper branch elongated if it is to the left front. The over-all length of the pattern decreases as the range increases.

(2) When informed by the outpost observer of the approximate location of the sound source, the reader visualizes the pattern that should be obtained. This frequently

enables him to pick out the correct pattern although there are other patterns present on the record.

(3) Patterns for a curved base, shown in figure 70, are generally shorter than for a straight base, making it easier for the reader to perceive the entire pattern at a glance and to visualize the curve connecting the initial breaks. At distances

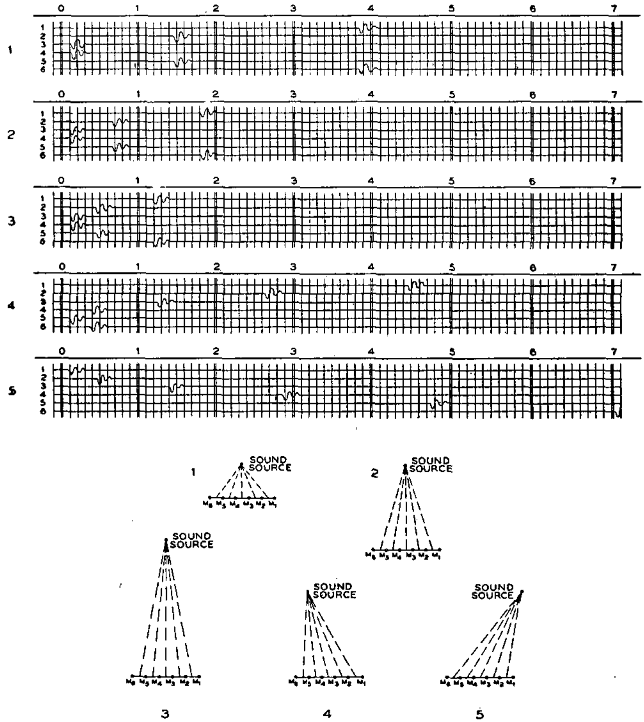


Figure 69. Typical patterns (not actual records) on a straight base for various locations of the sound source.

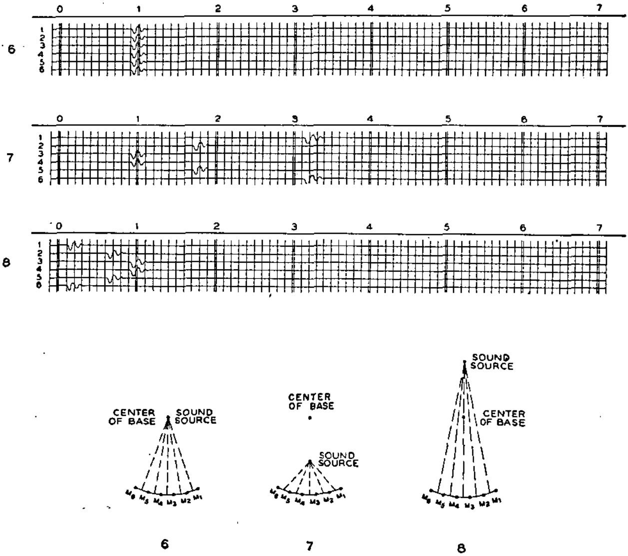


Figure 70. Typical patterns (not actual records) on a curved base for various locations of the sound source.

beyond the center of curvature of the base, the pattern becomes concave to the left. Such a pattern is not possible for a straight base.

d. Ballistic Waves. A projectile passing through the air at a velocity greater than the velocity of sound generates a sound known as a ballistic wave. This sound may easily be mistaken for the muzzle wave of a gun or other explosion. To the ear it often sounds louder and sharper than that of the gun firing the projectile. One ballistic wave may be formed by the projectile on the ascending branch of the trajectory, and still another on the descending branch. The ballistic wave which originates at the muzzle end of the trajectory is slightly elevated and appears to be a listener to come from the level of the top of the distant tree-line; whereas, the muzzle wave comes in at an apparent zero elevation. The ballistic wave on the impact end of the trajectory appears to a listener to come from a high elevation or overhead. Breaks produced on records by ballistic waves should not be mistaken for those produced by guns or bursting shells. Sound plotting methods assume that the sound originates at a fixed source. This is not the case for a ballistic wave. The ballistic wave striking one microphone may originate at one point on the trajectory, while that striking another microphone may have originated at another point. If an attempt is made to plot the sound source by the usual methods, the rays of the plot may be widely dispersed or they may converge to a reasonably small polygon of error. The resulting plot will be misleading. Since the sound originates in a moving source on the trajectory, it does not give the location of the gun. The sequence of arrival of the ballistic wave, sound of the shell burst, and gun wave at any one point varies with local conditions.

e. Characteristic Breaks.

(1) *General.* As the air enters the microphone, the trace moves downward, and as the air is expelled, it moves upward. Distinction between a ballistic wave and a gun wave is based upon the amplitude

and frequency of variations in the wave trace as shown on the sound record. Estimation of gun caliber is also based upon variations in wave amplitude and frequency. The accuracy of the interpretation is dependent in part upon the fidelity with which the trace follows sound pressure variations at the microphone.

(2) *Ballistic waves.* Recording equipment which is sufficiently sensitive to the higher frequencies may record a ballistic wave, as shown by the first break in the third (upper) trace in figure 71, so that it can readily be distinguished from a gun wave. Equipment less sensitive to higher frequencies may record the same sound, as shown in the first break in the fifth (lower) trace in figure 71, so that the trace may be mistaken

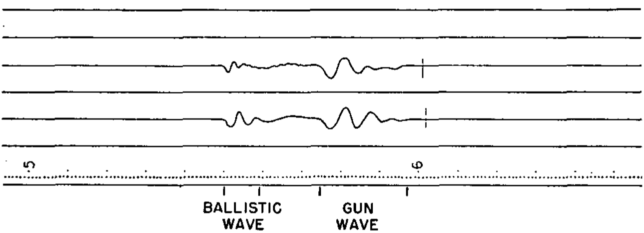


Figure 71. Ballistic and gun waves.

for that of a gun wave. Experience with a particular sound ranging set will determine into which class the wave falls. The relative amplitudes of recorded gun and ballistic waves do not agree with their relative loudness as heard by an observer and may be misleading to a reader. A ballistic wave may sound much louder than a gun wave, yet be recorded on the record with lower amplitude.

(3) *Caliber determination.* The period (fig. 67) of a gun wave is a function of the caliber of the gun. A measurement of the recorded period is an aid in estimating the caliber. Only smooth, typical gun waves with no obvious distortion should be used for this purpose. Results will be reasonably accurate *only* if the recording equipment is capable of following faithfully the sound pressure variations. (Note the breaks in fig. 71.) The recorded period will not be the same for all guns of the same caliber but will vary with the design characteristics of the gun, such as its tube length and powder charge, and with the weather and the distance to the gun from the sound base. Data should be accumulated for modern guns likely to be encountered in combat. Specific weapons cannot be identified positively by this method unless there are other indications as to weapon type or unless only a few types are in use on a given front. However, guns can be classified as light, medium, or heavy.

115. TIME INTERVAL DETERMINATION AND PROCESSING

a. General. Sound ranging plotting requires the determination of differences in time of arrival of the sound wave at successive pairs of microphones (par. 96*f*). All calculations pertaining to the time differences, or intervals, are made on the sound plotting record. This record is a form providing spaces for data descriptive of the sound base, meteorological data, computations of initial and final time intervals, coordinates of the sound source, and allied information. Figure 72 shows the sound plotting record with complete entries thereon; it should be referred to as the reader studies this paragraph. For special methods of processing time intervals see paragraph 117.

SOUND PLOTTING RECORD

Base: Location BALD RIDGE Type 6 MIC 4 SEC STRAIGHT Azimuth 224-10-00 Date 15 JUNE 1950

Record No. 8 Time 1154 Temperature 91 °F. Wind: Direction 3400 mils. Speed 12 m.p.h.

TIME READINGS

Results to (−)	28057	27321			
1. 28057	2. 27321	3. 27029	4. 27196	5. 27813	6. 28862
Results to (+)			27029	27196	28813

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		.736		.292	.167		.617		1.049	
Temperature Correction		.030		.012	.006		.025		.041	
Wind Correction		.053		.053		.053		.053		.053
Sub-Totals		.819		.357	.173	.053	.642	.053	1.090	.053
Subtract					.053		.053		.053	
Weather Corrected Time Interval		.819		.357	.120		.589		1.037	
Curvature Correction		.001		.001	.000		.001		.002	
Final Time Interval		.820		.358	.120		.590		1.039	
Approximate Distance	12600		12400		12300		12500		12800	

Coordinates: E. 67530 N. 92105 Accuracy 100 Meters. Caliber Hvy File No. 2

Area Shelled Unknown Number of Pieces 2 Time Reported 1160 Cons. No. 28

DA AGO FORM 1 JUN 51 6–4 REPLACES FAS FORM 4, 20 JUN 44, WHICH IS OBSOLETE.

Figure 72. Time interval computations using DA AGO Form 6–4.

b. Initial Time Intervals. Arrival times of the sound wave at each microphone along the sound base are determined as described in paragraph 114. The sound plotting record indicates the procedure by which the time intervals are found. A time interval is plus (+) when the lower-numbered microphone of a particular pair receives the sound wave first, minus (−) when the lower-numbered microphone receives the wave last. The proper sign of the interval is determined automatically by the manner in which arrival times are entered on the plotting record for calculations.

c. Weather Corrections.

(1) *General.* Nonstandard meteorological conditions affect the speed and direction of

WEATHER DATA FOR SOUND RANGING

STATION	LOCATION	DATE	RELEASE TIME (L.S.T.)	FLIGHT NO.
M/F	FORT SILL, OKLA.	15 OCTOBER 1948	1517	4

TEMPERATURE DATA

Dry Bulb Temperature	84	°F
Wet Bulb Temperature*	78	°F
Virtual Temperature*	89	°F

*Not required when dry bulb temperature is less than 60F.

FLIGHT DATA

Minutes	Elevation Angle, Degrees	Azimuth Angle, Degrees	Horizontal Distance, Yards	Wind Direction, Mils	Wind Speed - mph
(Surface)	32.4	313.5	XXXXXX	2400	14
1	20.4	332.8	650	2700	22
2	16.9	352.2	1510	3300	31
3	15.4	9.7	2470	3800	38
4	14.1	26.2	3540	4200	47

EFFECTIVE WINDS

Wind Structure	Weighting Factors (Check and use one column)				Weighted Wind Direction	Weighted Wind Speed
	✓					
	Normal	(2)	(3)	(4)		
2d min wind speed is:	1 to 2 Times 1st min.	Over 2 Times 1st min.	Less than 1st min. and Within 2 mph of sfc.	Less than 1st min. and not within 2 mph of sfc.		
Surface	0.2	0.4	0	0	480	2.8
1st Min.	0.5	0	1.0	0	1350	11.0
2d Min.	0.15	0.3	0	1.0	500	4.6
3d Min.	0.075	0.15	0	0	280	2.8
4th Min.	0.075	0.15	0	0	320	3.5
Totals (Effective wind)					2930	24.7

DATA REPORTED TO SOUND RANGING PLATOONS

EFFECTIVE TEMPERATURE	87	°F.
EFFECTIVE WIND DIRECTION	2930	mils
EFFECTIVE WIND SPEED	25	mph.
RELEASE TIME	1517	(L.S.T.)

DELIVERED TO		TIME
SGT. TOOHEY		1600
OBSERVER	**RECORDER**	**PLOTTER**
MOTT	OLSON	KLINE

DA AGO FORM 1 OCT 50 11-211 REPLACES SC FORM 435, WHICH IS OBSOLETE.

Figure 73: Reporting weather data for sound ranging using DA AGO Form 11–211.

the propagation of sound waves. Hence, initial time intervals must be corrected according to the effective values of temperature and wind reported by the meteorological section on the form for reporting weather data for sound ranging, DA AGO Form 11–211 (fig. 73). For a more detailed discussion, see TM 20–240.

(2) *Temperature.* Temperature correction is computed on a temperature correction chart (app. VIII). One chart suffices for all subbase lengths. The chart is entered with the initial time interval and effective temperature. The correction is found by prolonging a straight line from the time interval scale through the temperature scale to the correction scale. Should a time interval greater than 3.000 seconds be encountered, the correction is twice that for half the interval. The correction takes a sign according to instructions on the chart. Each initial time interval requires a correction.

(3) *Wind.*

(*a*) *General.* The wind correction may be determined by registration or by the use of the wind corrector M1 or wind charts. The wind corrector and wind charts are based on the equation $dt = \dfrac{ws \cos I}{V}$ where dt is the correction, w is the speed of the wind, s is the subbase length, I is the angle between subbase direction and wind direction, and V is the speed of sound at 50°F. Wind corrections for a straight, regular base, except when determined by registration, are the same for all subbases. In other cases, a correction is determined for each subbase. The same set of corrections is used for all sound sources and need not be redetermined until new weather data are obtained.

(*b*) *Wind corrector M1.* The wind arm of the wind corrector M1 (fig. 74) carries a strip with four scales engraved on it, one along each edge—front and back. The scales are graduated for 4.0-, 4.5-, 5.0-, and 5.5-second subbases. The strip is attached to the wind arm so that the desired scale is along the edge passing through the pivot. The wind arm is set at the reported wind azimuth in degrees (on the outer azimuth scale) or mils (on the inner azimuth scale). The five subbase markers are moved around the azimuth scales to mark the *back-azimuth* of each subbase. Only one marker is required for a straight base. The central disk is rotated to line up the arrow on it with the marker for the first subbase. Opposite the value

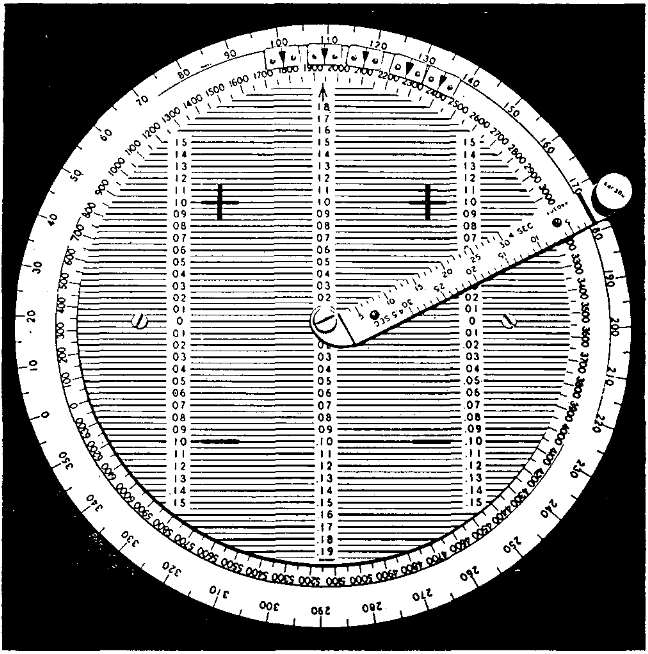


Figure 74. Wind Corrector, M1.

of wind velocity on the wind arm scale, the wind correction is read from the parallel lines on the central disk. The sign is indicated on the disk. Corrections for other subbases of different azimuths are found in the same manner.

(*c*) *Wind correction charts.* The wind corrections for standard subbase lengths may be determined from the appropriate chart. For examples of wind correction charts, see appendix VIII.

The wind correction chart for all subbases permits wind corrections to be determined for subbases of nonstandard lengths. The corrections are obtained from these charts by following the mechanics described for determination of the temperature correction; the proper chart is entered with wind speed and wind angle (difference between subbase and wind azimuths). The sign of the correction is such as to move the sound source upwind.

d. Weather-Corrected Time Intervals. Temperature and wind corrections are added algebraically to initial time intervals to obtain weather-corrected time intervals.

e. Curvature Correction.

(1) *General.* The method of plotting, described in paragraph 96*f*, is not mathematically exact. The resulting discrepancy is compensated for by the application of a curvature correction. This correction is applied to the weather-corrected time intervals to obtain final time intervals.

(2) *Rough plot.* Curvature corrections are based in part on approximate distances from subbase midpoints to the sound source. Distances may be determined from a rough plot of the sound source. The mechanics of making the rough plot with the fan are described in paragraph 116*a*, *b*, and *c*. Weather-corrected time

intervals are used.

(3) *Determining the Curvature Correction.* The approximate distance from each subbase midpoint to the sound source is scaled to the nearest 100 *yards* from the rough plot. This plot may be made on a separate board at a reduced scale and without a grid. The curvature correction chart for the proper length subbase is used. For an example of a standard length subbase chart, see appendix VIII—figure 151. The proper chart is entered with the time interval and distance. The mechanics of finding the correction follow those described for the temperature correction. The sign is always the same as that of the weather-corrected time interval. A curvature correction must be found for each weather-corrected time interval.

f. Final Time Intervals. Curvature corrections are added algebraically to weather-corrected time intervals to obtain final time intervals.

g. Mean Intervals for Several Records. If several records are obtained for one enemy gun or from the guns of a closely grouped battery, it is not necessary to complete the plotting record for each sound record. The corresponding initial time intervals for the several records should be compared to ascertain that all agree within a few thousandths of a second, and then averaged to obtain a set of mean time intervals. Corrections are applied to these averaged time intervals, and a corrected plot of the mean location is made.

116. METHODS OF PLOTTING

a. General. Sound plots may be made on grid sheets, maps, photomaps, photos, and the M1 sound plotting board. Because of the relative accuracies of present equipment, it is customary to make rough plots with plotting fans, and final plots on the M1 board. Relative locations (*h* below) may be made with sufficient accuracy with plotting fans. Final plots must, of course, be made on the grid system in use by supported artillery.

b. Regular Base Fan. A transparent fan (fig. 75) may be employed for plotting when the base is regular. Such a fan is constructed for a particular length subbase; fans are presently issued for subbases of 2 and 4 seconds. To prepare the board for plotting, the midpoints of the subbases are plotted near the lower edge of the board to the scale at which it is desired to plot sound locations. When plotting on a map or air photo, the scale of the map or photo is used. A segment of the reference line is drawn to fall under the time scales of the fan for each subbase. Each reference line is marked with a prominent arrowhead. A map pin is inserted at each midpoint. The fan is centered on the map pin at the first midpoint. The value of the first time interval t_1, found on the time scale of the fan, is set over the first reference line, and a ray is drawn along the appropriate edge of the fan. If t_1 is positive (+),

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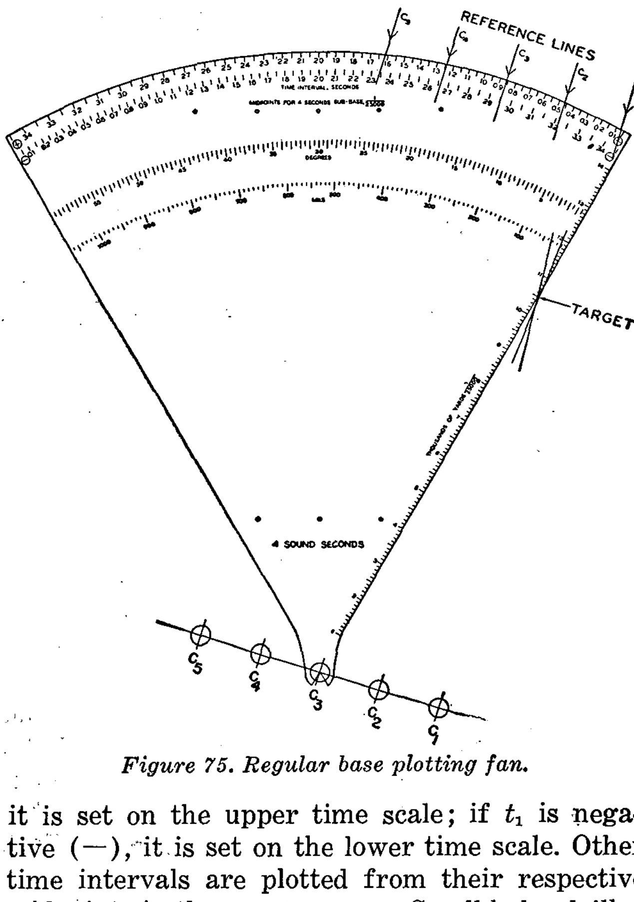


Figure 75. Regular base plotting fan.

it is set on the upper time scale; if t_1 is negative (—), it is set on the lower time scale. Other time intervals are plotted from their respective midpoints in the same manner. Small holes drilled through the fan constitute a template for plotting the locations of midpoints of a straight base at the scale for which the fan is designed. Similar holes below the time scales mark the corresponding positions for reference lines.

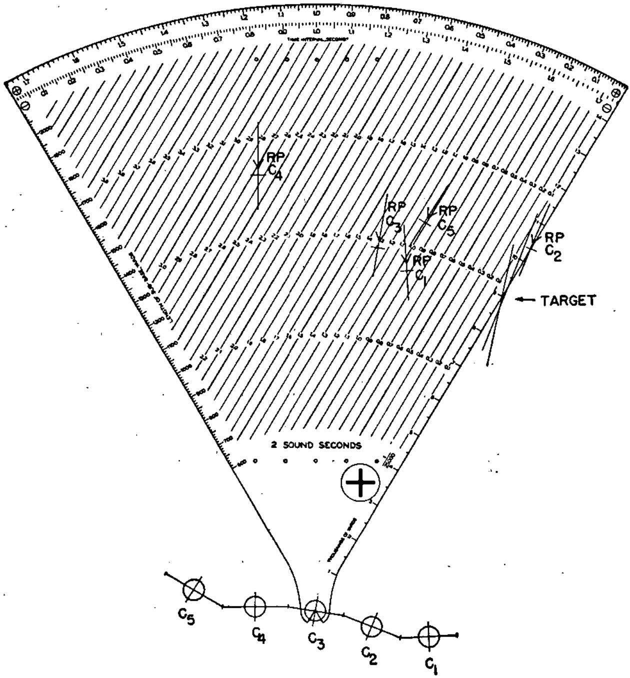


Figure 76. Irregular base plotting fan.

c. Irregular Base Fan.

(1) *General.* The irregular base fan is designed to plot for any length of subbase. Figure 76 illustrates a fan with both irregular base scales and 2-second base time scales. In preparing the plotting board, the midpoints are plotted and a reference line is drawn for each subbase. An index mark is constructed at right angles to each reference line, a subbase length distant from the mid-

point of the subbase, as measured by the subbase scale along the left edge of the fan. This scale is independent of the scale of the sound plot. The intersection of each reference line and the appropriate index is marked by a prominent arrowhead. A map pin is inserted at each midpoint. The fan is used face up for positive time intervals, and face down for negative time intervals. The fan is centered on the map pin at each midpoint in turn and rotated until the index mark lies under the computed time interval as read from the scale on the parallel time lines. A ray is then drawn along the edge of the fan which is parallel to the time lines.

(2) *Automatic temperature correction.* A temperature correction may be applied automatically to each ray by shifting the position of the index marks. The length of each subbase is multiplied by $337.6/V_x$, in which V_x is the velocity of sound at the existing effective air temperature (app. IX). The index marks are located on the basis of these modified subbase lengths.

d. Range-Deflection Fan. Plots for any type sound base may be made by solving the equation $t/s = \sin D$ to determine the angle D corresponding to each recorded time interval, and plotting the angle with a range-deflection fan. The equation may be solved with the military slide rule.

e. Improvised Plotting Board. Time scales similar to those on the sound plotting fan may be drawn on the surface of the plotting board (fig. 77). The positions of the midpoints are plotted and a separate scale drawn for each subbase, the zero point of which is on the perpendicular bisector of the subbase, positive values to the right and negative values to the left. All are constructed concentric about C_3. In plotting, a ray is drawn from each midpoint to the point on the time interval scale corresponding to the time interval for the corresponding subbase. Each ray may be materialized by a thread or gut stretched across the board, attached to the midpoint, and affixed at the proper point on the time scale, usually by means of a small weight. Applications of this type plotting board are limited. A plotting board constructed for a standard curved base or for an irregular base can be used only for the particular base for which constructed. A plotting board constructed for a standard straight base may be used for other length subbases, but the scale of plotting must be varied to correspond and a factor applied to each time interval (par. 123). For example, a board designed for 1/50,000 plotting for 4-second subbases may be used for 1/25,000 plotting for 2-second subbases providing each time interval is multiplied by 2 to adapt it to the 4-second time scales. Reference lines cannot be adjusted on this type plotting board and the polygon of error must be reduced by application of a constant time interval correction for each

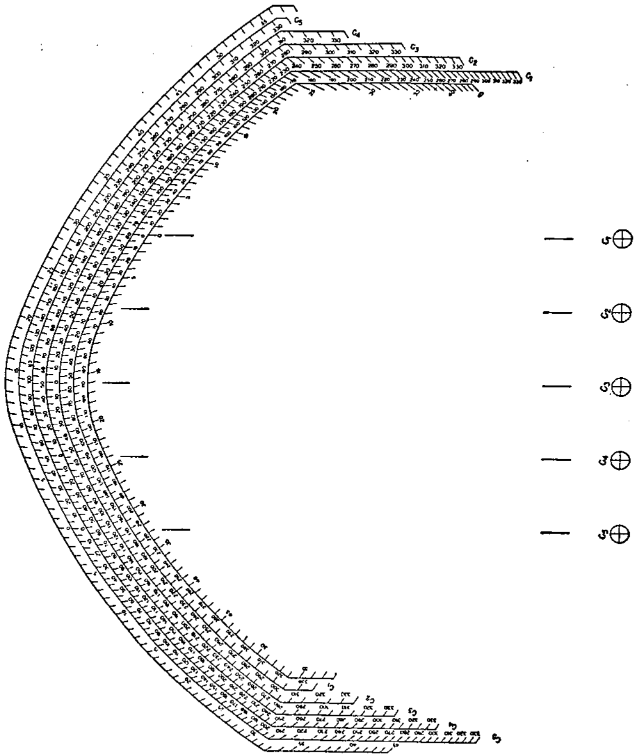


Figure 77. Improvised plotting board.

subbase.

f. Mechanical Plotting Board.

(1) *General.* The operation and care of the mechanical sound ranging plotting board (fig. 66) is described in TM 9–575. This board provides an accurate means of plotting. It can be used for any of the standard curved bases or for 4.0-, 4.5-,

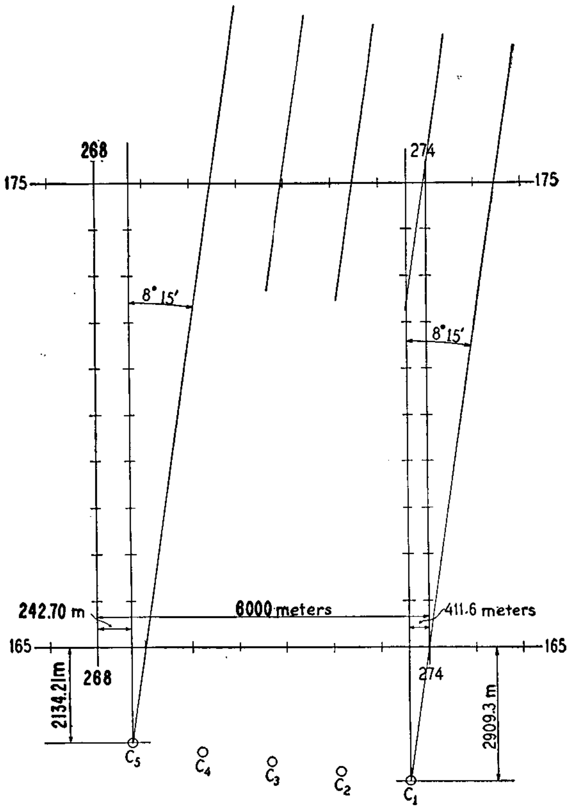


Figure 78. Constructing grid on plotting board.

5.0-, and 5.5-second, straight bases at a scale of 1/20,000. Plotting can also be performed for the same straight bases at a scale of 1/40,000. Other lengths of subbase may be used if the scale of plotting is changed accordingly and the proper factor applied to each time interval (par. 123).

(2) *Construction of grid on plotting board.* When time permits, a grid is constructed directly on the plotting surface of the board. One method is described in TM 9–575. The following method (fig. 78) is more rapid.

(*a*) Compute the angle between the reference line of subbase M_1M_2 and a grid line direction ((3) (*a*) below). For a curved base, the direction selected should be that which is nearest the reference line of the center subbase. The plotting arm is set at the computed angle and a long ray drawn from C_1. The same procedure is followed for the subbase on the opposite flank.

(*b*) Select a grid line perpendicular to the rays drawn, at a convenient distance in front of the base. From the coordinates of the midpoints, compute the distance from each of the two midpoints to the grid line. Mark off this distance on each ray, thus locating the grid line. Other parallel grid lines are laid off at 1,000-meter intervals.

(*c*) Compute the distance from each of the two rays to the next grid line parallel to it. Scale off these distances to fix points through which the grid lines should pass, and draw the grid lines parallel to the original rays. Draw parallel lines of 1,000-meter intervals to complete the grid.

(*d*) The grid must be inked if time permits. Inked grids are removable with alcohol.

(*e*) As an illustrative example, a 4-second, straight base has an azimuth of 278° 15′. The coordinates of C_1 are (273,588.40–162,090.70) and the coordinates of C_5 are (268,242.70–162,265.79). The azimuth of the base plus 90° is 368° 15′ or 8° 15′. The grid line direction nearest this azimuth is north, which is 8° 15′ to the left. Rays are drawn from C_1 and C_5 8° 15′ left of the reference lines. A grid line perpendicular to the rays drawn, and in front of the base, is north of both midpoints. The 165,000 grid line is selected. Comparison of this value with the N coordinates of C_1 and C_5 shows it to be 2909.3 meters north of C_1 and 2134.21 meters north of C_5. These distances are measured along the corresponding rays from C_1 and C_5. The 165,000 grid line is drawn through these points, and parallel grid lines are laid off at 1,000-meter intervals. The ray from C_1 is at an E coordinate of 273,588.40—411.6 meters left of the 274,000 grid line. This distance is measured and marked. Similarly, a distance of 242.70 meters is measured to the left of the ray from C_5 to locate the position of grid line 268,000. The distance between the two marks is measured to verify that the positions for grid lines 268,000 and 274,000 are exactly 6,000 meters apart. These grid lines are drawn parallel to the two rays, and other parallel lines are drawn at 1,000-meter intervals to complete the grid.

(3) *Positioning map or grid sheet on plotting board.*

(*a*) When the positions of the midpoints on the plotting board are fixed, as is the case with the mechanical plotting board or the improvised plotting board, the scale of the grid must correspond to the scale at which the midpoints are spaced. The map or grid sheet may be correctly positioned on the board as follows:

To the azimuth of a subbase (usually M_3 or M_4 add 90°. Determine the angle from the resulting azimuth to the nearest grid line direction. Set the plotting arm at the computed angle from the reference line of the subbase. On the mechanical plotting board this is done with the degree scale on the board. It is done on other boards with a range-deflection fan. On the map or grid sheet, a point is plotted a convenient distance from the midpoint, in the direction of the determined grid line. Draw a ray from this point parallel to the grid lines, toward the midpoint, and extend it in the opposite direction. Place the map or grid sheet under the plotting arm with the line along the edge of the arm and with the plotted point the correct distance from the midpoint. Affix the grid sheet to the board.

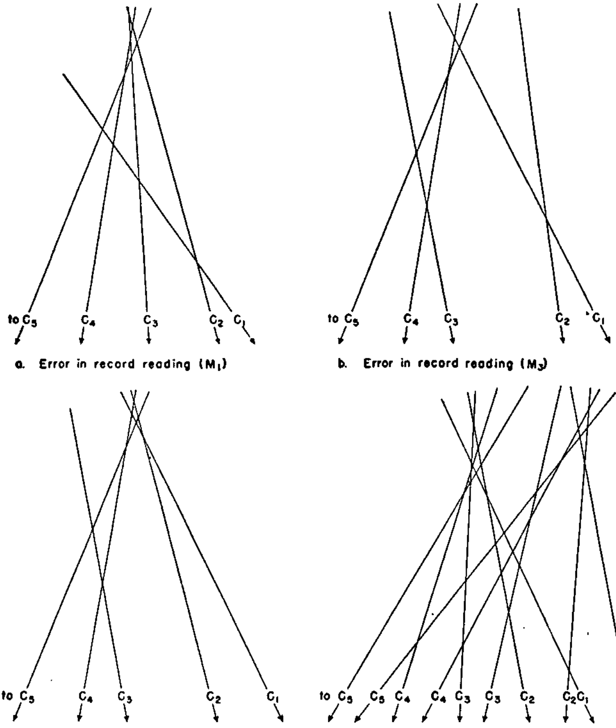
(*b*) As an illustrative example, the azimuth of a curved base is 201° 20′. The azimuth of the reference line from C_3 is 201° 20′ plus 90°, or 291° 20′. The nearest grid line direction is 270°, or 21° 20′ less than the azimuth of the reference line. The plotting arm is set at 21° 20′, through C_3 to the left of the reference line. The coordinates of C_3 are (205,343.20 – 403,439.00). A point 5,000 meters west of C_3 is selected, at coordinates (200,343.20 – 403,439.00). It is plotted on the grid sheet, and an east-west line is drawn through it. The grid sheet is placed under the plotting arm with this line along the edge of the arm and with the plotted point 5,000 meters from the center point.

g. Polygon of Error.

(1) *General.* Even with accurate survey and complete curvature and weather correc-

tions, a *point plot* (all rays of the sound plot intersecting at the same point) is seldom obtained, principally because exact weather corrections cannot be made. The polygon bounded by the intersecting rays is termed the *polygon of error*.

(2) *Interpretation.* Although a point plot or a small polygon of error gives the impression of being an accurate location, that is not necessarily true. Survey errors or weather effects can displace the entire plot without appreciably enlarging the polygon of error. Other factors as well as appearance should be considered (par. 118*c*) before a point plot is accepted as an accurate location. The application of weather corrections frequently enlarges the polygon of error but improves its position. A large polygon of error, particularly with one or two rays widely divergent from the rest, may indicate an error due to a terrain obstruction (large building or hill) or an error in record reading, computed time intervals, plotting, or survey. Certain of these errors produce characteristic plots which may indicate the source of error. If the affected microphone is on the flank, only the ray from the midpoint on that flank will be in error. If the microphone is an interior one, the two rays from the midpoints on either side will be in error



a. Error in record reading (M_1)

b. Error in record reading (M_3)

c. Error in computing time interval (ray from C_3).

d. Two plots; error in survey (subbase $M_3 - M_4$ too short).

Figure 79. Effects of common errors on appearance of plots.

in opposite directions. Plots similar to those described above result from an error in reading a break on the record, where only one ray is affected if the break on a flank microphone is read erroneously (a, fig. 79), while an error in reading the break on an interior microphone causes the two adjacent rays to be in error in opposite directions (b, fig. 79). An error in plotting or computing time intervals affects only one ray (c, fig. 79). An error in survey causes distortion of plots similar in shape for all sound sources (d, fig. 79). Any radical change in the appearance of the polygon of error between successive plots in the same general area suggests the presence of errors or a large change in weather conditions. None of the above effects are evident in a plot of less than three rays. *Two-ray plots are not reliable.*

(3) *Evaluation of polygon of error.* The polygon of error must be evaluated to determine the probable location of the sound source. This is accomplished by inspection unless the polygon is very large or time is available for a more careful evaluation. When the polygon is not evaluated by inspection, either of the methods described below may be used. In each case, a unit weight is given to the intersection of any two rays, which simplifies procedure but does not take into account relative strength of the intersection.

(*a*) *By computation.* If a grid has been placed on the sound plotting board, the coordinates of the intersection of each pair of rays is read. There are three such intersections in a three-ray plot, six in a four-ray plot, and ten in a five-ray plot. The E coordinates of all intersections are averaged to obtain the mean E coordinate, and the N coordinates of all intersections are aver-

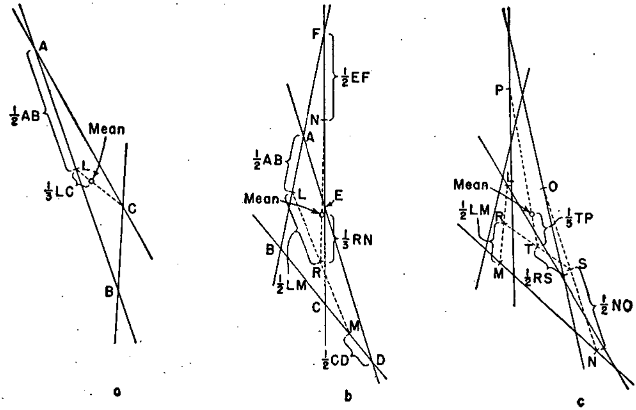


Figure 80. Graphical evaluation of the polygon of error.

aged to obtain the mean N coordinate.

(*b*) *Graphical method.* A graphical method of locating the same point is illustrated in figure 80. The intersection may be considered in any sequence, without varying results, but an orderly sequence simplifies the procedure.

1. Three-ray plot. In a, figure 80, A, B, and C are the three intersections of a three-ray plot. L is the midpoint of AB. The mean of A, B, and C lies on the line LC, one-third of the distance LC from L.

2. Four-ray plot. In b, figure 80, A, B,

C, D, E, and F are the six intersections of a four-ray plot. L, M, and N are the midpoints of AB, CD, and EF, respectively. The mean of L, M, and N, which is also the mean of the six intersections, is found in the same way as the mean for the three-ray plot.

3. Five-ray plot. The ten intersections are grouped into pairs (c, fig. 80) and the midpoint of each pair is located, as at L, M, N, O, and P. The mean, T, for four of these midpoints is found by locating R midway between L and M, S midway between N and O, then T midway between R and S. The over-all mean for the plot lies on a line joining T and P, midpoint of the fifth pair, one-fifth of the distance TP from T.

h. Relative Locations.

(1) *General.* When the internal survey (par. 104) is only approximate, when corrections are not applied, or when the chart location of the base is not accurately known, locations of sound sources are determined relative to other sound sources which have been plotted under identical weather conditions. In figure 81 the sound base has been surveyed by approximate methods. A, BP, and C are the true locations of the sound sources (which could not be plotted on the sound ranging

chart because their positions are unknown. A sound from A is recorded and plotted without corrections. The plotted location of A' is displaced from the true location of A due to weather effects and survey inaccuracies. Similarly, the plots of recorded sounds from BP and C are at BP' and C', respectively. Since A, BP, and C are in the same general area (within assumed standard transfer limits, FM 6–40), the factors which displaced A' from its correct position are approximately the same as those which displaced BP' and C', and it may be assumed that all have been displaced approximately the same distance and direction. If BP is a base point upon which artillery has registered and the approximate gun-target line is known, or if BP is the point of impact of a round fired at any known deflection and range, the shifts required to place fire on A or on C are measured from the sound plotting chart and reported as described in paragraph 118.

(2) *Conditions required for accuracy.* Relative locations are accurate only if no appreciable change in weather conditions has occurred during the period in which sounds from the various sources were recorded. The accuracy increases with improvement in survey and as the distance between sound sources decreases.

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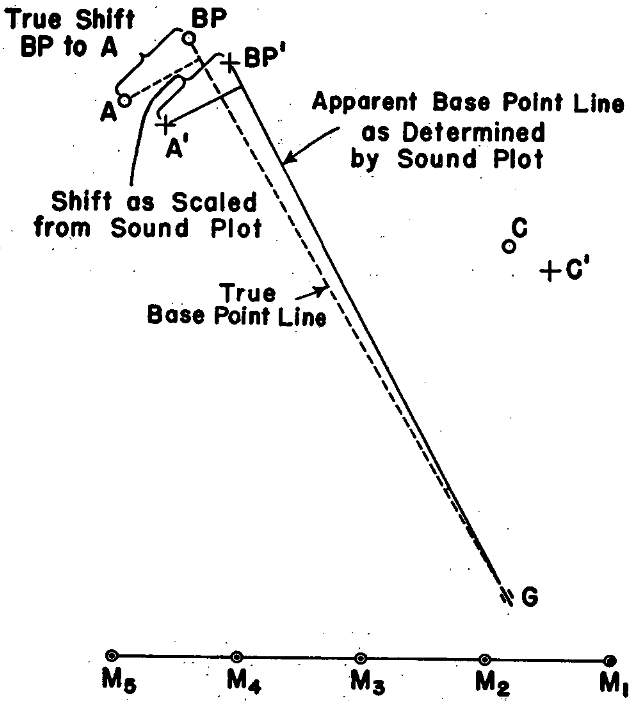

Figure 81. Relative locations.

Thus, in figure 81, if *C* is too far from *BP*, the shift from *BP′* to *C′* as scaled from the plot may not be sufficiently accurate for effective transfer of fire. If adjusting rounds are fired at the estimated position of *C*, they may be sufficiently near *C* to permit an accurate sensing to be made. As rounds fall progressively nearer to *C*, the accuracy of deviations as measured from the sound plot is progressively improved. In the limiting case, however inaccurate the survey, when a round is placed on C, no change having occurred in weather conditions, the record for the original plot at C' should be identical with the record from the round placed on C, and the two plots should coincide.

(3) *When employed.* Relative locations are used only when survey is performed by approximate methods. Weather and curvature corrections are normally omitted when relative locations only are made. In sound ranging adjustments, uncorrected plots are made to speed up the adjustment. If initial data have been determined from corrected plots, the target must be replotted without corrections. Relative locations can not be reported to the firing units in useful form until sound plots have been made on shell bursts fired by these units.

(4) *Adjusting reference lines.* When relative locations are plotted, the reference lines (par. 96*f*) may be adjusted to reduce the size of the polygon of error and to facilitate evaluation of the polygons by inspection. Adjustment of reference lines is not a correction for weather effects or inaccuracies of survey, nor does it move the position of the center of the plot appreciably. It must be verified that polygons of error are consistently of the same

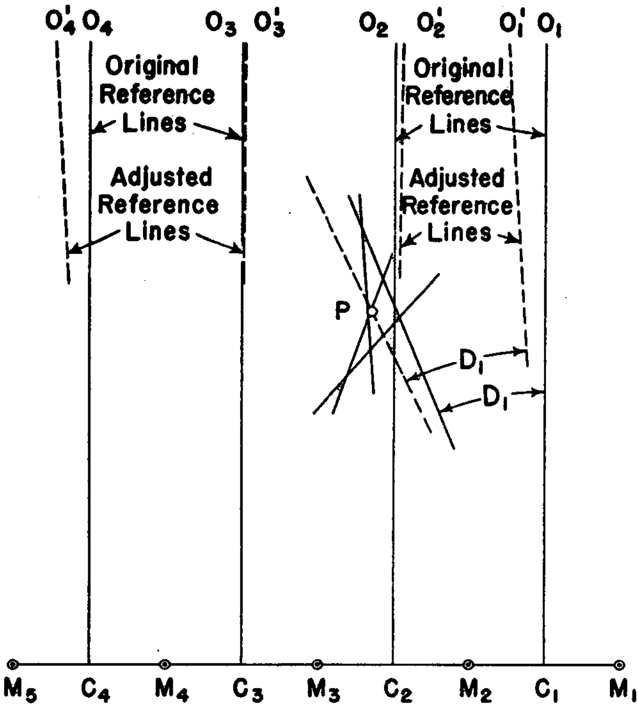

Figure 82. Adjusting reference lines.

approximate size and shape. A plot based on a single record, or on the average time intervals from several records obtained from the same sound source, is selected. The center, P, (fig. 82) of the polygon of error is determined by inspection. The angle D_1 which was originally plotted from reference line O_1C_1 to obtain one ray of the plot, is now plotted in the reverse direction from PC_1 to locate a new reference line O'_1C_1. In the same way, O_2C_2, O_3C_3, etc., are adjusted. As a check, the original set of time intervals from the new reference lines are replotted and should produce a point plot at P. Plots of other sounds in the vicinity of P should also afford point plots or small polygons of error. If the polygon opens up, a readjustment is made. Transfer of fire from one plotted point to another may be made only when the same reference lines are used in plotting both points. If survey errors result in inaccuracies in certain elements of the sound base, it may be assumed that some rays of a plot are more accurate than others. In such cases, the position of point P, to be used as a basis for adjusting reference lines, is determined by proper weighting of the various rays. If M_1, M_2, and M_3 are accurately located, while M_4 and M_5 are not, P is the intersection of the rays from C_1 and C_2, in which case only reference lines O_3C_3 and O_4C_4 would be adjusted.

(5) *Forcing plots.* When the true or approximate location of a sound source in relation to the base is known, regardless of the accuracy of the internal survey of the base, the reference lines may be adjusted to obtain a point plot at the known location of the sound source.

(6) *Adjusting reference lines and forcing*

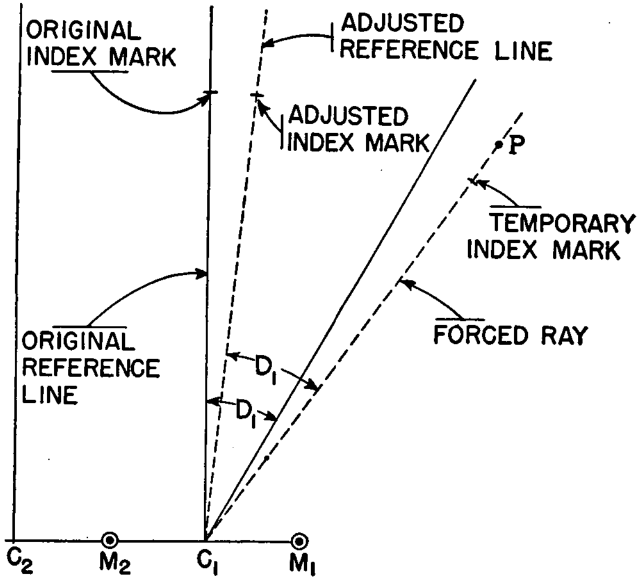

Figure 83. Forcing plots.

plots with irregular base fan. To force a plot through a point P, when plotting with the irregular base fan, draw a line from the first midpoint through P (fig. 83). Place a temporary index mark (c(1) above) on this line at the proper distance from the midpoint as measured by the subbase scale. Reverse the sign of the measured time interval for the first subbase, and draw a ray using this time interval and the temporary index mark. This ray is the adjusted reference line. Place an index mark on the adjusted reference line and erase the line through

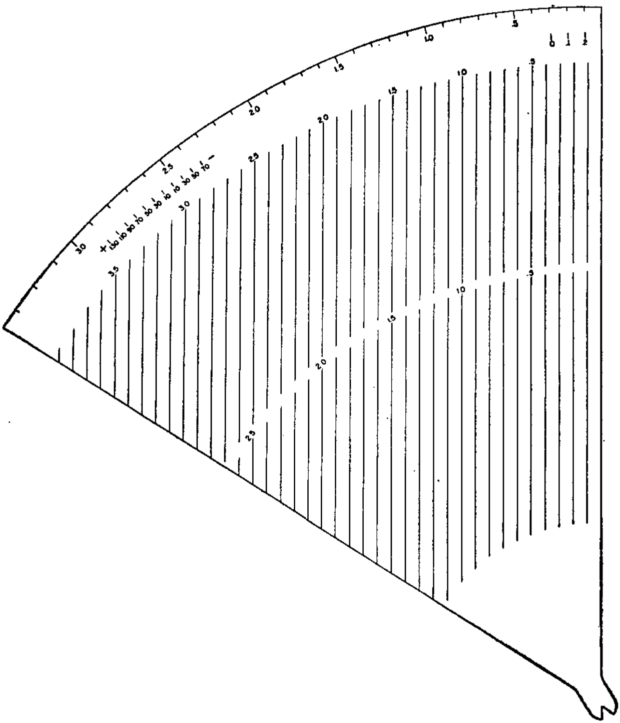

Figure 84. The special plotting fan.

P. Repeat for each subbase. As a check, use the adjusted reference line and the same set of time intervals with the original signs to verify a point plot at *P*.

117. SPECIAL METHODS FOR PROCESSING TIME INTERVALS

a. General. Two methods for processing time intervals employing the automatic application of weather corrections to initial time differences have been devised. The first method necessitates the use of a specially constructed plotting fan; the second makes use of mechanical calculators. Both methods utilize the principle that a time interval for any length subbase may be converted to the interval which would be obtained were the subbase 4 sound-seconds in length.

b. Special Plotting Fan (fig. 84).

(1) The special fan, an improvised item, is similar in appearance to the standard irregular base fan (fig. 76). However, the single outer time scale is constructed for 4-second subbases rather than 2-second subbases. The time lines are so spaced as to permit direct reading to the nearest hundredth of a second; colored time lines enable the plotter to determine time intervals rapidly. A temperature scale, graduated in °F., appears below the outer time scale. A short time scale having a maximum value of 0.3 second is placed below the zero end of the outer time scale for use as described below.

(2) When using this fan, a preliminary plotting chart is set up as follows:

(*a*) Center points for all common length subbases, regardless of actual length, are plotted 4 sound-seconds apart (1350.4 meters) at a scale of 1/25,000. The center points of noncommon length subbases must be plotted at proportional distances from the other center points. For example, subbase number 1 of a six-microphone, straight base is 1,500 meters long; the remaining subbases are 1,200 meters long. The 1,200 meter subbase midpoints are plotted as described above. Microphone number 2 is plotted 675.2 ($1350.4 \div 2$) meters from midpoint 2. Midpoint 1 is then plotted 843.6 meters $\left(\frac{1}{2} \left(\frac{1{,}500 \times 1350.4}{1{,}200} \right) \right)$ from microphone 2. Reference lines are constructed for the center points. Each reference line bears an index mark similar to that used with the standard irregular base fan. The special fan is centered on a midpoint and rotated until the current effective temperature, read on the temperature scale, lies over the reference line. The index mark is then the intersection of the reference line and the time line having the value—

$$\frac{\text{Subbase length in meters} \times 2.}{1000}$$

For example, the time line having the value 2.400 seconds is used for a 1200 meter subbase. A beam compass facilitates marking the index point.

(*b*) The wind correction *for a 4-second subbase* is determined in the usual manner. Its value, read on the outer time scale of the fan, is placed over the reference line with due regard to sign. A portion of the ray adjacent to the index mark is drawn along the edge of the fan. With the index mark as a center, a semicircle is drawn tangent to the ray. Construction of the semicircle for each reference line completes preparation of the preliminary plotting chart.

(3) The fan is now used in the same manner as the standard irregular base fan except that the fan is rotated about a particular midpoint until the time line having the value of the corresponding uncorrected time interval lies tangent to the semicircle. The ray, and the resulting plot, have been automatically corrected for both temperature and wind. The time interval for each subbase is read on the outer scale of the fan and entered on the sound plotting record. Curvature corrections are determined either in the usual manner, or by the method described in *d* below, as though each subbase were 4 seconds in length. The final plot is made on a chart having midpoints plotted in their actual position; final time intervals are set off with a fan or other device having a 4-second scale.

(4) When a wind correction (i.e., the graphical correction on the plotting chart) exceeds in absolute value, and is opposite

in sign to, the uncorrected time interval, the fan will not cover the reference line; consequently, the outer scale of the fan cannot be used. When this condition exists, a segment of an additional reference line is placed at an angle of 0.300 seconds away from the established reference line and on the same side as the semicircle representing the wind correction. The position of this additional reference line is determined by using the 0.300-to 0-second time scale at the zero end of the outer scale. The short scale is then used to read weather-corrected time intervals; values read on the scale have a sign opposite to that of the uncorrected time interval.

c. Calculator Method.

(1) A straight regular base requires the use of the two calculators provided in the table of organization and equipment—one to process plus time intervals, the other to process minus time intervals. The requirements of other bases are discussed below.

(2) Before placing the machines in operation, a "factor" and the wind correction must be found. The factor is the result of dividing the conversion number, found opposite the current effective temperature in the temperature-time conversion table (app. IV), by 1/1,000 of the subbase length in meters. The quotient

is taken to the nearest thousandth. The wind correction is determined in the usual manner (except for a 4-second subbase) regardless of the actual length of the subbases in use.

(3) The calculators may now be prepared for use. The carriage is cleared, and the red indicators are moved to mark decimal points between columns 3 and 4 on the top row and 6 and 7 on the bottom row. (Columns are counted from the right.) Each carriage is moved to the extreme left position. The wind correction is placed on the keyboards by punching the proper numbered keys, taking into account the position of the decimal point. If the wind correction is plus, the operating crank of the plus machine is turned forward and that of the minus machine is turned backward; the procedure is reversed for minus wind corrections. The upper rows of the carriages are again cleared. The factor, referred to in (2) above, is set and remains on each keyboard. Each key marked *R* (repeat) is punched, and the calculators are ready for operation. The settings change only when the wind and/or the temperature changes.

(4) A given time interval is processed on the machine having the same sign. The process is accomplished merely by turning the operating crank forward until the

initial time interval appears on the upper row of the carriage; the carriage must, of course, be shifted after the correct number in a particular column appears. The desired time interval, automatically corrected for temperature and wind and converted to a 4-second scale, may be read from the lower row of the carriage. Other time intervals are processed by turning the operating crank forward or backward until the initial times appear on the upper row of the carriage. The disposition of the time intervals is the same as that when the special fan is used (*b*(3) above).

(5) A special case arises when the wind correction is of opposite sign to, and greater in absolute value than, the initial time interval after the latter is converted to its 4-second equivalent. In such a case, the initial time interval is processed on the machine of opposite sign, by rotating the operating crank backwards until the initial time appears in red numbers on the upper row of the carriage. The weather-corrected time interval, converted to its 4-second equivalent, is read as before from the lower row of the carriage.

(6) When the calculator method is used for a regular curved base, the wind correction is not set on the machine and only one machine is used. The wind correc-

tions are determined using the azimuth of each subbase; they are read from the 4-second wind arm of the corrector (even though subbases are other than 4 seconds in length) and applied algebraically to the temperature-corrected time interval read from the machine.

(7) When this method is applied to a base wherein the only irregularity is in the direction of one or two subbases, the calculators are operated as described above. In the case of any subbase off-line, a small additional wind correction can be determined easily and applied to the converted time interval; the latter then includes the entire wind correction.

(8) If the method is applied to a base having all but one of the subbases of common length, an additional calculator may be used to convert time intervals from the noncommon length subbase to equivalent intervals from the common length subbases. The intervals are then processed by the plus or minus calculators, as above. For example, four subbases may be 1,200 meters long, and the fifth, 1,500 meters long. A time interval of 2.500 seconds from the 1,500 meter subbase should be multiplied by 1,200/1,500; the resulting figure 2.000 is then processed normally.

d. Curvature Correction Fan.

(1) The curvature correction fan, an impro-

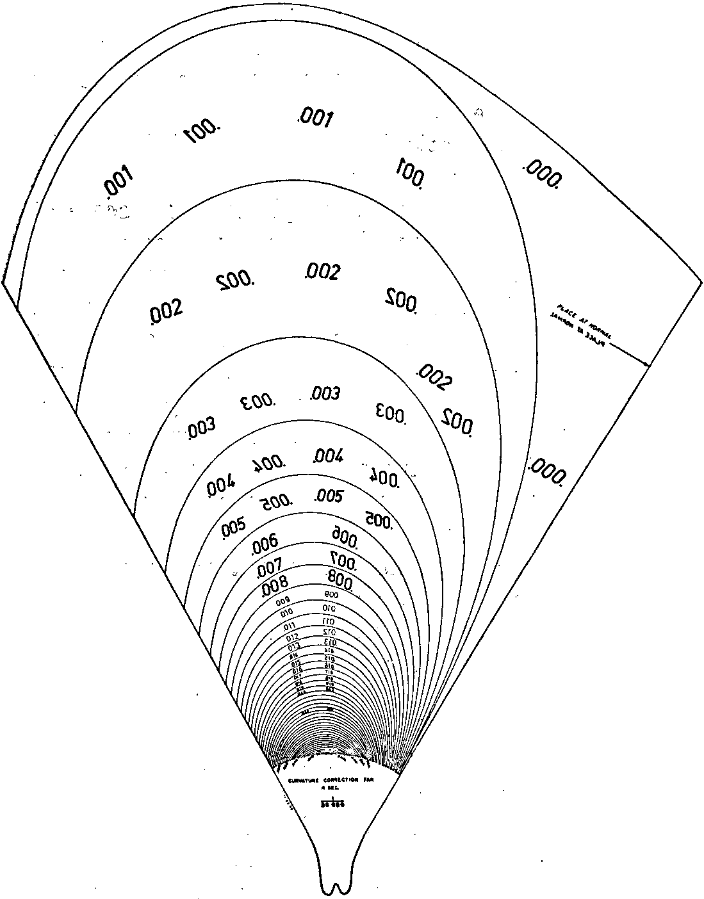

Figure 85. The curvature correction fan.

vised item, (fig. 85), is a device for the rapid determination of curvature corrections on 4-second subbases. Instructions for its use are printed on the fan.

The value of the correction is read from the fan according to the position of the plot within a particular correction sector of the fan.

(2) In the *calculator* and *special fan* methods, center points for common length subbases are to be plotted at a scale of 1/25,000 as if they were 4 seconds in length. The resulting plot is not to true scale: distances from these center points have been converted to distances which would exist for 4-second subbases. Thus, the curvature correction may be determined using the 4-second curvature fan. This is convenient since only one curvature fan or chart is needed regardless of subbase length.

(3) To determine the curvature correction for a subbase whose length is not common, the center of plot is shifted along the ray from this subbase, by the ratio of common length subbase to noncommon length subbase. For example, if the common subbases were 1,200 meters in length, the center of plot for a 1,500 meter subbase would be shifted to a point 4/5 (1,200/1,500) the distance from the center point of the 1,500 meter subbase along its ray to the sound-source plot. The curvature correction for this subbase may be read directly on the fan where this point appears.

118. REPORTING TARGETS

a. General. Targets located by sound ranging normally are reported by coordinates. In the absence of a coordinate system common to both sound ranging and firing units, sensings may be made in relation to the base point (check point or reference point). The number of plots and accuracy of location should be given, and the number and type of guns and their approximate caliber should be announced if known. If conditions are favorable for a sound ranging adjustment, WILL ADJUST should follow the report of the target. In sound-base survey and computation, coordinates and distances are expressed in meters.

b. Prearrangement. When the battalion is operating under centralized control, targets are reported to the observation battalion operations section. Missions are evaluated and transmitted to the corps artillery fire-direction center which assigns the mission to a firing unit, specifies the type of mission, the number of rounds to be fired, the channel of communication to be used, and designates a concentration number. Under decentralized control, when an observation battery is assigned to support an artillery unit, targets are reported directly to the fire-direction center of the supported unit.

c. Accuracy of Location. The estimated accuracy of the location of a target is expressed as the number of meters that it is estimated that the determined location of the target may vary from its true location. For example, accuracy of loca-

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tion is estimated as being within 50 meters, within 100 meters, within 150 meters, or over 150 meters. The estimate of the accuracy of location is based on an estimate of the accuracy of survey, length of sound base, distance to the sound source, weather conditions, readability of the records, and appearance of the polygon of error. The accuracy of a sound ranging location is somewhat better in deflection (measured from the perpendicular bisector of the base) than it is in distance (measured perpendicular to the base). Thus, a reported accuracy of 50 meters may represent a possible error of 50 meters in distance, but only 20 to 30 meters in deflection.

119. SOUND-ON-SOUND ADJUSTMENT

A sound-on-sound adjustment is the adjustment of fire by sound on a sound-located target. Data are measured on the sound plotting chart from a previously plotted sound source which is used as a reference point. If the initial shift is to be of maximum accuracy, check rounds should be fired on or near the reference point. The locations may be relative only (par. 116*h*). The sound platoon considers itself as an observer at one of the subbase midpoints, usually C_3. Adjustment follows the procedure employed by an observer using the target grid system (FM 6–40). Request for fire on the target must include the azimuth of the target from the midpoint utilized. An adjustment should be completed as soon as possible after the target is reported to avoid the effect of changes in weather conditions.

120. SURVEILLANCE OF FIRE

A heavy concentration of fire produces complicated records. If the records obtained from fire for effect are not usable, the sound unit requests, after the completion of fire for effect, one or more single rounds at the center of impact of the concentration to check the accuracy of the fire.

121. TRANSFER OF FIRE

If surprise fire is desired, an auxiliary target may be selected by the observation unit. This is done with the assistance of the firing unit. The auxiliary target then becomes a point at which a center of impact registration is fired. This point is selected about 500 meters from the target and on terrain similar to that in the vicinity of the target itself. This prevents errors resulting from differences in site. A transfer of fire is then made from the auxiliary to the real target.

122. REGISTRATION

Registration of artillery by sound ranging should be attempted only if visual adjustment is impossible.

Section V. MISCELLANEOUS

123. ADAPTING TIME SCALES AND CHARTS TO SUBBASES OTHER THAN THOSE FOR WHICH THEY ARE CONSTRUCTED

a. General. When it is desired to use a correction chart or the time scale of a plotting fan or plotting board for a subbase length other than that for which they were designed, the procedure is as follows:

(1) *Time scales.*

(*a*) Assume that a time interval t_a has been recorded on a subbase s_a seconds long. The only fan available has time scales for a subbase of s_b seconds. Then $\left(\frac{s_b}{s_a}\right) t_a$ is the time interval that must be laid off on the fan calibrated for a subbase of s_b seconds to obtain the proper angle.

(*b*) A 4-second fan may be used with a 2-second subbase if each time interval is multiplied by a 2 (4/2) or with a 5-second subbase if each time interval is multiplied by 4/5. The irregular base fan shown in figure 76 may be used for a 2,400 *yard* subbase by locating the index mark 1,200 *yards* along the subbase scale, and dividing the time intervals by 2. The midpoints of the subbases are plotted in their true positions as measured by the scale of the plot.

(2) *Temperature correction chart.* The temperature correction chart applies without modification for any length of subbase.

(3) *Curvature correction chart.* A curvature correction chart designed for subbase s_b

may be used for any subbase s_a by *multiplying* both the distance and the measured time interval by $\frac{s_b}{s_a}$ before entering the chart. The correction read from the chart is *divided* by the same factor. In the simple case where $\frac{s_b}{s_a}$ is 2, such as when a 4-second chart is used for a 2-second subbase, the same result is obtained if each figure on the scales of the chart is divided by 2, converting it to a 2-second chart. The same method is used to adapt the irregular base curvature chart to cover a wider variety of subbases.

(4) *Wind correction.* The wind correction is directly proportional to the length of the subbase. A wind corrector may be prepared for a subbase s_b and the correction as read from the corrector multiplied by the factor $\frac{s_a}{s_b}$ to obtain the correction for a subbase of s_a seconds. (Note that this factor is the reciprocal of that used in (1) above.)

b. Missing Trace Plots. The missing trace plot for a regular straight base is a special case of adapting both the time scale and the correction charts to a double-length subbase. Assume that on a five-microphone, straight base a record possessed readable breaks for all microphones except M_2. The subbases used in making a plot would be M_1M_3, M_3M_4, and M_4M_5, the first of which is double the normal length. The following simplified procedure for plotting the ray for the double-length subbase produces the same results as obtained by following the procedures of *a* above.

(1) Determine the time interval for the double length subbase, and divide it by 2. *All further reference below to time interval refers to this half value.*

(2) Apply curvature and weather corrections to the time interval in the normal way, except that half the actual distance is used in entering the curvature correction chart.

(3) Plot the corrected time interval (using a time scale for a normal length subbase) from the midpoint and reference line of the double-length subbase. For a curved base, the above method is not exact since the subbase M_1M_3 is less than twice the normal value. When using the mechanical plotting board, the pivot of the plotting arm cannot be set exactly over the midpoint of subbase M_1M_3. Errors introduced by these effects are small and will not affect materially the final locations.

124. PLOTTING WITH SOUND SOURCE TO REAR

a. Straight Base. With a straight base, if a sound from the rear of the base is recorded and plotted in the normal manner, a false location is obtained to the front of the base. The plot itself

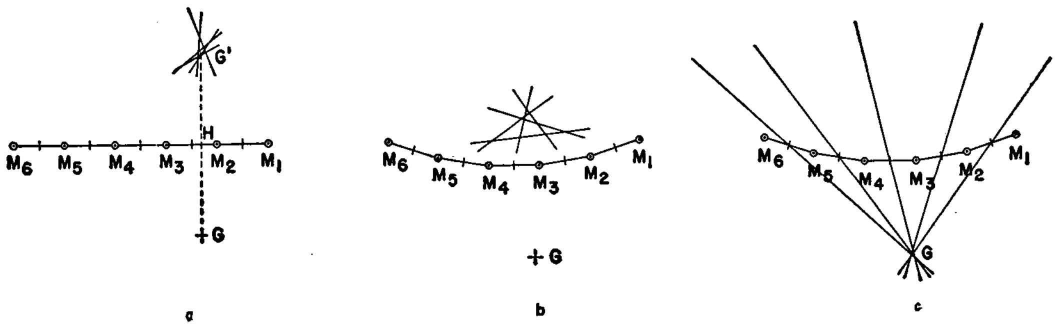


Figure 86. Plotting with sound source to the rear.

affords no indication of this error. Normally, the reports of the outpost observers or the installation of an offset microphone will prevent such errors. In the event it is desired to obtain sound locations to the rear of the base, such as the location of a battery, a plot is made to the front at G' (a of fig. 86), and a perpendicular to the base is drawn through the plot crossing the base at H. The true sound source is located on this line at G—a distance GH (equal to $G'H$) to the rear of the base.

b. Curved or Irregular Base. A sound from the rear, recorded on a curved or irregular base, will result in a scattered plot (b of fig. 86). To determine the location of such a sound source, the signs of all time intervals are reversed and a plot is made. The rays in this plot diverge when extended to the front of the base (c of fig. 86); they must be extended to the rear of the base to provide an intersection at the sound source G.

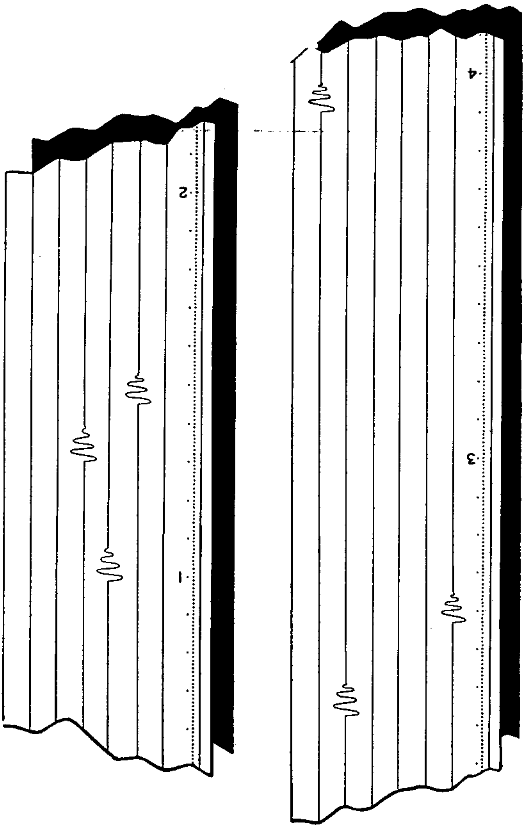
125. PLOTTING BALLISTIC WAVES AND SHELL BURST WAVES

a. Application. Under certain weather conditions, ballistic waves and shell burst waves may be recorded for long-range guns, although the gun waves cannot be recorded. In such cases, the following method is an approximate determination of the line of fire. Two lines of fire from one gun to different targets afford an approximate location of the gun. This method is valid only if the line of fire and the sound base (or their prolongations) intersect; in addition, any intersection with the prolongation of the sound base should fall within one subbase length of the end of the base.

b. Record Reading. A position of zero time is selected on the record ahead of the first break made by the ballistic wave. The seconds are numbered on the records to a point beyond the last break for the shell burst, as shown in figure 87. Readings of times of arrival for the ballistic and shell burst waves are entered on separate computing forms (figs. 88 and 89).

c. Plot of Shell Burst. To locate one point on the line of fire of the projectile, a plot of the shell burst is made in the usual manner. The shell burst may be either to the front or rear of the sound base. If a straight sound base is used, the fact that the burst is to the front or rear of the base must be determined by ear or by visual observation, since it cannot be determined from the record reading.

d. Plot for Ballistic Wave. On the computing form for the ballistic wave (fig. 88) the time intervals are computed between the first break and each of the other breaks. These intervals are corrected for temperature in the usual way. No wind correction is applied because no simple method of determining such a correction has been devised. For each microphone, a distance in meters corresponding to the corrected time interval is found by multiplying the interval by 337.6. Using this distance as a radius and the plotted microphone position as a center, an arc is drawn to the front of each microphone (fig. 90). A smooth curve *PQ*, through the microphone position corresponding to the first break, is drawn tangent to all of these



1
2
3
4

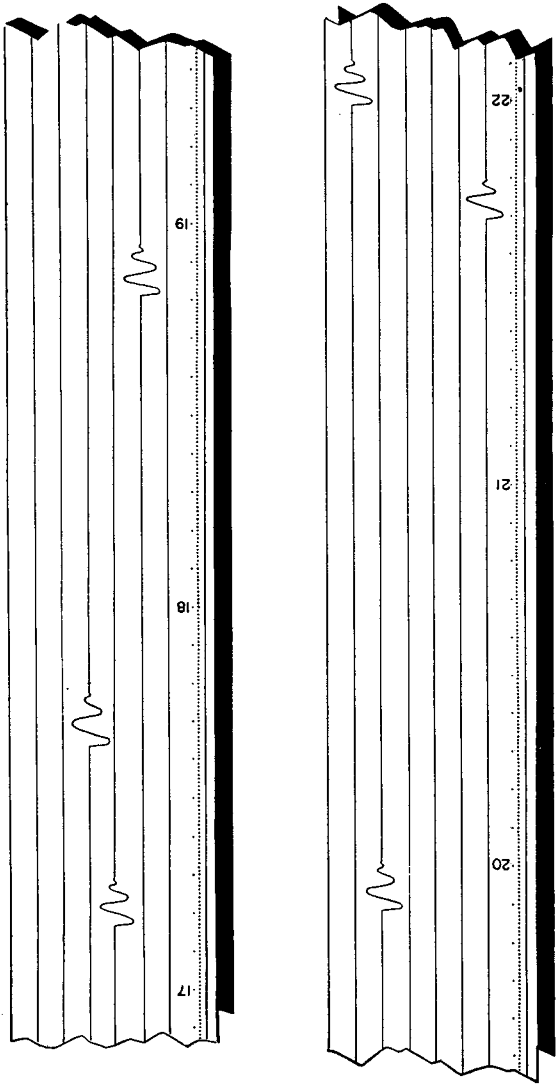


Figure 87. Record of ballistic wave and shell burst wave.

SOUND PLOTTING RECORD

Base: Location GRIERSON HILL Type 6 MIC. 4 SEC. STRAIGHT. Azimuth 0°-00'-00" Date 8 MAY 1949

Record No. 49 Time 2119 Temperature 58 °F. Wind: Direction 820 mils. Speed 10 m.p.h.

TIME READINGS

Readings to (−)	22.989	19.883	17.633		
1 22.989	2 19.883	3 17.633	4 17.166	5 18.809	6 21.692
Results to (+)				17.166	18.809

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		3.106		2.250		0.467	1.643		2883	
Temperature Correction		0.024		0.018		0.004	0.013		0.023	
Wind Correction		0.037		0.037		0.037		0.037		0.037
Sub-Totals							1.656	0.037	2.906	0.037
Subtract							0.037		0.037	
Weather Corrected Time Interval		3.167		2.305		0.508	1.619		2.869	
Curvature Correction		0.019		0.041		0.018	0.044		0.027	
Final Time Interval		3.186		2.346		0.526	1.663		2.896	
Approximate Distance	4200		3200		2600		2900		3700	

Coordinates: E 52750 N 95435 Accuracy 100 Meters. Caliber 155 GUN File No.

Area Shelled Number of Pieces Time Reported Conc. No.

DA AGO FORM 1 JUN 51 6–4 REPLACES FAS FORM 4, 10 JUN 44, WHICH IS OBSOLETE.

Figure 88. Computing for ballistic wave using DA AGO Form 6–4.

SOUND PLOTTING RECORD

Base: Location GRIERSON HILL Type 6 MIC. 4 SEC. STRAIGHT. Azimuth 0°-00'-00" Date 8 MAY 1949

Record No. 49 Time 2119 Temperature 58 °F. Wind: Direction 820 mils. Speed 10 m.p.h.

TIME READINGS

BALLISTIC WAVE M, AT 55245.0 – 91415.0

Readings to (−)					
1	2 1 3.891	3 2 2.320	4 3 1.292	5 1.450	6 2.569
Results to (+)	4 0.984	4 0.984	4 0.984	4 0.984	4 0.984

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval	2.907		1.336		0.318		0.466		1.585	
Temperature Correction	0.023		0.010		0.002		0.004		0.012	
Wind Correction										
Sub-Totals										
Subtract										
Weather Corrected Time Interval										
Curvature Correction										
Final Time Interval	2.930		1.346		0.310		0.470		1.597	
Approximate Distance	990		445		104		159		540	

Coordinates: E N Accuracy Meters. Caliber 155 GUN File No.

Area Shelled Number of Pieces Time Reported Conc. No.

DA AGO FORM 1 JUN 51 6–4 REPLACES FAS FORM 4, 10 JUN 44, WHICH IS OBSOLETE.

Figure 89. Computing for the shell burst using DA AGO Form 6–4.

arcs with the aid of a flexible drafting curve. This curve is not extrapolated.

e. Determining Line of Fire. Using the plotted

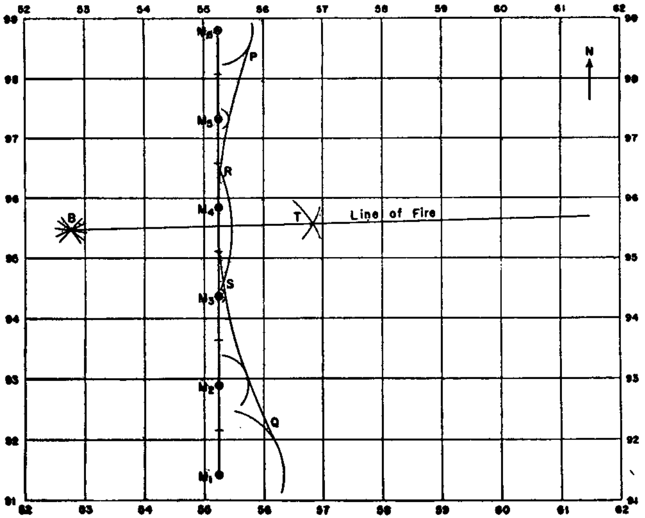


Figure 90. Line of fire determined from ballistic wave and shell burst wave.

position of the shell burst (*B* in fig. 90) as a center, an arc is drawn intersecting curve *PQ* at two points, *R* and *S*, not more than 2 or 3 inches apart. (If this is not possible, see *f* below.) Two arcs of equal radius are drawn using *R* and *S* as centers. From their intersection at *T*, a line is drawn to *B*. Line *BT* is the required line of fire (or its extension).

f. Special Case in Which Line of Fire Does Not Cross Base. If the line of fire (or its extension) does not cross the sound base, a circular arc drawn with *B* as the center can be made to intersect curve *PQ* at only one point, regardless of the radius chosen. In such a case, the procedure described in *e* above is replaced with the following:

(1) An arc is drawn with B as the center, using a radius which will not cause the arc to intersect curve PQ but to come close to one end of it where it approaches parallelism (fig. 91). At the end of the curve, the end subbase is divided into four equal parts by points a, b, c, d, and e. A straight line is drawn from B through each of these points, cutting both the arc and the curve PQ. The distance along each of these lines between the arc and the curve PQ is measured and recorded as x_a, x_b, x_c, x_d, and x_e, respectively. Their differences $(x_b - x_a)$, $(x_c - x_b)$, $(x_d - x_c)$, and $(x_e - x_d)$ are computed.

(2) On a separate sheet, a graph is drawn with the line ae and its intermediate points along the horizontal axis (fig. 92). A point is plotted a distance $(x_b - x_a)$ directly above the midpoint of line ab. Similarly, a point is plotted a distance $(x_c - x_b)$ above the midpoint of line bc, and so on for each of the four sections of the line ae. (Note that in this graph a larger scale may be used for distances along the vertical axis than for distances along the horizontal axis.) A smooth curve is drawn through the four plotted points and is extended until it cuts the horizontal axis at f. The distance ef (or af if a is at the end microphone of the sound base) is scaled.

(3) Point f is transferred to the original plot

(fig. 91) on the extension of the line of subbase *ae*. A line from *f* to *B* is the required line of fire. If point *f* is more than one subbase length from the end microphone, this method becames inaccurate and should not be used.

126. DETERMINATION OF CALIBER FROM PLOT OF GUN WAVE AND SHELL BURST WAVE

Whenever a record is obtained on which both the pattern of a gun wave and of the corresponding shell burst wave can be identified, an estimate of the caliber and type of the piece which fired the round may be made. This estimate is based upon a comparison of the computed time of flight with known times of flight of enemy weapons. The method is described below.

a. Record Reading and Determination of Range. A position of zero time is selected on the record

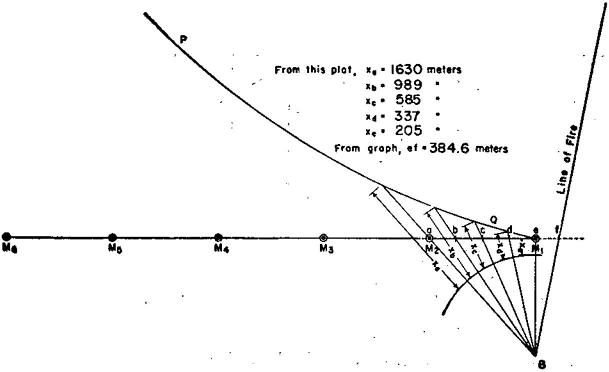
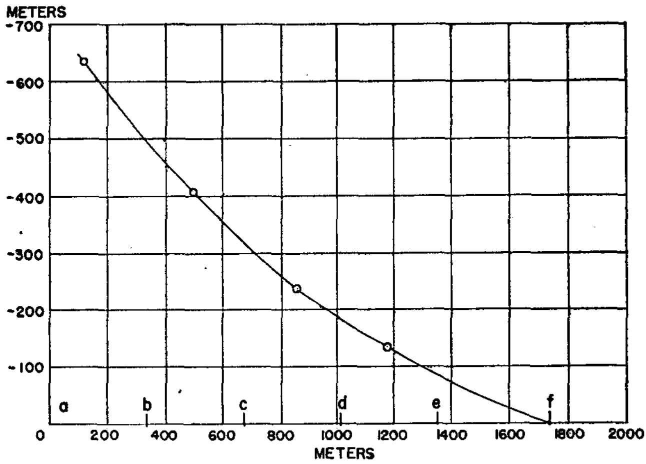


Figure 91. Plot for the special case in which the line of fire does not cross the sound base.

ahead of the first break of either the gun or shell burst wave, whichever appears first, and 1-second intervals are numbered consecutively to a point beyond the last break of the second pattern. Readings for the two waves are entered in separate computing forms, and locations corrected in the normal manner are plotted on the plotting board. The range at which the piece was fired is determined by scaling the distance between the gun and shell burst locations. No correction for difference in altitudes of the gun and the burst need be made unless it would change the measured range



From Plot Of Figure 91

$ab = bc = cd = de = 337.6$ Meters

$x_b - x_a = -641$ Meters $\quad x_c - x_b = -404$ Meters

$x_d - x_c = -248$ Meters $\quad x_e - x_d = -132$ Meters

From Graph Above: $ef = 1735 - 1350.4 = 384.6$

Figure 92. Graph for the special case in which the line of fire does not cross the sound base.

by more than 50 yards. When a straight base is used, it is necessary to determine by ear, by visual observation, or by an offset microphone whether the shell burst is in front or in rear of the base.

b. Determination of Time of Flight. To determine the time of travel of each sound wave, the distance (in yards) from the points of origin of the waves to the microphone selected for computations are scaled on the plotting board and each distance is divided by 369.2, the speed of sound in yards per second at 50°F., to give the travel time in seconds. In determining caliber, since yards rather than meters are the unit of measure used on the plotting equipment and in the firing tables, it is necessary to use the speed of sound expressed in yards per second in computations. The difference in arrival times is added to (or subtracted from) the difference in travel times to give the time of flight. Weather corrections should be applied to obtain the plotted locations of the gun and shell burst, but the accuracy required in the time of flight does not justify correcting the velocity of sound. Also, since the projectile is subject to the same meteorological conditions as the sound, neglect of weather corrections in the time of flight computation will often tend to compensate for deviations from the standard time of flight as determined from firing tables.

c. Application and Expected Accuracy.

(1) Use of this method of determining caliber and type of artillery depends upon the availability of information regarding the characteristics of enemy weap-

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ons. Time of flight often can be determined from a single record to within an error of a few tenths of a second, but an average from several records is more reliable. This degree of accuracy is usually sufficient to distinguish between pieces firing at ranges in excess of 3,000 to 4,000 yards, but is of little or no value for shorter ranges. It should be noted, however, that on a front where the enemy may be using artillery of different nations, it may be necessary to find out from other sources what types of artillery are being used in the sector. Firing tables for enemy artillery are useful for the solution of this problem. It will be found helpful, in practice, to plot on a single sheet a series of curves of time-of-flight versus range for all known weapons. After computations have been made, the most likely weapon can be spotted from the graph without the necessity of searching through firing tables.

(2) This method of caliber determination does not depend upon the fidelity of response of the microphones, as does the method described in paragraph 114*e*. Estimates of caliber based upon a comparison of times of flight should, however, be verified from other sources of intelligence.

d. Example. An example of the computation of

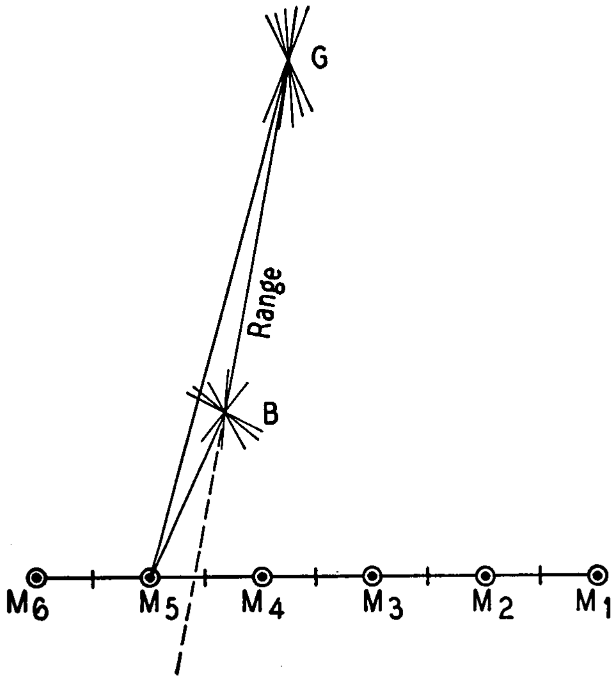


Figure 93. Plot of gun position and shell burst location.

time of flight is shown below. Referring to figure 93 (not to scale), the gun and shell burst locations have been plotted with data shown in the sound plotting records (fig. 94). Since the extended line of flight, *GB*, crosses the sound base nearest to M_5, data pertaining to this microphone are used. With a plotting scale, the lengths of the lines M_5G, M_5B, and GB are scaled.

SOUND PLOTTING RECORD

Base: Location Gun. Snow Ridge. Type 6 Mic. 4 sec. Straight Azimuth 2°25'20" Date 6 Aug 1949

Record No. 103 Time 1500 Temperature 97 °F. Wind: Direction 3000 mils Speed 7 m.p.h.

TIME READINGS

Results to (−)	3.090	1.760	0.771	0.264	
1 3.090	2 1.760	3 0.771	4 0.264	5 0.148	6 0.508
Results to (+)					0.148

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		1.390		0.989		0.507		0.116	0.360	
Temperature Correction		0.063		0.047		0.024		0.006	0.017	
Wind Correction		0.035		0.035		0.035		0.035		0.035
Sub-Totals									0.377	0.035
Subtract									0.035	
Weather Corrected Time Interval		1.428		1.071		0.566		0.157	0.342	
Curvature Correction		0.002		0.001		0.001		0.000	0.000	
Final Time Interval		1.430		1.072		0.567		0.157	0.342	
Approximate Distance										

Coordinates: E.......... N.......... Accuracy.......... Meters. Caliber.......... File No..........

Area Shelled.......... Number of Pieces.......... Time Reported.......... Conn. No..........

DA AGO FORM 1 JUN 51 6-4 REPLACES FAS FORM 4, 10 JUN 44, WHICH IS OBSOLETE.

Figure 94. Computations for gun and shell burst locations using DA AGO Form 6-4.

Shell Burst

SOUND PLOTTING RECORD

Base: Location Snow Ridge. Type 6 Mic. 4 sec. Straight Azimuth 2°25'20" Date 6 Aug 1949

Record No. 103 Time 1500 Temperature 97 °F. Wind: Direction 3000 mils Speed 7 m.p.h.

TIME READINGS

Results to (−)	8.512	6.103	4.213	3.048	
1 8.512	2 6.103	3 4.213	4 3.098	5 2.676	6 3.231
Results to (+)					2.672

	1 +	1 −	2 +	2 −	3 +	3 −	4 +	4 −	5 +	5 −
Time Interval		2.409		1.890		1.165		0.372	0.559	
Temperature Correction		0.114		0.090		0.056		0.018	0.027	
Wind Correction		0.035		0.035		0.035		0.035		0.035
Sub-Totals									0.586	0.035
Subtract									0.035	
Weather Corrected Time Interval		2.558		2.015		0.425		0.425	0.551	
Curvature Correction		0.006		0.007		0.002		0.002	0.004	
Final Time Interval		2.564		2.022		0.427		0.427	0.555	
Approximate Distance										

Coordinates: E.......... N.......... Accuracy.......... Meters. Caliber.......... File No..........

Area Shelled.......... Number of Pieces.......... Time Reported.......... Conn. No..........

DA AGO FORM 1 JUN 51 6-4 REPLACES FAS FORM 4, 10 JUN 44, WHICH IS OBSOLETE.

Figure 94—Continued.

RANGE *GB*	6,510 yd.
Range M_5G	12,598 yd.
Time of travel $\left(\frac{12598}{369.2}\right)$	34.122 sec.
Range M_5B	6,086 yd.
Time of travel $\left(\frac{6086}{369.2}\right)$	16.484 sec.
Record reading—gun	0.148 sec.
Record reading—shell	2.676 sec.
Difference in arrival times	+2.528 sec.
Difference in travel times	17.638 sec.
Time of flight	20.166 sec.

From firing tables (or graph constructed as described in *c* above), the time of flight for 155-mm howitzer, M1, charge 5, at a range of 6,500 yards, is 20.0 seconds. Time of flight for the 105-mm howitzer, M2, charge 6, at 6,500 yards, is 20.6 seconds. The piece firing the round might have been either, but it probably was not a 155-mm howitzer, M1917, whose time of flight for charge 6, at 6,500 yards, is 18.8 seconds.

CHAPTER 8

FLASH RANGING

Section I. GENERAL

127. DEFINITIONS

a. Flash Ranging. Flash ranging is the procedure employed in locating points in the target area by visual observation and intersection from two or more observation posts.

b. Flash Ranging Location. Flash ranging location is the location of an enemy installation or activity by flash ranging methods.

c. Flash Ranging Adjustment. Flash ranging adjustment is the location of friendly shell bursts either in the air or on the ground for the purpose of adjusting friendly artillery.

d. Flash Ranging Registration. Flash ranging registration is the location of a series of friendly shell bursts by flash ranging methods for the purpose of obtaining data for the computation of corrections for friendly artillery. Flash ranging methods are used with both center-of-impact and high-burst registrations.

128. MISSIONS

The flash ranging platoon is employed to perform the following four missions:

a. Locate targets.

b. Adjust friendly artillery.

c. Collect and forward combat intelligence.

d. Perform comparative calibration of friendly artillery.

129. GENERAL DESCRIPTION

a. Flash ranging installations are of two general types—rapid and deliberate. In a rapid installation, two observation posts and a small plotting center are connected by wire, radio, or both; they are not necessarily tied to survey control, nor are they necessarily in communication with observation battery headquarters. Deliberate installations consist of two or more surveyed observation posts and a plotting center, connected by wire, radio, or both, operating under observation battery control. Selection of the type of installation to be employed is governed by the situation. A deliberate installation may be developed using observation posts from rapid installations.

b. In either type installation, each observation post is equipped with an observing instrument for reading horizontal and vertical angles (fig. 95). In a rapid installation, the instruments are oriented to measure angles to points in the target area. In a deliberate installation, they are oriented to measure azimuths. When these angles are plotted, the points are located as discussed in sections II and III below. In rapid installations, the instrument of one observation post is oriented with reference to the companion observation post (par. 131). In deliberate installations, observing instruments normally are oriented on grid north (par. 140). The observers, having

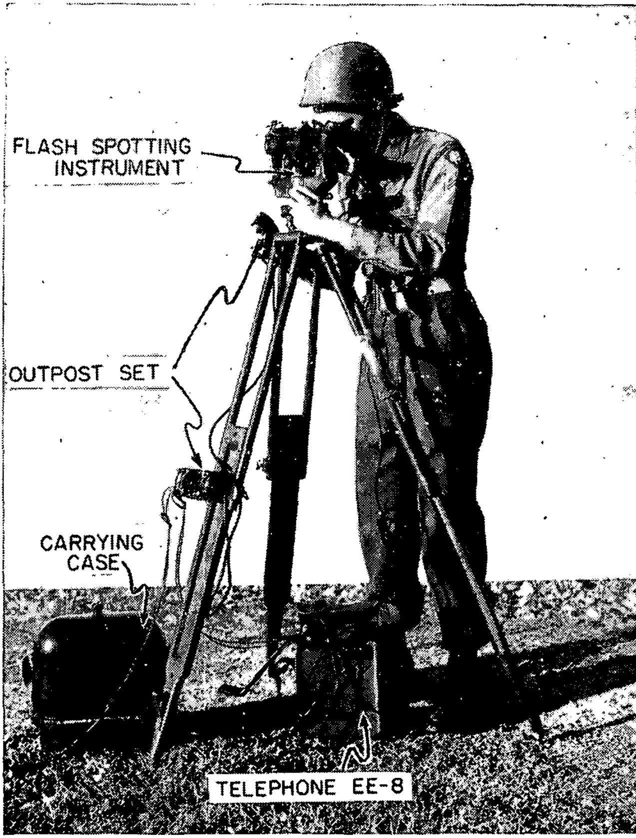


Figure 95. Equipment used at a flash observation post.

sighted a target, report its instrument reading (or azimuth) to the plotting center. There the position of the target is plotted, or its range and direction are computed.

Section II. RAPID INSTALLATIONS

130. GENERAL

In rapid installations, target location is based upon the solution of oblique triangles. A base line which is very short in proportion to the ranges sought is established. (This is a target area base as described in FM 6–40.) The length of the base is expressed in yards. Angles to targets are measured from the observation posts which have been established at the ends of the base, and the resultant triangles are solved using the trigonometric sine law.

a. General Considerations. A rapid installation is used when conditions are not suitable for a deliberate installation. Factors to be considered are—

(1) *Time.*

(2) *Survey.* A rapid installation is not dependent on common survey control.

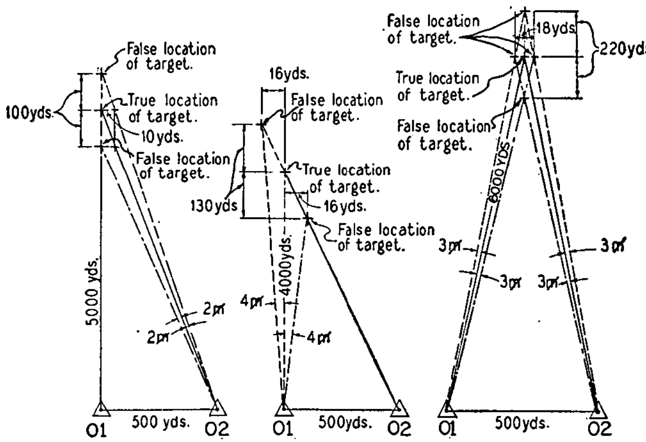
(3) *Terrain.* A rapid installation may be used when the terrain is wooded or hilly, and where it is impossible to get more than one small area that overlooks the enemy area.

(4) *Communication.* A rapid installation does not require the laying and subsequent recovery of a large amount of wire.

b. Selection of Observation Posts. Both observation posts must afford observation throughout the same area in the assigned zone. Care must be taken during reconnaissance and occupation not to disclose the observation post positions; full advantage must be taken of camouflage and background. An observation post seen by the enemy usually is lost. Movement must be reduced to a minimum.

c. Intervisibility of Observation Posts. Installation and operation are simplified when observation posts are intervisible; however, very little time should be spent in trying to achieve this.

d. Consideration of Base Length. The base length should be at least one-tenth of the estimated distance to the far limit of the target area. Time available and unsuitable observation may dictate installation of a shorter base; however, immediate steps should be taken to extend the length to a 1 to 10 ratio.



Note: Mil deviations shown indicate errors in instrument readings. Diagrams not to scale.

Figure 96. Target location errors due to incorrect instrument readings.

e. Orientation of Base With Respect to Zone of Observation. A base line is most effective when a line perpendicular to the center of the base line passes through the center of the zone of observation. When this is not possible, a compensating increase should be made in the length of the base line.

f. Accuracy of Locations. Figures 96, 97, 98, and 99 illustrate the effects of errors—errors in the length of the base line and especially errors in reading instrument directions—on the accuracy of target locations. Rapid-installation locations are not as accurate as deliberate-installation locations. Targets must have clearly defined features.

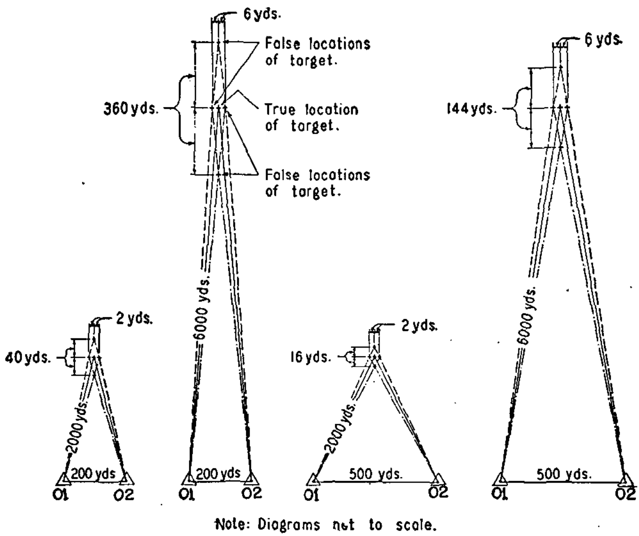


Figure 97. Target location errors due to 1-mil error in instrument readings.

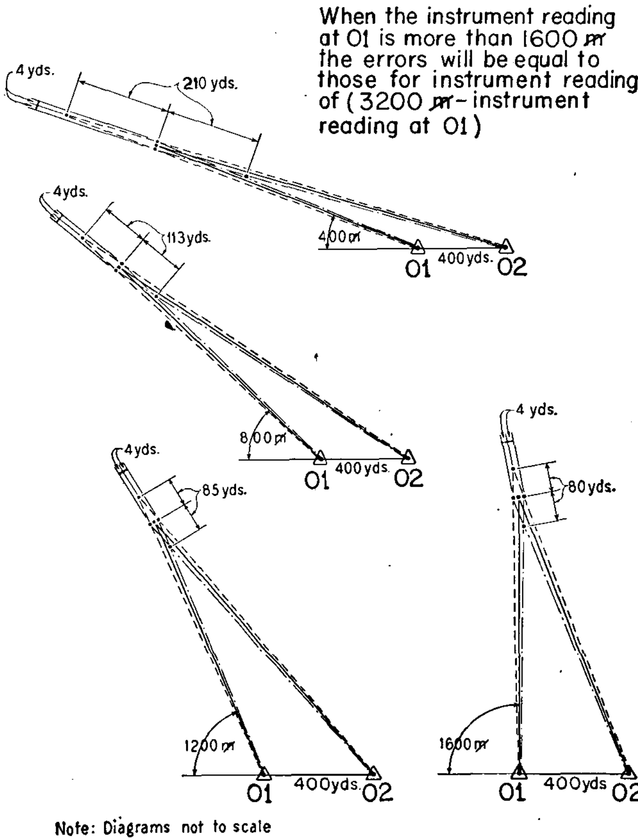


Figure 98. Variation in target location errors due to varying instrument readings when the base length, distance, and error in instrument readings are constant.

131. ORIENTATION OF INSTRUMENTS

a. Direct Orientation. When the observation posts are intervisible, the observing instruments

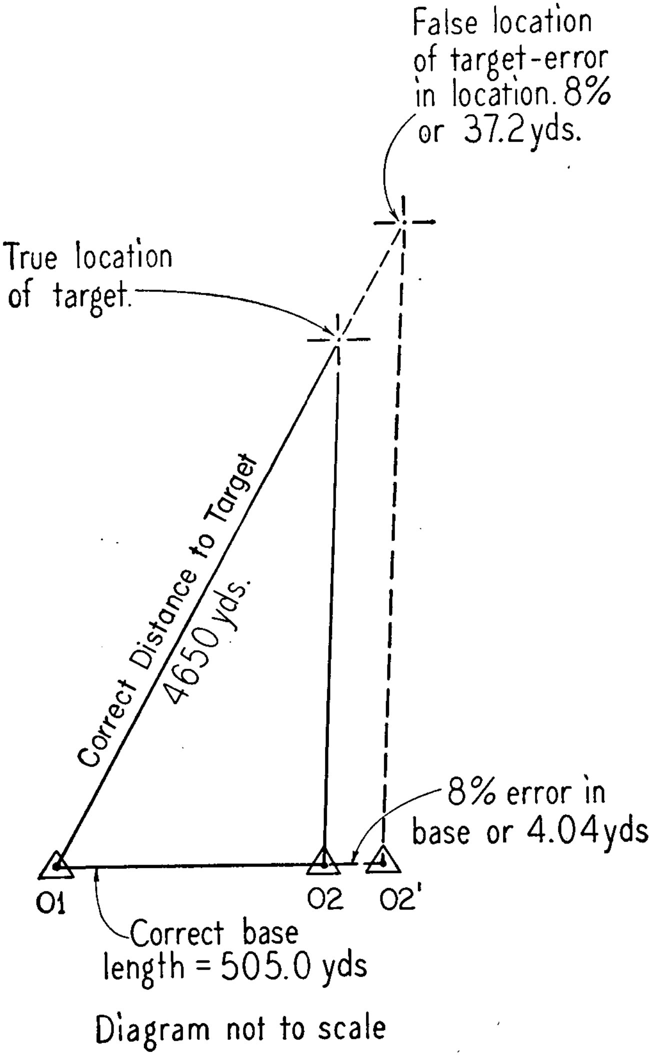


Figure 99. Error in distance directly proportional to error in base.

are oriented directly on each other. For definitions concerning the target area base, see FM 6–40.

(1) *01*. With 3,200 mils set on the instrument scale, sights on the center (sighting post) of the *02* observing instrument.

(2) *02*. With zero mils set on the instrument scale, sights on the center (sighting post) of the *01* observing instrument.

(3) *Both observation posts.* Upon completion of (1) and (2) above, both observers swing their instruments to the front. The observers are then ready to observe and report. (Night orientation stakes are installed.)

b. Indirect Orientation. When the observation posts are not intervisible, the observing instruments must be oriented on an auxiliary point, either to the front or to the rear of the base. During the computation of the base length, the interior angles at *01* and *02* are determined, and the instrument readings are computed (fig. 100 and par. 132).

(1) *Orienting the instruments.* The observers set the computed instrument readings on the scales of their instruments and sight on the orienting point.

(2) *Observing target area, orienting point to front or to rear of base.* Upon completion of the steps above, both observers swing their instruments to the front. The observers are then ready to

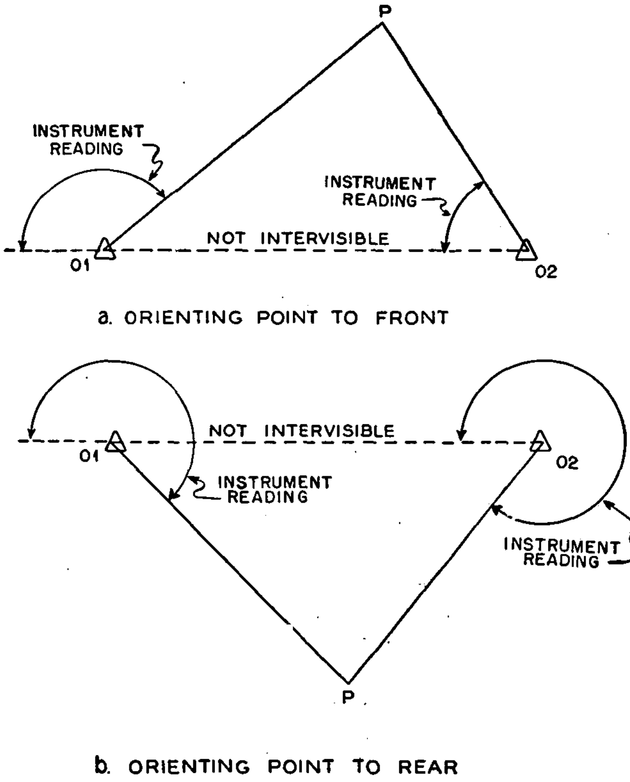


Figure 100. Indirect orientation.

observe. (A stake is established at least 100 meters distant from each observation post for night orientation.)

132. SURVEY METHODS

a. General. The internal survey for a rapid installation consists of two operations:

(1) Determination of the length of the base line in yards.

(2) Determination of instrument readings for the observing instruments.

b. *Accuracy Required.*

(1) *Orientation of instruments.* Since a very small error in orientation will produce large errors in distances, the observing instruments are oriented as carefully as possible.

(2) *Measurement of the length of the base line.* Since the error in distance is proportional to the error in the measurement of the base line, this distance should be determined to a degree of accuracy not less than 1 in 500.

c. *Measurement of Base Length.*

(1) *Selection of survey method.* The selection of the method used for determining the base length depends upon the intervisibility of the observation posts and upon the accessibility of the intervening terrain. Accessibility of the terrain depends not only on the topography but also on possible exposure of personnel to the enemy. Thorough reconnaissance to determine these factors is necessary before a survey method is selected. Alternate survey methods are illustrated and described in figures 101 to 108 inclusive. (In figures 101–108, *L* and *R* are substituted for *01* and *02* respectively.) In using methods involving aux-

iliary bases, consideration must be given to the strength of figure. Avoid use of angles of less than 300 mils (pars. 78 and 80).

(2) *Direct taping method.* When the observation posts are intervisible and the intervening terrain is accessible for taping, the base length may be taped directly. Direct orientation is used. In figure 101, the distance *LR* is taped.

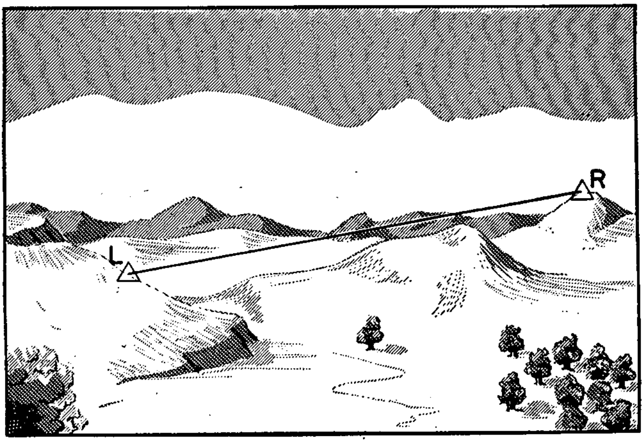


Figure 101. Direct taping method.

(3) *Cotangent relation method* (fig. 102). When the observation posts are intervisible but the intervening terrain is

inaccessible, an auxiliary base may be taped at right angles to the base from either observation post (side LA). The angle LRA is measured at the observation post opposite the auxiliary base. The base length is determined by the formula: $LR = LA \cot < R$.

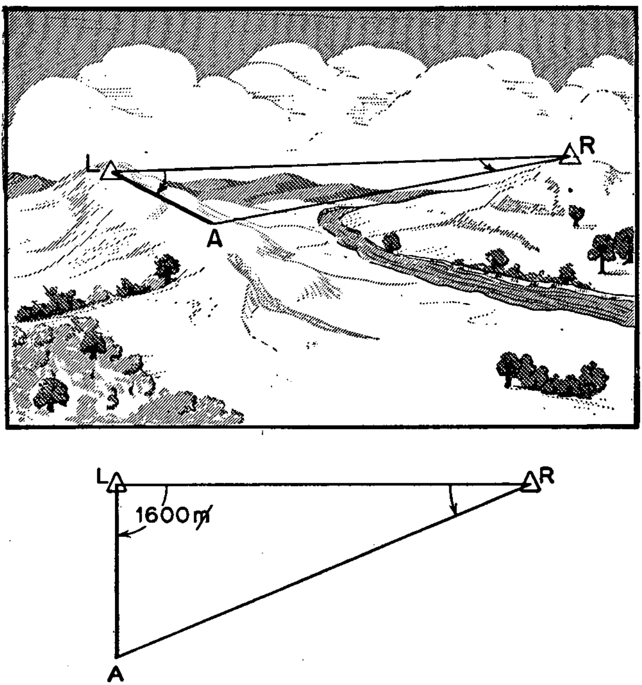


Figure 102. Cotangent relation method.

(4) *Sine law relation method* (fig. 103). When the observation posts are intervisible but the intervening terrain is

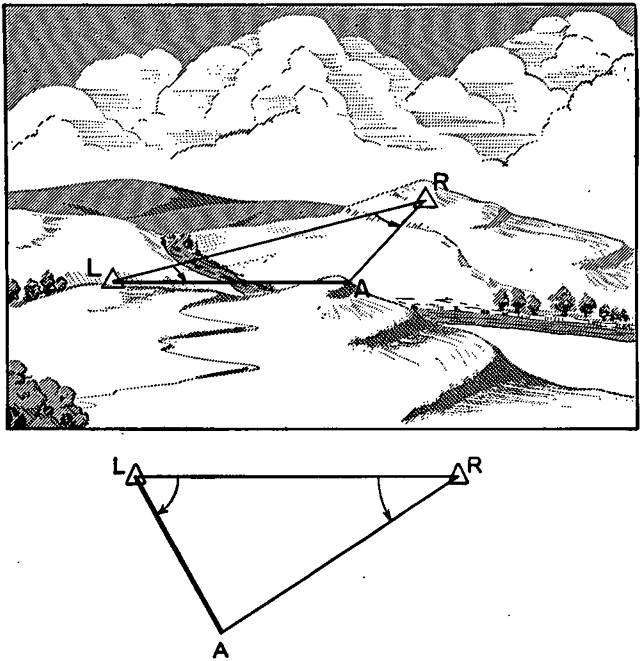


Figure 103. Sine law relation method.

inaccessible and the terrain precludes the use of an auxiliary base at right angles to the base from either observation post, an auxiliary base may be taped at any angle to the base from either observation post (side *LA*). The observer at *L* measures the angle *RLA* and the observer at *R* measures angle *LRA*. Angle *LAR* is computed as follows:

$$< A = 3{,}200 - (< L + < R)$$

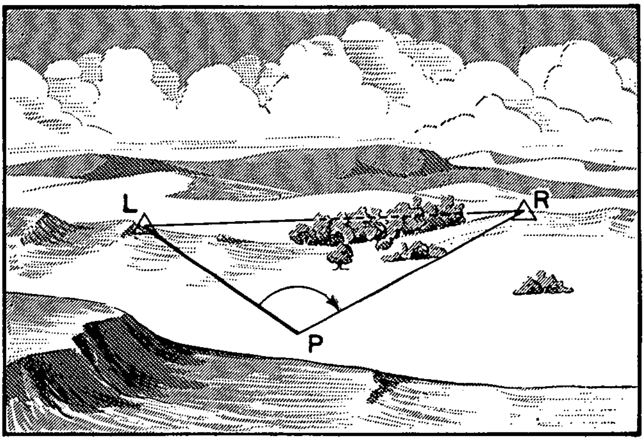
The base length is determined by the

formula:

$$LR = \frac{LA \sin < A}{\sin < R}$$

Direct orientation is used.

(5) *Point "P" method* (fig. 104). When the observation posts are not intervisible but the terrain to either the front or to the rear of the base is accessible for taping from the observation posts, a point *P*, visible from both observation



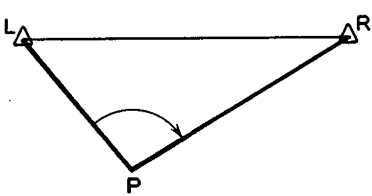


Figure 104. Point P method.

posts, may be selected to the front or rear, and the distances from the point P to each observation post are taped. The angle LPR is measured and the base length LR is determined in two steps, by the formulas:

(a) $$\tan < L = \frac{PR \sin < P}{PL - PR \cos < P}$$

(b) $$LR = \frac{PR \sin < P}{\sin < L}$$

(c) $$< R = 3{,}200 - (< L + < P)$$

If the angle at P is greater than 1600 mils, it must be borne in mind that $\cos < P$ is negative. When $PR \cos < P$ is positive and greater than PL, $\tan < L$ is negative and $< L$ is greater than 1600 mils. Indirect orientation is used (fig. 100).

(6) *Triangulation methods* (par. 79).

(a) *General.* Triangulation may be used under the following conditions:

1. When the terrain between the observation posts is not accessible for taping.

2. When the terrain either to the front or to the rear of the base is not accessible for use of other methods described above.

3. When the terrain to either the front or to the rear is accessible for establishing, by direct taping, an auxiliary base, both ends of which are visible from both observation posts.

(b) *Intervisible observation posts* (fig. 105). The length of the auxiliary base AB is taped, and the angles 1 and 2 at point L and angles 3 and 4 at point B are measured. The base length is determined by the formulas:

$$< A = 3{,}200 - (< 1 + < 3)$$

$$< R = 3{,}200 - (< 2 + < 4)$$

$$LB = \frac{AB \sin < A}{\sin < 1}$$

$$LR = \frac{LB \sin < 4}{\sin < R}$$

Direct orientation is used.

(c) *Nonintervisible observation posts* (fig. 106). The distance AB is taped, the angles 1 and 2 are measured at point A, and the angles 3 and 4 are measured at point B. The base length is determined by solving successive triangles.

In triangle LAB:

$$<BLA = 3{,}200 - (<1 + <2 + <3)$$

$$LB = \frac{AB \sin (<1 + <2)}{\sin <BLA}$$

In triangle RAB:

$$<ARB = 3{,}200 - (<2 + <3 + <4)$$

$$RB = \frac{AB \sin <2}{\sin <ARB}$$

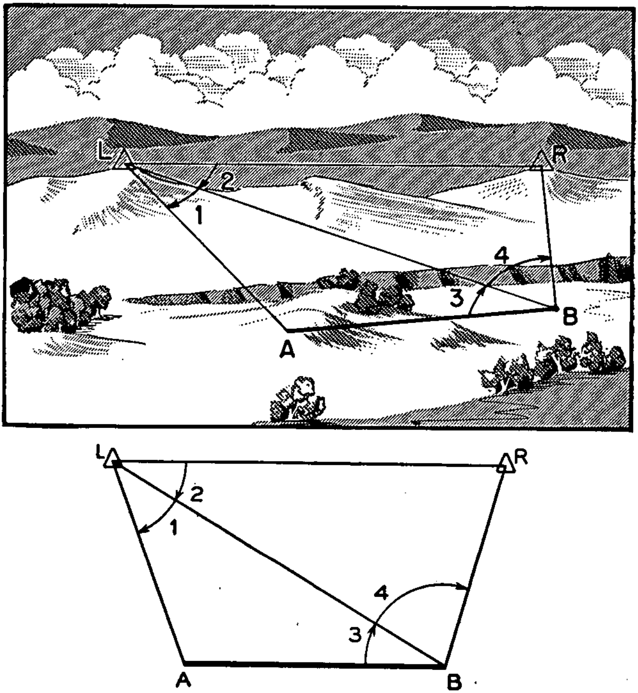


Figure 105. Triangulation, intervisible observation posts.

In triangle LBR:

$$\text{Tan } <RLB = \frac{RB \sin <4}{LB - (RB \cos <4)}$$

$$<LRB = 3{,}200 - (<4 + <RLB)$$

$$LR = \frac{RB \sin <4}{\sin <RLB}$$

Indirect orientation on point B is used.

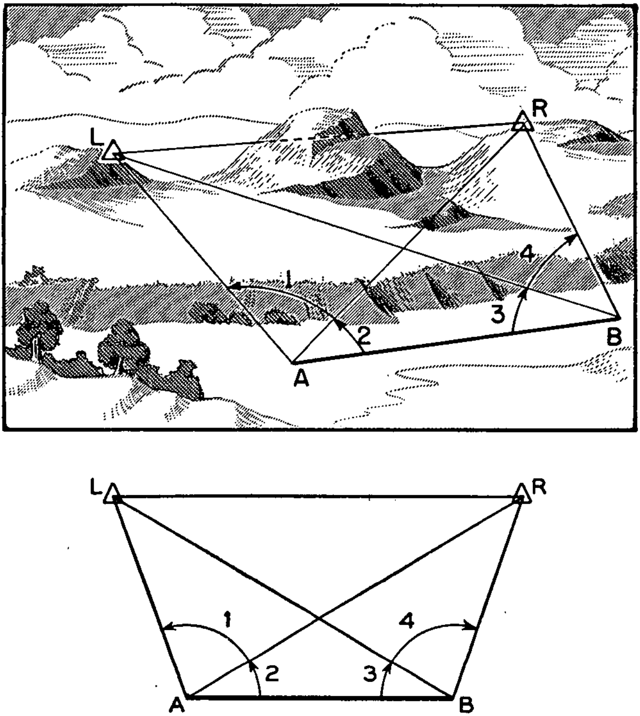


Figure 106. Triangulation, nonintervisible observation posts.

(7) *Two-point resection method* (fig. 107). For a discussion of the two-point resection, see paragraph 88. When the observation posts are intervisible and conditions exist as described in (6) (*a*) above, a two-point resection may be performed to determine the base length. An auxiliary base *AB* is established as

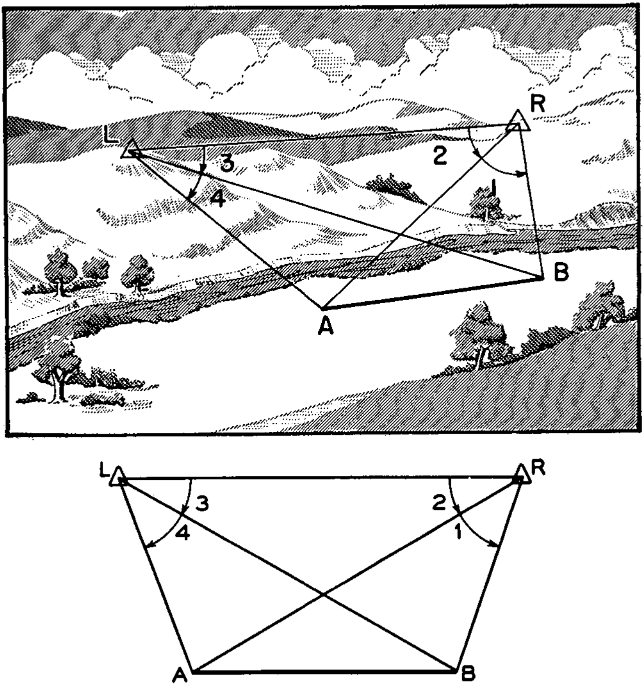


Figure 107. Two-point resection method.

for a solution by triangulation. Distance *AB* is taped, and angles 1, 2, 3, and 4 are measured. An arbitrary base length *LR* is assumed, and a corresponding auxiliary base length *AB* is computed by the method in (6) (*b*) above. The true base length *LR* is determined by the proportion:

$$\frac{LR \text{ (true)}}{LR \text{ (assumed)}} = \frac{AB \text{ (true)}}{AB \text{ (assumed)}}$$

Direct orientation is used. This method has the advantage that observing instruments need be set up only at observation posts.

(8) *Traverse method* (fig. 108) (par. 74). When the observation posts are not intervisible and none of the previously described methods of survey are applicable, it will be necessary to run a traverse from one observation post to

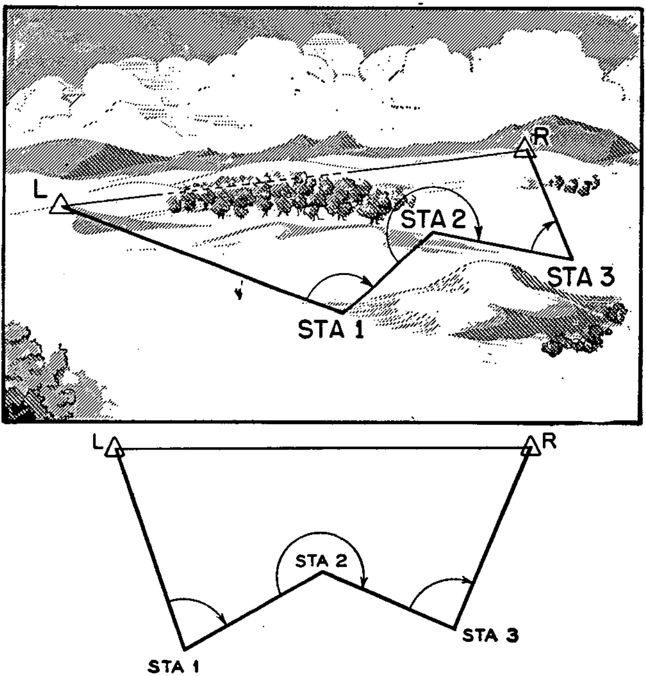


Figure 108. Traverse method.

the other and to compute the base length. Assume coordinates for one observation post and an azimuth to station 1 on the traverse. Upon completion of the traverse, compute the coordinates of the other observation post and the distance and azimuth of the base (*LR*) (par. 76). Compute the angles at each observation post between the base and the next adjacent leg of the traverse by determining the differences in the respective azimuths. Indirect orientation is used (fig. 100). Each observation post is oriented on the next adjacent traverse station.

d. Survey Control. The survey for a rapid installation is connected to established control as soon as practicable. It can be accomplished by—

(1) Traverse, triangulation, resection, or a combination of these. This should replace any other method as soon as possible.

(2) Inspection or short traverse from some identifiable feature on an accurate large-scale map or air photo.

(3) Any graphical solution.

(4) Compass direction and location (coordinates) of the base or check point.

(5) Firing. An adjustment is fired and the firing chart location of the target is obtained. The observation post is located with respect to the point on which the adjustment was fired by determining the compass direction and distance from the

observation post to the point concerned.

133. COMMUNICATION

Communication between the two observation posts and the plotting center in a rapid installation is by a "closed loop" wire circuit (fig. 109). A circuit is first laid from the plotting center to each observation post. Later the observation posts are interconnected by a wire circuit, thereby completing the loop so that communication may be maintained between the three stations if one leg of the loop is broken. Each flash ranging team is also equipped with two radios. Radio is used initially for communication between the most distant observation post and the plotting central; after the wire circuit is installed, it is used as an alternate means of communication.

134. POLAR PLOTTING

A point (target) is located by plotting its distance and direction from *01*. Base length and instrument directions from both observation posts are necessary to determine the distance. The distance may be determined by—

a. Computation (Law of Sines). (The solution outlined below is for target 1 in figure 110.)

$$\text{Distance} = \frac{\text{base x sin instrument reading } \mathit{02}}{\text{sin apex angle}}$$

$$\text{Distance} = \frac{483 \text{ x } \sin 1187\text{₥}}{\sin 106\text{₥}}$$

Log 483 = 2.68395
Log sin 1187₥ = 9.96328 − 10
Log sin 106₥ = 9.01652 − 10
Log distance = 3.63071
Distance = 4273 yards

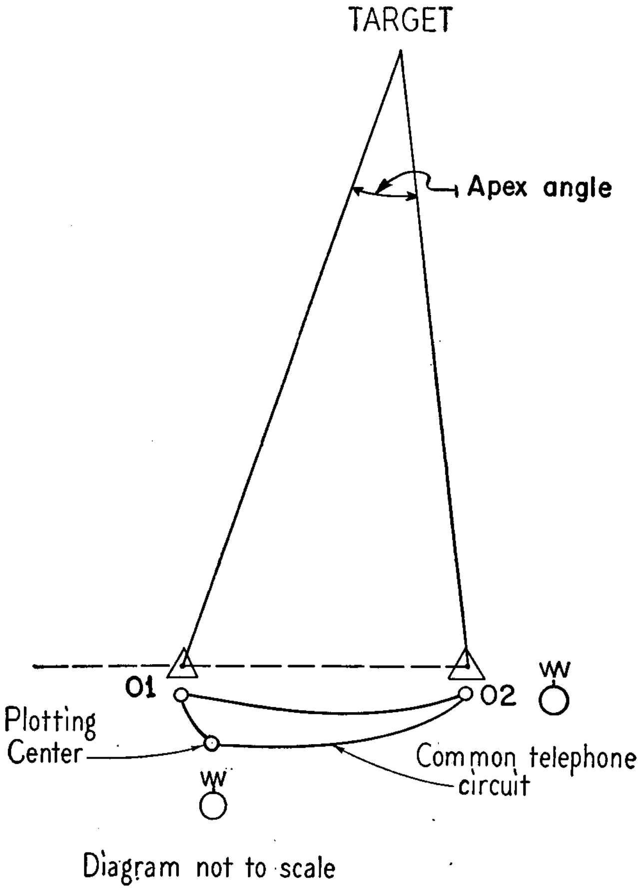


Figure 109. Flash ranging system for a rapid installation.

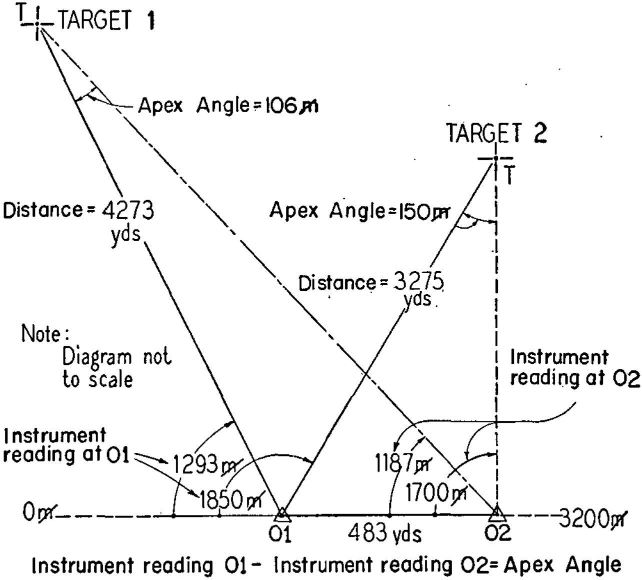


Figure 110. Instrument readings to targets in a rapid installation.

b. Military Slide Rule. The military slide rule is designed to simplify and speed up the solution of the oblique triangle. This slide rule is a special type Mannheim slide rule that can be used in performing many arithmetic and trigonometric calculations in the same manner as standard commercial slide rules. It is used primarily in the solution of military survey. Oblique triangles and computations of coordinates from distance and bearing are quickly solved by means of the rule (TM 6–240). Example (target 2, figs. 110 and 111): To determine distance *01* to *T,* set 150 on

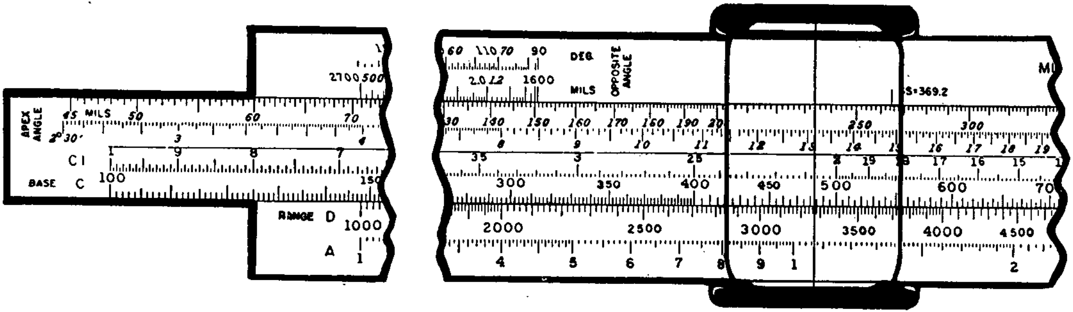


Figure 111. Solving for target 2 in figure 110 using the military slide rule.

the APEX ANGLE SCALE under 1700 on the OPPOSITE ANGLE SCALE; move the hairline to 483 on the BASE SCALE; under the hairline read 3,280 yards on the RANGE SCALE.

c. Plotting. See figure 112 for method of polar plotting.

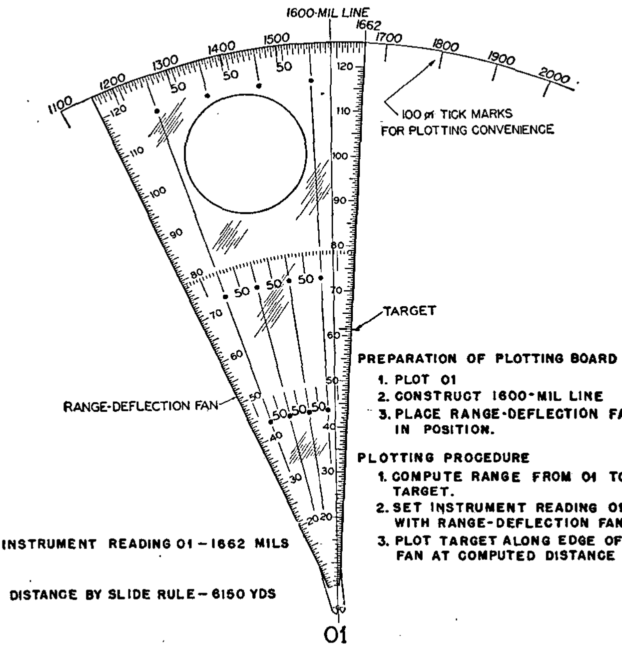


Figure 112. Polar plotting.

135. TYPES OF PLOTTING CHARTS AND METHODS OF REPORTING TARGETS

The type of plotting chart used depends upon the survey by which the flash installation is tied to the firing chart of the supported unit. Plotting is done from *01* on the chart by setting off a direction and distance. The method of reporting targets depends upon the type of plotting chart and firing chart being used.

a. Grid Sheet. A grid sheet may be used when the flash base and the supported unit are connected by common survey and when the supported unit is using a grid sheet as a firing chart. Targets are usually reported by rectangular coordinates.

b. Battle Map and (air) Photos. When either a battle map or air photo is being used as a firing chart by the supported unit, flash units may also plot their *01* station on a similar map or photo, and plot locations by any of the methods described above directly on the map or photo.

c. Target Grid Methods. Target grid methods are used in reporting targets when no common grid exists (fig. 113). For target grid procedure, see FM 6–40.

d. Instrument Reading and Distance. Targets may be located and reported by instrument reading and computed distance from *01*, as shown in figure 114.

136. OPERATING PROCEDURE

a. Installation. Rapid flash ranging installations will often be made by a minimum number of personnel, and no fixed procedure for installation is prescribed. The observation posts are selected by the flash platoon leader, with the assistance of the flash ranging chief, chief flash

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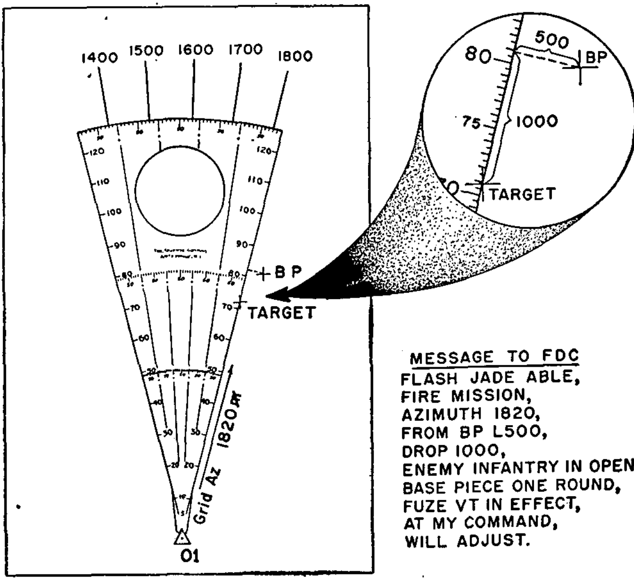


Figure 113. Reporting targets to the fire-direction center using target grid methods.

ranging observer, or the flash ranging observers, in accordance with the considerations listed in paragraph 130. Survey of the base is performed and communication between the plotting center and observation posts established by the members of the team under the direction of the flash platoon leader and his assistant. The plotting chart is prepared as soon as survey of the base, computation of the base length, and orientation are completed. The observation posts are furnished the data with which to orient their instruments when indirect orientation is used. For method of verifying orientation by astronomic observation, see paragraph 140.

b. Observer Procedure.

(1) Upon occupation of his post, an observer sets up the observing instrument and commences a methodical and careful search of the target area; he does not wait until survey and communication are complete to begin to observe. An observer makes pertinent notes regarding targets, check points, etc. *He should prepare a panoramic sketch of the target area* (fig. 115). Readings to targets may be made before orientation is possible by zeroing the instruments on a selected reference point. An aiming stake should be set out not less than 100 meters from each observation post for night orientation. A complete target area survey is begun by locating all important terrain features, such as crossroads, hills, buildings, clumps of trees, etc. In short, an observer begins immediately to *index* the terrain.

(2) As soon as both observation posts are occupied, the observers identify reference points to each other. These should be distributed both in distance and direction. Computed distances to these reference points should be memorized and noted on panoramic sketches as guides in estimating target distances. When a target is discovered by one observer only, he reads the instrument direction

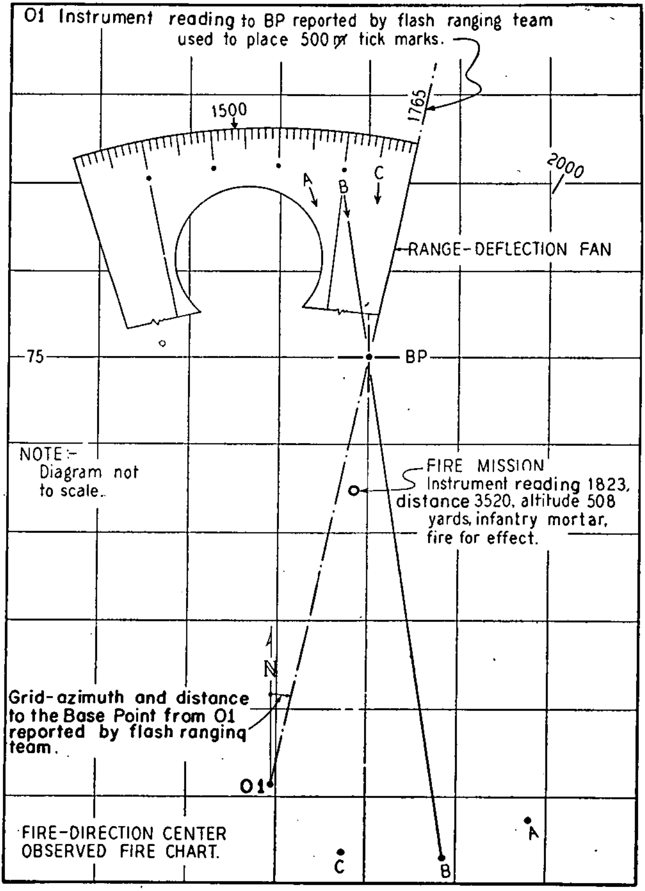


Figure 114. Reporting targets to the fire-direction center by polar coordinates.

and, using the estimated distance, applies the computed apex angle (using military slide rule) to provide the ap-

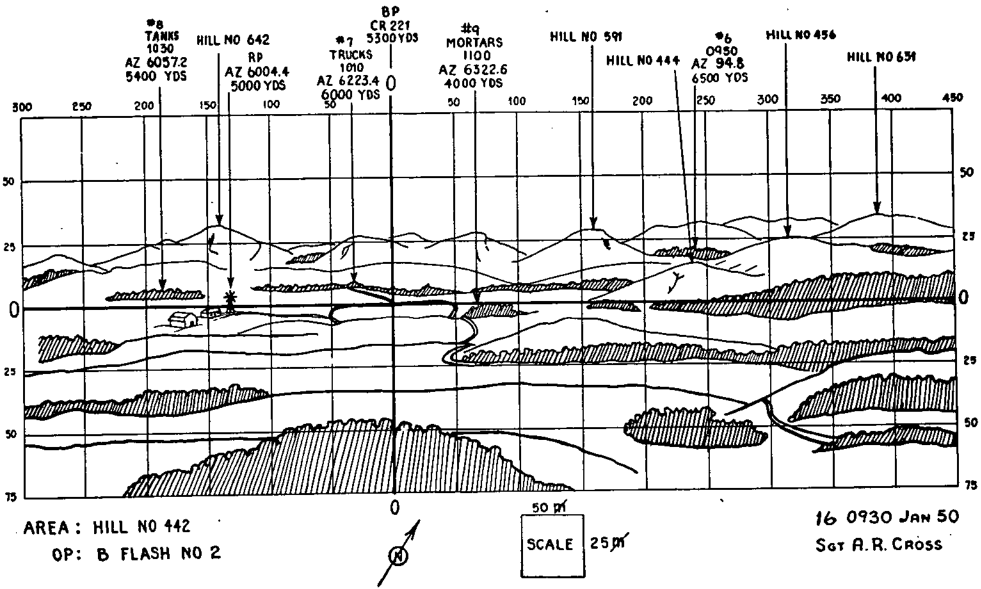


Figure 115. Panoramic sketch.

proximate instrument direction for the other observation post. The results are then reported, for example, ENEMY TANKS ASSEMBLING, 1,350, DISTANCE 6,000. If there is any question regarding the proper identification, the observer should attempt immediately to identify the target by additional means. Panoramic sketches are essential observation post records, which aid in identification of targets.

(3) When an enemy gun is firing and is visible to only one observation post, an observer may have to resort to the *flash-bang* method. In this method, the observer, in addition to obtaining the direction to the gun, measures the time interval between the instant he sees the flash of the gun and the instant he hears the sound of the gun. He is equipped with a stop watch for this purpose. The time interval is used to determine the distance to the gun (par. 96*b*).

(4) Location can also be made from a single observation post by determining the direction and angle of site to a target. The ray is drawn on a map. A profile section along this line is made, and the line of site is drawn. The intersection of this line with the ground, with proper corrections for curvature and refraction, will give the distance to the enemy gun. Direction and distance to the target are

then reported. *Where targets are visible to single observation posts, observers must be prepared to adjust fire on the target using the target grid procedure* (FM 6–40).

(5) When observing on a moving target, both observers track the target until the directing observer indicates the instant to stop tracking and read. A prearranged count should be used. *Example: 01*: TRACK MOVING GUN; *02*: ON; *01*: 1–2–3–MARK. Both instruments are read and reported to the plotting center in turn.

c. Flash Ranging Location. The instant a target is sighted by either observer, he reports FLASH. When a flash from the same target is sighted by the other observer, he reports ON. The computer (draftsman) then commands *01 (02), REPORT*. In response, the *01 (02)* observer reports instrument reading, accuracy of reading, and angle of site to the target; for example, 1895.6, ABLE, ANGLE OF SITE MINUS 3, ENEMY GUN FIRING. Observers qualify all readings as Able, Baker, or Charlie, according to the following standards of accuracies:

Able—reading accurate.

Baker—reading in error less than 2 mils.

Charlie—reading in error greater than 2 mils.

(In rapid installations, only Able readings are of value in plotting. Baker and Charlie readings are too inaccurate for a location, but indicate that the observer is on the target and should be able to report an Able reading on the next observation.) The computer (draftsman) records this information on the Flash Ranging Record for Rapid Installations (fig. 116) and calls for a report from the other observer, who reports in a like manner. The computer (draftsman) plots the location of the target, recording distance, coordinates (if applicable), and altitude. Altitude is corrected for curvature and refraction for distances over 5,000 yards (tab. XI).

137. ADJUSTMENT AND TRANSFER OF FIRE

Transfer limits and the selection of check points for registration are governed by gunnery considerations (FM 6–40). Surprise fire may be placed on any targets within transfer limits since accurate locations of targets are made by the flash ranging team in a rapid installation. Transfers may be made from appropriate centers of impact or high-burst centers, base points, check points, reference points, or previous targets and concentrations upon which fire has been delivered. Procedure during adjustments is discussed in paragraph 147.

138. ALTERNATE OBSERVATION POSTS

Reconnaissance to locate the best observation posts and alternate observation posts must be continuous. New observation posts should be surveyed, by taking advantage of the base in operation, and made ready for occupancy and changeover with a minimum of interruption.

BASE LENGTH 665 YDS

FLASH-RANGING RECORD FOR RAPID INSTALLATIONS

File No.	Conc. No.	Date	Time		Nature of Target	No. of Plots	Accuracy Meters	Caliber	Area Shelled
			Observed	Reported					
14	1	1-16-50	0920	0923	ENEMY GUN	2	25	LIGHT	UNKNOWN

Angle	Mils	Distance	Site		Coordinates	
			01	02	E	N
01	+1655.0					
02	-1545.0					
Apex Angle	110	6160	-10		549630	839240
01	+1654.8					
02	-1545.0					
Apex Angle	109.8	6160	-10		549631	839239
01	+					
02	−					
Apex Angle						
01	+					
02	−					
Apex Angle						
01	+					
02	−					
Apex Angle						
01	+					
02	−					
Apex Angle						
01	+					
02	−					
Apex Angle						
01	+					
02	−					
Apex Angle						
01	+					
02	−					
Apex Angle					1099261	1678479
		Sum	-20		549630.5	839239.5
		Mean	-10			
		O-T Distance	6160			
		Altitude of OP	1400			
		Target Altitude above OP ±	-184			
		Curvature and Refraction Correction	+ 6.9	+	Sum Z	Mean Z
		Z Coordinate of Target	1322.9			1322.9

DA AGO FORM 1 JUN 57 6–3b REPLACES FAS FORM 3c, 10 JUN 44, WHICH MAY BE USED.

Figure 116. Flash Ranging Record for Rapid Installations, DA AGO Form 6–3b.

Section III. DELIBERATE INSTALLATIONS

139. GENERAL

When all observation posts are located and oriented on a common grid and when adequate communication is established, a deliberate installation exists. Locations of targets and points in the target area are determined by plotting the grid azimuth to the target from each observation post. A typical installation is shown diagrammatically in figure 117.

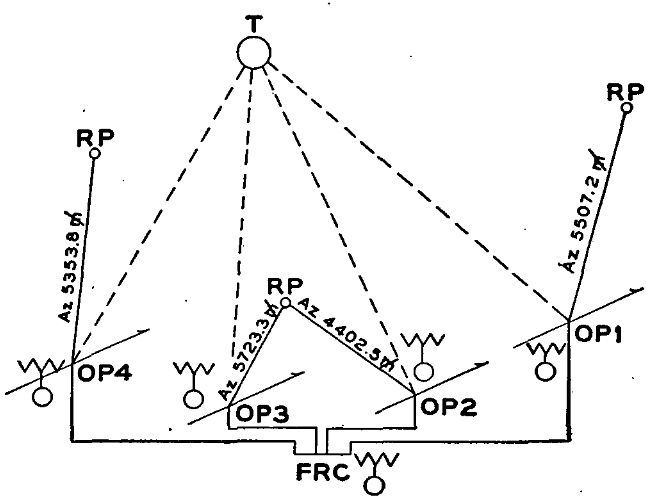


Figure 117. Flash ranging diagram, four observation posts.

a. General Considerations. Whenever conditions permit, an accurately surveyed flash ranging installation with multiple observation posts is employed to secure maximum accuracy and reliability of locations. The necessary conditions for such an installation include—

(1) *Adequate time for installation.* Time must be adequate to allow completion of accurate survey of the observation posts and installation of the necessary communication facilities.

(2) *Survey control.* Common survey control should be available to permit accurate survey of all observation posts on the existing grid system.

(3) *Suitable terrain.* The terrain should afford multiple vantage points, overlooking the target area, for siting the observation posts. In order to obtain the maximum number of intersecting rays on targets, all observation posts must be able to observe in the same target area. Intervals between adjacent observation posts should be not less than one-tenth of the distance to the far limit of the target area.

(4) *Communication.* The flash ranging central (FRC) and observation posts may be connected initially by radio, but wire is installed as soon as practicable. Each observation post normally is connected to the flash ranging central by a single wire line with radio as an alternate means of communication (fig. 117).

(*a*) *Flash switchboard.* All wire circuits from the observation posts to the flash ranging central terminate at the switchboard (fig. 118). The flash switchboard is a specially designed switchboard which, in addition to normal switchboard equipment, has means to indicate by a visual as well as audible signal the instant that a target has been sighted by the observers. When the signals from all

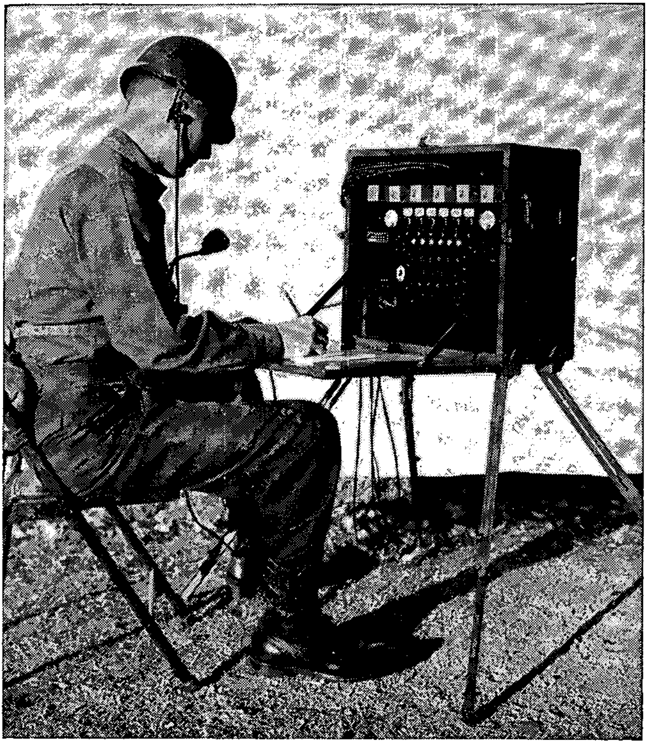


Figure 118. The flash switchboard.

observation posts occur at the same instant, the switchboard operator can assume with reasonable accuracy that all observation posts have sighted the same target.

(*b*) *Observation post equipment.* Each observation post is equipped with an observing instrument, an outpost set (fig. 95), a map, compass, and a stop watch. Various types of observing instruments may be in use. All should be designed to measure horizontal and vertical angles. The outpost set enables the observer to use a single line to talk on the telephone as well as to activate the signal on the switchboard the instant a target is sighted. An oriented map or panoramic sketch will aid the observer in identification and location of targets.

b. Orientation of Base with Respect to Target Area. Observation posts may be spaced irregularly or at fairly regular intervals, depending upon the terrain. The ideal installation will permit the perpendicular bisector of a line connecting the two extreme observation posts to pass near the center of the target area.

c. Numbering of Observation posts. Observation posts are numbered consecutively from right to left facing the front (fig. 117).

d. Advantages and Disadvantages.

(1) A deliberate flash ranging installation affords greater accuracy and reliability

of target locations than a rapid installation; in a deliberate installation, multiple rays can be constructed through any one target, and the angles of intersection are large. Locations are made on a grid system and reported by coordinates. Control of all observation posts is centralized at the flash central, thus providing for maximum coördination of flash observation facilities.

(2) More time, survey, and wire are necessary for the complete installation of a deliberate flash base than for a rapid flash base. The terrain must be suitable for this type of installation.

140. ORIENTATION OF INSTRUMENTS

Each observing instrument must be oriented so that the zero on the scale is on grid or prescribed assumed north. To accomplish this, the observer sights on the orienting point with the azimuth of the orienting point set off on the instrument. He then swings the instrument to the front and is ready to observe and report. Auxiliary orienting points should be used, and an aiming stake should be established not less than 100 meters from each observation post for night orientation. The orienting point may be any point of known direction from the observation post. The azimuth to the orienting point may be determined from the coordinates of the observation post and the coordinates of the orienting point. This information is recorded on DA AGO Form 6–3, Orienting Data for Flash Ranging Observation Posts (fig. 119). *Orientation must be checked repeatedly.*

a. Reciprocal Orientation. When two or more observation posts are intervisible and one of them has been oriented properly, the others may be oriented reciprocally (fig. 120).

Orienting Data For Flash-Ranging Observation Posts

Date 16 JANUARY 1950 Time 1450 Position BATEMAN WOODS

OP No.	Coordinates of Observation Posts			Orienting Point		
	E	N	Z	Description	Azimuth	Site
1	548901	839713	1525	Signal Mountain	3910	+18
2	551538	838803	1320	Signal Mountain	4390	+25
3	552996	838175	1368	Grierson Hill	3420	-9
4	553926	837835	1335	Grierson Hill	3740	-8

Orienting Data For Flash-Ranging Observation Posts

Date............ Time............ Position............

OP No.	Coordinates of Observation Posts			Orienting Point		
	E	N	Z	Description	Azimuth	Site
1						
2						
3						
4						

Orienting Data For Flash-Ranging Observation Posts

Date............ Time............ Position............

OP No.	Coordinates of Observation Posts			Orienting Point		
	E	N	Z	Description	Azimuth	Site
1						
2						
3						
4						

DA AGO FORM 1 JUN 51 6-3 REPLACES FAS FORM 3a, 1 JUN 44, WHICH MAY BE USED.

Figure 119. DA AGO Form 6–3 for recording orienting data for flash ranging observation posts.

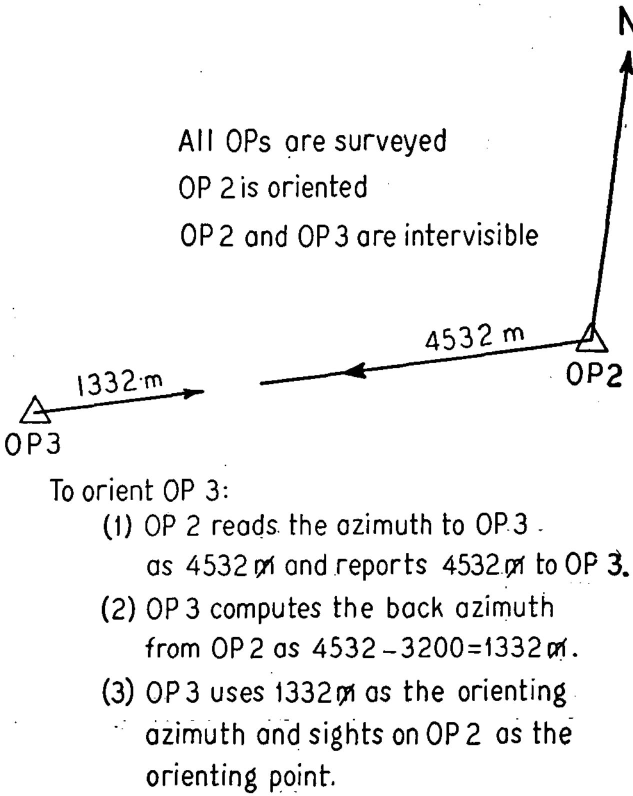


Figure 120. Reciprocal orientation.

b. Astronomic Orientation. Orientation of instruments may be obtained or verified by an astronomic observation. See paragraphs 90 and 91 for a discussion of procedure in obtaining an azimuth from sun or star observation. Orientation may be checked at any time by having all observers sight simultaneously on the *same* astronomic body. If all instruments are oriented on a common direction, they should all obtain the same reading to the astronomic body.

141. SURVEY METHODS

a. The survey of a flash observation post consists of two operations—determination of the coordinates and altitude of the observation post, and determination of the orienting data for the observing instrument.

b. The observation posts should be located and altitudes determined by survey personnel using precise methods as described in chapter 6.

c. The coordinates of an observation post may be determined by a short traverse (fig. 121), without the use of survey personnel if survey control is furnished to a point near the observation post. The observers traverse from the control point to the observation post using the observing instrument and tape. This method is particularly valuable when—

(1) Survey personnel are unable to bring control to the exact position of the observation post because of security reasons.

(2) The exact location of the observation post has not been selected when the survey control is brought up to the general location of the observation post.

(3) The observation post has been moved a short distance after survey control has been established.

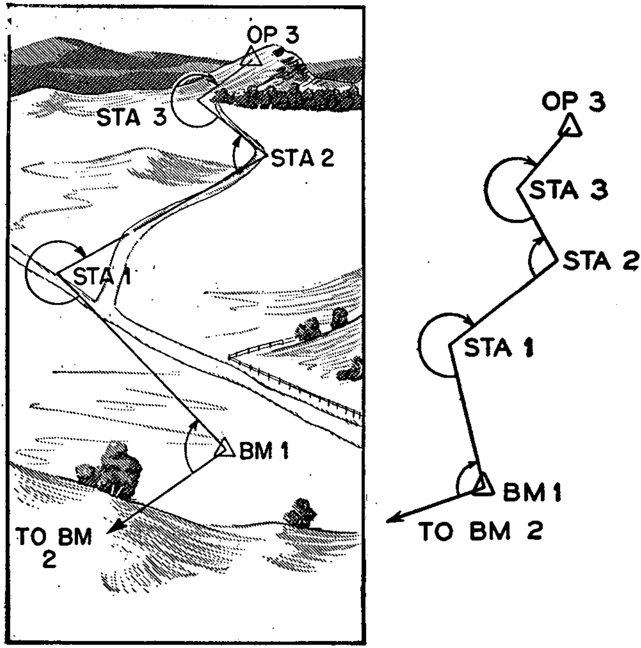


Figure 121. Location of an observation post by short traverse.

d. The coordinates of an observation post may be determined by resection without the use of survey personnel if sufficient points of known coordinates are visible from the observation post. Detailed procedure for resection by the flash observing plotting personnel is discussed in paragraph 143.

142. PLOTTING

a. General. Rapid, accurate plotting for a deliberate flash ranging installation is best performed by means of a mechanical plotting board (figs. 122 and 123, and TM 9–575).

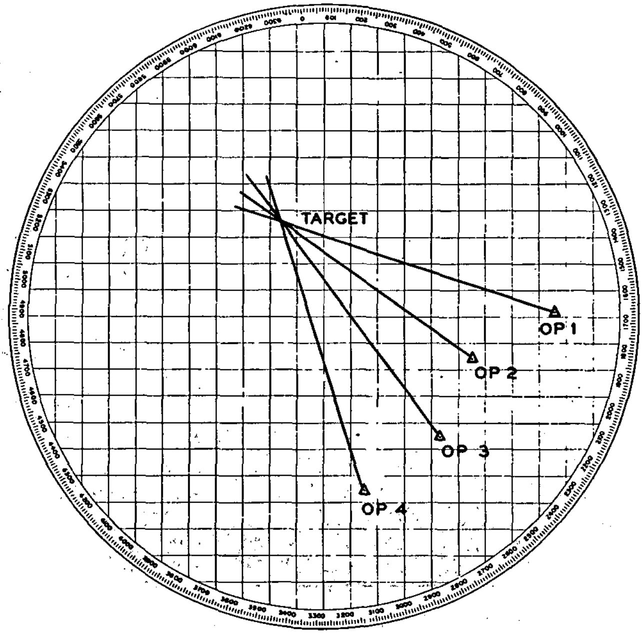


Figure 122. Flash Ranging Plotting Board, M5, with observation posts, rays, and target plotted.

b. Numbering Grids. In orienting the board for numbering grid lines, the zero reading on the plotting board scale is north. The grid lines must be so numbered as to include the area occupied by the observation posts and the target area in their proper relation.

c. Plotting Observation Posts. The observation posts are plotted by coordinates on the plotting

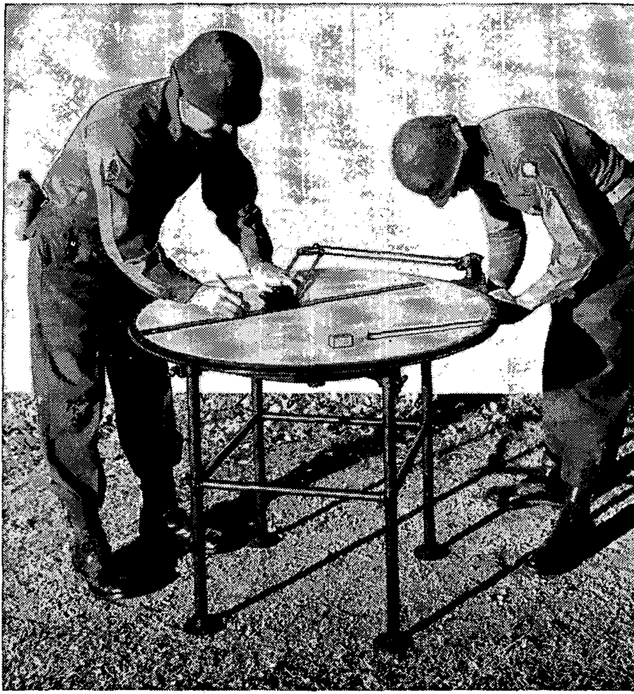


Figure 123. Flash Ranging Plotting Board, M5.

board, as carefully as possible, using a 2H or 3H pencil.

d. Orientation for Observation posts. If the orienting point is a point in the target area, it may be plotted on the plotting board and the azimuth to it read from the plotting board and furnished to the observer. Orientation should be checked frequently to insure that the instrument has not been disturbed. For more precise orientation, computed azimuths should be used.

e. Locations of Points in Target Area.

(1) As the azimuths from the observation posts are announced, they are set off on the azimuth scale and rays are drawn through the proper observation posts well into the target area. The intersection of these rays is the location of the target, the coordinates of which are scaled from the plotting board.

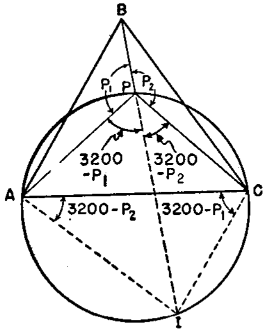
(2) The rays will not always intersect at a point but frequently will form a polygon, called the polygon of error (fig. 80). The procedure for solving the polygon of error and for assessing an accuracy of plot is the same as described in paragraph 116*g* for sound ranging plots. Greater weight should be given to the rays that have Able readings of accuracy (par. 136*c*).

143. LOCATING OBSERVATION POSTS BY RESECTION

Resection may be employed to locate an observation post, without the use of survey personnel, if sufficient points of known coordinates visible from the observation post exist in the area.

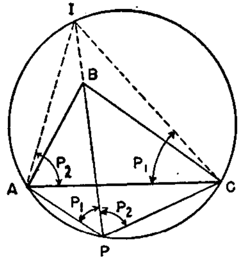
a. Three-Point Resection (fig. 124). Angles at the observation posts between the known points are read by the observers and reported to the plotting center, where the position of the observation post is determined on the plotting board.

(1) *Procedure for case 1.* The observer at P reads angles P_1 and P_2. The azimuth

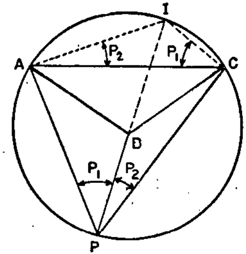


CASE 1

Az A to C + $(3200-P_2)$ = Az A to I
Az C to A − $(3200-P_1)$ = Az C to I
Az P to B − P_1 = Az P to A
Az P to B + P_2 = Az P to C



CASE 2



CASE 3

Az A to C − P_2 = Az A to I
Az C to A + P_1 = Az C to I
Az P to B + P_2 = Az P to C
Az P to B − P_1 = Az P to A

Points A, B, and C are three points of known coordinates. These points are plotted on the plotting board. Point P is the position of the observer and is to be located. In cases 2 and 3, point P falls outside the triangle formed by the three known points. In case 1, point P falls inside the triangle formed by the three known points.

Figure 124. Three-point resection.

from A to C is measured on the plotting board. The azimuth A to C plus (3,200 minus P_2) is equal to the azimuth A to I. The azimuth from C to A (or 3,200 plus or minus the azimuth A to C) is measured on the plotting board. The azimuth C to A minus (3,200 minus P_1) is equal to the azimuth C to I. The azimuth rays A to I and C to I are drawn on the plotting board. The intersection of these rays fixes the point I. Line BI extended is drawn on the plotting board and the azimuth from P to B (I to B) is measured. The azimuth P to B minus P_1 is equal to the azimuth P to A. The azimuth P to B plus P_2 is equal to the azimuth P to C. The azimuth rays P to A and P to C are drawn through A and C, respectively, on the plotting board. The intersection of these rays with the ray P to B fixes the point P unless a triangle of error exists, in which case proceed by the triangle of error method as described in *b* below.

(2) *Procedure for cases 2 and 3.* The observer at P reads angles P_1 and P_2. The azimuth from A to C is measured on the plotting board. The azimuth A to C minus P_2 is equal to the azimuth A to I. The azimuth from C to A (or 3,200 plus or minus the azimuth A to C) is measured on the plotting board. The azimuth C to A plus P_1 is equal to the azimuth

C to I. The azimuth rays A to I and C to I are drawn on the board. The intersection of these rays fixes the point I. Line BI extended is drawn on the plotting board and the azimuth from P to B (I to B) is measured. The azimuth P to B minus P_1 is equal to the azimuth P to A. The azimuth rays P to A and P to C are drawn through A and C, respectively, on the plotting board. The intersection of these rays with the ray P to B fixes the point P unless the intersection results in a triangle. In this case, proceed by the triangle of error method as described in *b* below. The point I is not a point on the ground; it is *only* a point on the circle that must be located to determine the azimuth P to B.

b. Triangle of Error Method. The position of an observation post may be located graphically by a three-point resection by the triangle of error method in the following manner. Assume an azimuth (as nearly correct as possible) from P to B (fig. 124). Then the azimuth P to A equals azimuth P to B minus P_1, and azimuth P to C equals azimuth P to B plus P_2. Draw these azimuth rays through A, B, and C in the direction of point P. If the three rays do not intersect at one point, new azimuths must be assumed for P to B, and the above procedure repeated until they do intersect. For further discussion of this method, see TM 5–235.

c. Two-Point Resection (fig. 125).

(1) Points *A* and *B* are two points of known coordinates. Points *C* and *D* are two points (observation posts) to be located. Points *A* and *B* are visible from both *C* and *D*. Observing instruments are set up at points *C* and *D*. The observer at *C* orients on *D* with 0 mils. The observer at *D* orients on *C* with 3,200 mils. With this orientation, both observers read azimuths to points *A* and *B*. Assuming that *C* and *D* are oriented on zero azimuth (both zeroes on north), the angles read to *A* and *B* become azimuths. Assume points *C* and *D* at any convenient location along a *N* grid line (3,000 to 5,000 meters apart), and plot them on the plotting board. From *C*, draw azimuth rays to *A* and *B*. From *D*, draw azimuth rays to *A* and *B*. The intersection of the rays *C* to *B* and *D* to *B* determines the assumed location of point *B*. The intersection of the rays *D* to *A* and *C* to *A* determines the assumed location of point *A*. Measure the assumed azimuth from *A* to *B* on the plotting board, and determine the assumed azimuth *B* to *A*. Plot the true positions of points *A* and *B* on the plotting board. Measure the actual azimuths from *A* to *B* on the plotting board, and determine the true azimuth *B* to *A*. Since the assumed figure and the actual figure are similar, all angles in

the two figures are equal. Determine a K-correction by finding the difference between the true azimuth A to B and the assumed azimuth A to B. The K-correction is then applied to the assumed azimuth, with proper regard to its sign, to determine the true azimuths.

(2) The following example is presented:

(*a*) Step 1.

Assumed azimuth A to B =	6070 mils
True azimuth A to B =	5020 mils
K-correction =	−1050 mils

(*b*) Step 2. Determine the assumed azimuths of B to D, B to C, A to D, and A to C. To these azimuths, the K-correction is applied algebraically to find the true azimuths B to D, B to C, A to D, and A to C.

Assumed azimuth B to C =	3820 mils
K-correction =	−1050 mils
True azimuth B to C =	2770 mils

(*c*) Step 3. From the true locations of A and B on the plotting board, plot the true azimuths as found above; the resulting intersections of these rays determine the actual location of points C and D.

d. Locating Observation Posts Reciprocally (fig. 126). OP 1 and OP 2 are intervisible. OP 2 is neither located nor oriented. OP 1 is located and oriented. OP 1 and X are known points and are plotted on the plotting board. The observer at OP 1 reads azimuth to OP 2. The observer at OP 2

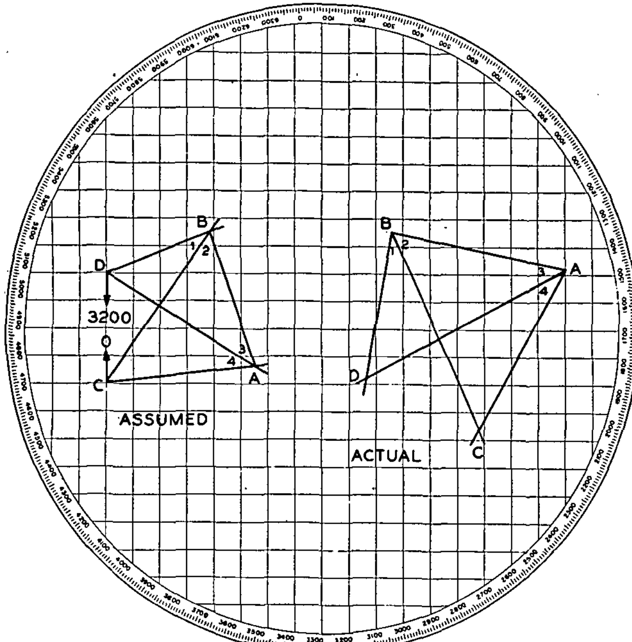


Figure 125. Two-point resection.

sets this azimuth ±3,200 mils on his instrument and sights on OP 1 which orients OP 2. OP 2 reads an azimuth to *X*. Rays are now drawn on the board at the correct azimuth from OP 1 and *X* to OP 2, thus locating OP 2. It is desirable to have more than one known point in order to check on the location of OP 2.

144. OPERATING PROCEDURE

a. General. The observers, plotting team, and switchboard operator form a highly coordinated team; to function accurately and rapidly, a high degree of discipline must be maintained, and a definite procedure of operation must be followed.

b. Organization and Duties.

(1) *Observer team.* The observer team consists of a minimum of three men—observer, assistant observer, and recorder. Since observation posts must be manned continuously (24 hours a day) every man must be able to perform the duties of every other man in the team. Addi-

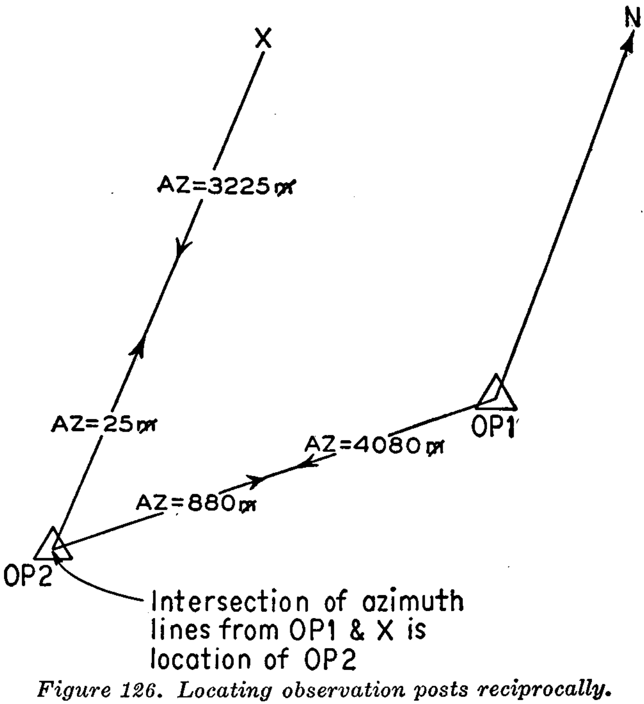


Figure 126. Locating observation posts reciprocally.

tional men are necessary for an extended operation. Two men must be on duty at all times. The observer operates the instrument and reads the horizontal and vertical angles; reports to the flash central all azimuths and sites to targets; announces accuracy of readings as Able, Baker, or Charlie (par. 136); executes all instructions from the switchboard operator; and maintains a record of his observations. The assistant observer maintains a constant lookout to locate targets, collect combat intelligence, and provide for local security; he keeps all necessary records and sketches at the observation post.

(2) *Plotting team.* The plotting team consists of a minimum of three men—the armsetter, the draftsman, and the computer. These may be supplemented by a recorder, although the computer or the switchboard operator may serve as a recorder if reports are not arriving from the observers too rapidly.

(*a*) The armsetter sets and reads the mil scale of the plotting board.

(*b*) The draftsman performs all drafting, reads coordinates and distances, assesses accuracy of location, and manipulates the plotting board.

(*c*) The computer determines the altitude of targets and performs any other necessary computations. Corrections for curvature and refraction are applied for distances over 5,000 yards (tab. XI).

(*d*) The recorder maintains a record of the coordinates and altitude of each target plotted, accuracy of each plot, description of target, and time of location. This is recorded on (Record of Sound, Flash, and Radar Locations) DA AGO Form 6–6 (fig. 127).

(3) *Switchboard operator. The switchboard operator is responsible for communication discipline and assists in observer control.* He records and announces to the plotting team the reports from the observers, and he transmits to the observers data for orientation and approximate azimuths.

c. Plotting Team Procedure.

(1) *Plotting azimuths.* The armsetter sets off on the scale of the plotting board the desired azimuth and reports *SET*. The draftsman draws a ray from the proper observation post to the target area and reports *LINE*.

(2) *Reading azimuths from plotting board.* The draftsman rotates the board until the two points between which the azimuth is desired are properly aligned and commands READ. The armsetter then clamps the board and reads aloud the scale setting, for example, 2850.5.

(3) *Plotting targets.* When rays from at least

RECORD OF SOUND, FLASH, AND RADAR LOCATIONS

Period Covered: Time 0001 Date 1 JAN 1950 to Time 2400 Date 1 JAN 1950 Sheet 1 of 3 Sheets

FILE No.	CONC. No.	SOURCE	COORDINATES E	COORDINATES N	COORDINATES Z	NUMBER OF PLOTS	ACCURACY METERS	NATURE OF TARGET	CALIBER	AREA SHELLED	TIME OBSERVED	TIME REPORTED TO Opns. CP	TIME REPORTED TO Arty. CP	MISSION FIRED BY	NUMBER OF ROUNDS	EFFECT
1	30	BF	96.340	972.460	592	3	50	Enemy Btry	—	Unknown	1310	1315	1320	170th	72	Neutralized
2	37	BF	95.410	981.360	485	4	30	Bn Cp	—	—	1315	1320	1325	172d	24	Destroyed

Number Consecutively

Assigned By FDC

B = Btry "B" F = Flash

Caliber of Hostile Artillery

Area Shelled By Hostile Guns

Z Coordinate is in Yards

DA AGO FORM 1 JUN 51 6-6 REPLACES FAS FORM 6, 10 JUN 44, WHICH MAY BE USED.

Figure 127. Sample record of flash locations using DA AGO Form 6-6.

three observation posts intersect, it may safely be assumed to be a target location. Reported azimuths from each observation post are plotted as in (1) above. The draftsman reads the coordinates of the target and assesses the accuracy of the plot, announcing to the recorder COORDINATES: 96156932, ACCURACY 100 METERS. He also reads and announces to the computer the distance from the observation posts as: DISTANCE FROM OP 2, 6,175 YARDS. The computer determines and announces the altitude of the target to the recorder as ALTITUDE, 517 YARDS. The recorder records and repeats back the coordinates, altitudes, and nature of target, as he receives them.

d. Testing Communication. Immediately upon completion of communication installations, the switchboard operator checks the switchboard circuits by the tests prescribed in TM 11–439; he checks the line circuits by ringing each observer in turn. The test is essentially as given in the example below—

Switchboard operator calls: OP 1.

Observer answers: OP 1.

Switchboard operator: PRESS YOUR OUTPOST SWITCH. If there is no signal, the switchboard operator makes proper adjustments.

Switchboard operator: GIVE ME A RING. The observer rings the switchboard.

Switchboard operator: ROGER.

This procedure is repeated, the switchboard operator calling each observation post in turn until all lines have been checked for outpost circuit, ringing circuit, and talking circuit. If radio is being used, the procedure must be modified to comply with radio procedure.

e. Orienting Observers. All circuits having been checked, the switchboard operator furnishes each observer orientation data, proceeding as follows:

Switchboard operator calls: ALL OP's REPORT WHEN READY FOR ORIENTATION.

Each observer reports in turn:

Observer: OP 1 READY.
OP 2 READY . . . etc.

When all observers have reported:

Switchboard operator: ALL OP'S, ORIENTATION FOLLOWS.

To each observer in turn:

Switchboard operator: OP 1, ORIENTING POINT, CENTER OF TOWER ON LITTLE HILL, AZIMUTH 5103.2, ANGLE OF SITE PLUS 10.

Each observer repeats back data to switchboard operator:

Observer: OP 1, ORIENTING POINT, CENTER OF TOWER ON LITTLE HILL, 5103.2, ANGLE OF SITE PLUS 10.

When all observers have been oriented:

Switchboard operator: ALL OP'S, REPORT WHEN READY TO OBSERVE.

948797°—51—21

Each observer replies in turn when ready to observe:

Observer: OP 1, READY TO OBSERVE.

When all observers have signified they are ready to observe:

Switchboard operator (to the plotting team): All observers are ready to observe.

f. Flash Ranging Location.

(1) When a target is observed, the observers immediately signal the switchboard.

Switchboard operator: OP 1 (2), (3), (4), REPORT.

Observer at OP 1: 6093.4, ABLE, ANGLE OF SITE MINUS 7.5, ENEMY GUN FIRING.

The switchboard operator records these data on the flash ranging record, DA AGO Form 6–3a, (fig. 128) and repeats back the data to the observer loud enough for the armsetter of the plotting team to hear. He then calls the other observation posts in turn for their reports. The plotting team plots the target using the procedure outlined in *c* above.

(2) If only one observer reports the azimuth to a target, the switchboard operator calls for an estimation of distance from that observation post to the target.

Switchboard operator: OP 1, REPORT ESTIMATED DISTANCE.

Observer: 4500.

The plotting team plots the approximate position of the target from these data

FLASH-RANGING RECORD

File No.	Conc. No.	Date	Time Observed	Time Reported	Nature of Target	No. of Plots	Accuracy Meters	Caliber	Area Shelled
10	63	9-9-49	0922	0930	ENEMY GUN	3	50	88	

Round No.	OP-1 Azimuth	OP-1 Site	OP-2 Azimuth	OP-2 Site	OP-3 Azimuth	OP-3 Site	OP-4 Azimuth	OP-4 Site	Coordinates E	Coordinates N
Initial	6075.7	-07.4	6151.0	-4.5	97.0	-2.5	342.0	-5.0		
1	6093.4	-07.5	6155.0	-5.0	100.5	-3.0	342.5	-5.0	68 678	99 800
2	6078.8	-07.4	6153.0	-5.0	97.3	-2.5	342.0	-5.0	68 712	99 860
3	6088.9	-07.4	6156.5	-5.0	98.0	-2.5	342.0	-5.0	68 695	99 815
4										
5										
6										
7										
8										
9										
10										
Sum	18261.1	-22.3	18464.5	-15.0	295.8	-8.0	1026.5	-15.0	206 085	299 475
Mean	6087.0	-07.4	6154.8	-5.0	98.6	-2.7	342.2	-5.0	68 695	99 825
O-T Distance	3368 yds.		3540 Yds		3450 Yds		3700 Yds			
Altitude of OP	1278 FT.		1259 FT.		1226 FT.		1257 FT			
Target Alt. above OP ±	-75		-53		-55		-55		Sum Z	Mean Z
Curv. and Refr. Corr. +	+2		+2		+2		+2			
Z Coordinate	1205 FT.		1208 FT.		1200 FT.		1204 FT		4817 FT	1204.2 FT.
					Altitude (Yards) =					x 3

DA FORM 6-3a 1 JUN 51 — REPLACES FAS FORM 3b, 12 JUN 44, WHICH MAY BE USED.

Figure 128. Sample record of flash ranging using DA AGO Form 6-3a.

and reads from the plotting board the approximate azimuth to the target for each of the other observation posts, announcing to the switchboard operator:

Draftsman: OP 2, 1950.

OP 3, 2150, etc.

The switchboard operator transmits these data to appropriate observers:

Switchboard operator: OP 2, OBSERVE NEAR 1950, ENEMY GUN FIRING.

(3) If any two observers signal the switchboard simultaneously, they are probably observing the same flash. The switchboard operator calls for their reports; the plotting team plots the rays and determines approximate azimuths to the target for all other observers. The procedure is the same as outlined in (2) above.

Section IV. CONDUCT OF FIRE

145. GENERAL

a. Targets located by flash ranging normally are reported by coordinates. In the absence of a coordinate system common to both flash ranging and firing units, initial fire commands are determined by the personnel at the flash ranging central using the M5 plotting board and transmitted to the firing units. Since the firing unit will be using the target grid, the azimuth from any suitable observation post to the target can be used to orient the grid. If conditions are favorable for a flash ranging adjustment, WILL ADJUST should follow the report of the target. Subsequent rounds of the adjustment are plotted at the flash ranging central as prescribed in paragraph 144*c* to determine the necessary fire commands to complete the adjustment. The same general principles apply in the conduct of fire by flash ranging as apply in conduct of fire by sound ranging.

b. When the battalion is operating under centralized control, reports of locations of targets are made to the battalion operations section. Missions are evaluated and transmitted to the corps artillery fire-direction center; there they are assigned as missions to a firing unit. The corps artillery fire-direction center also specifies the type of mission, the number of rounds to be fired, the channel of communication to be used, and designates a concentration number. Under decentralized control, targets are reported directly to the fire-direction center of the supported artillery unit.

146. REGISTRATION (CENTER-OF-IMPACT) (HIGH-BURST)

a. Observer Procedure.

(1) When a firing unit requests the registration, it should furnish the coordinates and altitude of the registration point so that the flash ranging observers may be oriented to bring the first burst into the field of view of their observing instruments. Time of flight and ON THE WAY should be announced by the firing unit to assist the observers in identify-

ing the burst. As soon as the round appears in the field of view of his observing instrument, the observer applies the reticle readings to the instrument scales to place the instrument cross hairs on the point of burst, and "clamps the instrument." The scale reading (clamping angles) are then reported to the flash ranging central. The instruments are not disturbed during the firing of the group of rounds for registration. Observers report reticle readings for each burst as follows:

(*a*) *Observable rounds:* RIGHT (LEFT) 10, PLUS (MINUS) 5, ABLE (BAKER, CHARLIE) (par. 136).

(*b*) *Observable rounds outside of the instrument field of view:* DOUBTFUL.

(*c*) *Nonobservable rounds:* LOST.

(2) The switchboard operator should check clamping angles at the completion of the registration. If these angles are not the same as reported initially, the observations are unreliable and should be discarded. Particular care must be taken in reading the vertical angle. For calibration of instruments, see appendix III.

b. Flash Ranging Central Procedure. The flash ranging central plots the initial round to make sure that all observers are observing the correct burst. Thereafter, all readings are evaluated by the flash ranging central, and erratic readings are rejected. The plot for the registration is made by averaging the reliable readings for six rounds. Additional rounds may be requested if the desired results are not obtained because of erratic readings, lost rounds, or erratic dispersion of shell bursts.

c. Center-of-Impact Registration. The flash ranging unit may request that one or more orienting rounds be fired at its command to orient observers and assure positive identification of the initial rounds. Smoke shell may be specified to insure that the initial rounds are identified. The flash ranging unit may specify the number of rounds (usually six) and the time interval between rounds to be fired in the group for registration. The flash ranging unit commands FIRE for each of the initial orienting rounds; the firing unit reports ON THE WAY for every round that it fires. When the registration is completed, the coordinates and altitude of the center of impact are reported to the firing battalion.

d. High-Burst Registration. High-burst registration may be used when impact bursts (shell HE or smoke) would not be visible to observers. Groups of rounds are fired as in *c* above, and the coordinates and altitude of the center of burst are reported (FM 6–40).

147. ADJUSTMENTS

During adjustments, the firing unit reports ON THE WAY when the round is fired and SPLASH when the projectile is due to burst. The flash unit conducts fire using target grid procedure. The adjustment is continued until the flash ranging unit estimates that the next shift will obtain effect on the target at which time it commands FIRE FOR EFFECT; adjustment by surveillance is continued during fire for effect.

148. TRANSFER OF FIRE

a. General. If surprise fire is desired and the target is located accurately, preliminary adjustment of fire on the target itself may be eliminated. It is the function of the firing battalion to determine whether prior registration is necessary and, if it is, to choose the point for registration with the assistance of the flash ranging unit. The facilities of the flash ranging unit may be employed also to conduct area adjustments and precision adjustments for destruction.

b. Example.

(1) An enemy battery has been located by the flash ranging platoon of Battery A ("Able Flash"), and is reported to the observation battalion command post as follows: FLASH REPORT, COORDINATES 96827943, ALTITUDE 315 YARDS, ENEMY BATTERY, THREE PLOTS, ACCURACY 50 METERS, TIME OBSERVED 0900, WILL ADJUST.

(2) The observation battalion evaluates this report and reports to corps artillery fire-direction center: FLASH REPORT, COORDINATES 96827943, ALTITUDE 315 YARDS, ENEMY BATTERY LOCATED BY ABLE FLASH, ACCU-

RACY 50 METERS, TIME OBSERVED 0900, WILL ADJUST.

(3) Corps artillery fire-direction center directs the 170th Field Artillery Battalion to fire the mission with surprise fire and to use the flash platoon to observe registration, if one is necessary; the corps artillery fire-direction center notifies the observation battalion of these arrangements. A concentration number is assigned and the target location is given. The type and amount of ammunition to be fired on the target and the channel of communication to be used are specified.

(4) The observation battalion directs "Able Flash" to stand by to adjust the 170th Field Artillery Battalion; it assists in arranging direct communication between "Able Flash" and the fire-direction center of the 170th Field Artillery Battalion; and it announces the concentration number.

(5) The S3 of the firing battalion decides to obtain corrections from a six-round, center-of-impact registration. Direct communication is established between the fire-direction center of the firing battalion and "Able Flash."

If time fire is used, additional rounds may be necessary to establish the proper height of burst over the registration point (auxiliary target).

ABLE FLASH TO FDC	FDC TO ABLE FLASH	REMARKS
	PREPARE TO OBSERVE CENTER-OF-IMPACT REGISTRATION; COORDINATES 965790, ALTITUDE 300 YARDS, 6 ROUNDS.	
READY TO OBSERVE; ONE ROUND, AT MY COMMAND; REPORT TIME OF FLIGHT, ON THE WAY, AND SPLASH.	TIME OF FLIGHT, 25 SECONDS . . . BATTERY IS READY.	
FIRE.	ON THE WAY . . . SPLASH.	Orienting round for flash platoon.
ONE ROUND, FIRE.	ON THE WAY . . . SPLASH.	Second orienting round.
5 ROUNDS AT 30-SECOND INTERVAL, FIRE.	ON THE WAY . . . SPLASH.	After the 5 rounds are complete, the flash plotting team plots the CI and reports the coordinates and altitude to the FDC. The FDC determines

ABLE FLASH TO FDC	FDC TO ABLE FLASH	REMARKS
		corrections from these data.
READY TO OBSERVE CONCENTRATION NO. 90.	BATTALION FIRING FOR EFFECT . . . ROUNDS COMPLETE ALL BATTERIES.	
CEASE FIRING, END OF MISSION; MISSION ACCOMPLISHED.		

149. COMPARATIVE CALIBRATION OF FRIENDLY ARTILLERY

Comparative calibration is the comparison, under the same firing conditions, of range quality of a given piece with that of another piece accepted as standard. The range of each piece is determined by firing. The center of impact of a group of six rounds or more is used to calibrate each piece for a given powder lot, projectile, and charge. The flash ranging unit performs the necessary survey work and observes the firing, reporting the coordinates and altitude of each round to the firing unit. The procedure is similar to a center-of-impact registration (par. 146 and FM 6–40). The firing of all pieces should be completed in a short time to insure that all firing is conducted under the same weather conditions.

CHAPTER 9
RADAR RANGING

Section I. GENERAL

150. DEFINITION

Field artillery radar ranging is the procedure employed in locating the origin or the terminus of the trajectory of a projectile by calculations based upon radar observations of the projectile in flight.

151. MISSIONS

The radar sections of the field artillery observation battalion perform both radar ranging and normal radar observation. Their missions include the following:

a. Location of hostile weapons.

b. Adjustment and registration of friendly weapons.

c. Battlefield surveillance.

d. Determining firing chart locations of friendly elements.

152. BASIC THEORY OF RADAR

a. The functioning of all radar equipment involves the following four basic steps.

(1) A radio signal is sent out (transmitted).

(2) The transmitted signal strikes an object.

(3) The transmitted signal is reflected in all

directions from the object.

(4) An infinitesimal part of the reflected signal returns to the radar and is picked up by the receiver.

b. The interval of time between transmission of the signal and reception of the echo is dependent upon the distance from the radar to the object. In radar terminology this distance is called range. Since all radio signals travel at a constant speed of approximately 186,000 miles per second, the distance to a reflecting object can be found by measuring the time required for the signal to reach the reflecting object and return to the radar set. High frequency radio energy pulses of extremely short duration are transmitted at regular time intervals. This time interval is adequate to permit an echo from a particular transmitted pulse to return from the maximum range of the radar before another pulse is sent out or transmitted (fig. 129). Radar antenna systems are directional and by utilizing these directional characteristics, it is possible to determine azimuth and elevation to an object. Thus, azimuth, elevation, and range from the radar to the object may be determined.

153. PRESENT EQUIPMENT

a. In practice, radar antennas are highly directional. They can measure azimuth and elevation with an accuracy of ± 1 mil. The range units of the radar can measure range with an accuracy of ± 25 yards. A sector scan unit sweeps the antenna back and forth through an arc of selected

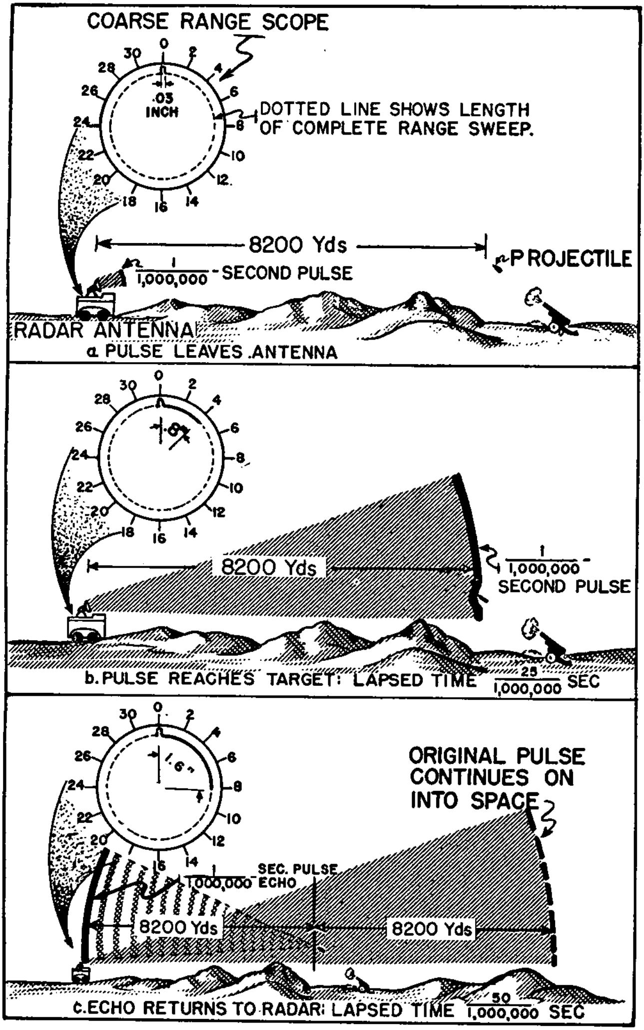


Figure 129. Schematic diagram showing a radar transmitting a pulse and receiving the return echo from an artillery projectile.

size thereby limiting the radar pulses to a desired sector in azimuth. Although most of the material in this chapter is applicable to any radar set, some information applies only to tracking radars, a type which will detect and track a target passing through the air. Radars of the SCR–784 or SCR–584 type are tracking radars.

b. A projectile is detected by seeing the echo as a bright spot on a cathode ray tube called the plan position indicator (PPI) scope. The position of the bright spot (echo) on the PPI scope indicates the range and azimuth from the radar to the projectile (fig. 130). The location of

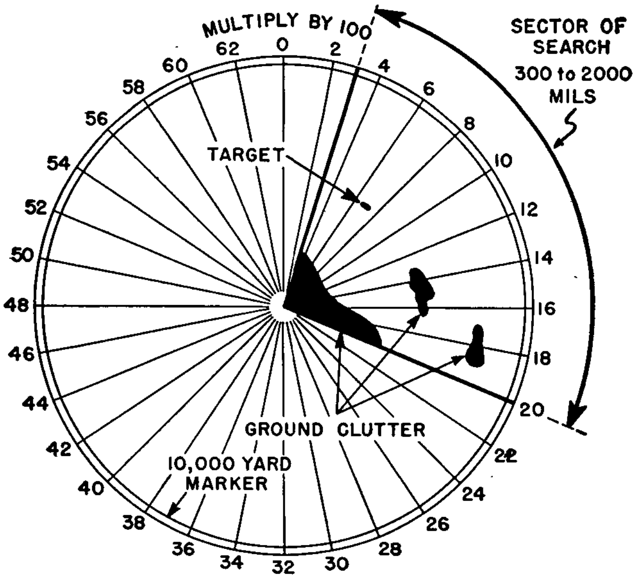


Figure 130. Schematic drawing of a plan position indicator (PPI) scope showing a projectile echo.

the weapon or burst is determined by tracking the projectile through that part of the trajectory visible to the radar and interpreting the record of this track. Figure 10 shows the Radio Set SCR–784, with the generating unit and plotting trailer in position. FM 44–45 covers the Radio Set SCR–784 and FM 44–44 covers the Radio Set SCR–584.

Section II. SELECTION OF POSITION

154. GENERAL

There are many factors which influence the choice of a radar position. In addition to the usual considerations of cover, concealment, security, routes of approach, survey, and communications, a radar site requires consideration of clutter, the reflecting properties of projectiles, speed of targets, minimum and maximum range of the radar, and the effect of electrical screening. The observation battery commander will designate the general areas for radar positions and assign zones of observation. It is essential that consideration be given to the proper coordination of radar sets to insure complete target area coverage.

155. SHELL ASPECT

a. General. One of the factors that affect the choice of a position is shell aspect. Shell aspect is a phenomenon that relates the angle formed between the reflecting surfaces of a projectile and the axis of the radar beam to the strength of the signal returned to the radar antenna (fig. 131). This angle is defined as the angle formed by the intersection of the axis of the projectile and the axis of the radar beam. There are three general types of shell aspect:

(1) *Nose.* This aspect results when projectiles are fired toward the radar.

(2) *Side.* This aspect results when the direction of fire is approximately perpendicular to the axis of the radar beam.

(3) *Tail.* This aspect results when the projectile is fired away from the radar set.

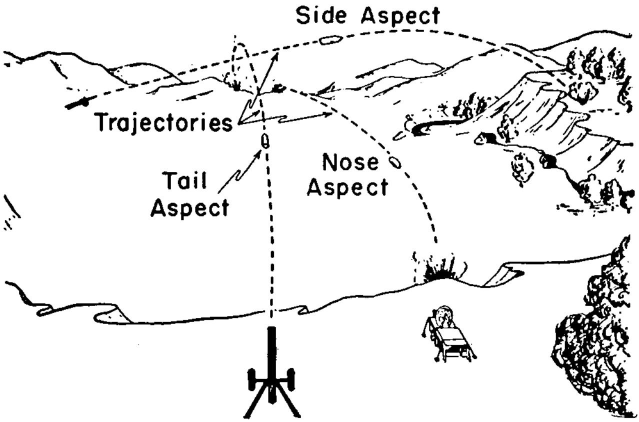


Figure 131. Shell aspect.

b. Theory of Aspect. When a projectile in flight passes through a radar beam, it reflects radio energy. The intensity of the reflection (echo) depends upon (1) the angle at which the energy strikes the projectile; (2) the contour of the projectile (fig. 132). When the dimensions of a shell are of the same order of magnitude as the radar wave length, the shell acts as a directional reflector; therefore, the aspect angle may be the most important factor.

c. Effects of Aspect on Projectile Tracking. Side and tail aspects are, in general, favorable to tracking projectiles. Nose aspect returns a much weaker signal to the radar than either side or tail aspect (fig. 132) ; thus the maximum tracking range for nose aspect is considerably less than for other aspects.

d. Tactical Significance. Since weak signals cause difficulty in tracking, aspect angle must be considered in selecting a radar position. Side and nose aspects will most frequently be encountered in the location of enemy weapons. Since best results are obtained from side aspect, it is desirable to emplace the radar sets as near to the flank of the zone of action as possible. This will also give flank or tail aspect in the adjustment of friendly artillery fire.

156. SCREENING

a. Clutter. Signals are received from objects such as dense woods, buildings, and sides of hills which lie in the radar beam. These unwanted signals cause fixed echoes to appear on the indicator scopes. Such echoes are known as clutter. Where clutter appears on the radar scopes, it will block or conceal any echoes from possible targets (fig. 130). For example, a projectile may

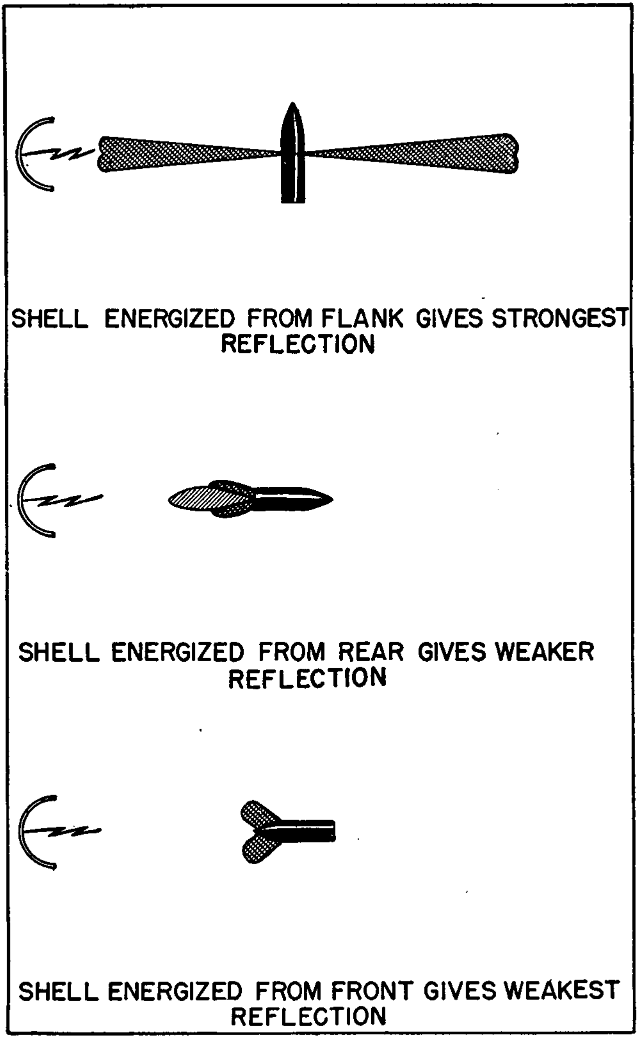


Figure 132. Comparative strength and shapes of fields of radio energy reflected by a shell which has passed through a radar beam.

not be detected if there is a fixed echo from some terrain feature at the same range and azimuth. Also to be considered is the fact that the radar beam is composed of the main lobe and side lobes (fig. 133). Echo signals may return from the side lobes and cause clutter from objects at azimuths other than that at which the antenna is pointing.

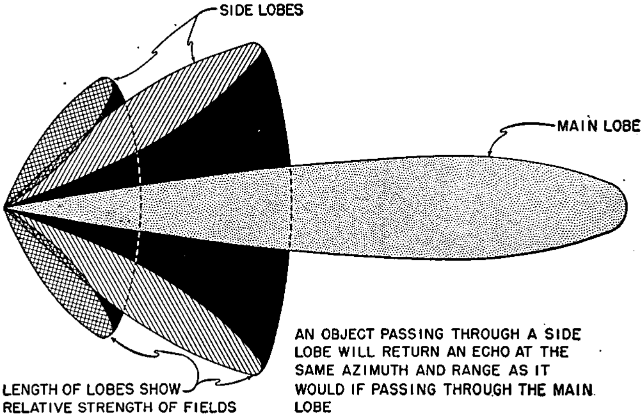


Figure 133. Side lobes.

b. Minimizing Effect of Clutter. With radar equipment having a narrow beam, it is possible to eliminate clutter by elevating the beam. If projectiles are to be detected close to the ground, clutter must be minimized by siting the radar so that unwanted echoes are screened by the ground adjacent to the radar (a, fig. 134). Siting must be done carefully, for a high screening crest may result in the elimination of some of the projectile echoes (b, fig. 134). It is desirable that the screening crest extend in azimuth beyond the area to be searched in order to minimize the effects of clutter from side lobes. Thus, the ideal radar position is a shallow *terrain saucer*. The rim of the saucer minimizes clutter in that portion of the PPI scope which represents the area being searched, but the rim must be low enough to permit the radar to receive echoes from the projectiles it is expected to track (c, fig. 134).

157. RECONNAISSANCE

a. Map Reconnaissance. As soon as the general radar position area is designated, a thorough map or photo reconnaissance should be made. This study should include—

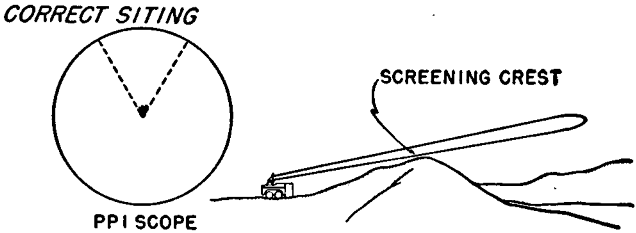
(1) Indication of landmarks forming limiting boundaries.

(2) Choice of at least two routes over which the radar may be moved.

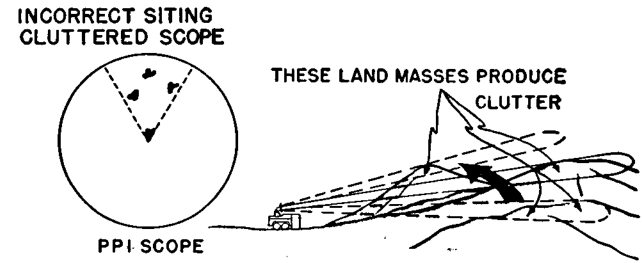
(3) Determination of the locality and identity of units occupying adjacent areas.

(4) Selection of those portions of the general area which appear most likely to contain good radar sites. This selection is based on a consideration of which portions will give the best electrical screening and the most favorable aspect angle in the zone to be searched.

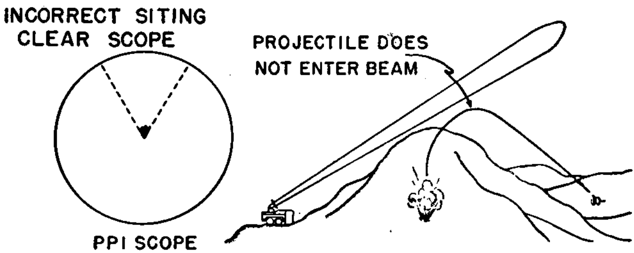
b. Ground Reconnaissance. Ground reconnaissance should follow the map or photo reconnaissance to insure speedy occupation of position. Road conditions and overhead clearances should be noted and a defiladed route of approach selected.



a. CORRECT SITING - SCREENING CREST MINIMIZES CLUTTER IN SECTOR OF SEARCH



b. INCORRECT SITING - NUMEROUS FIXED ECHOES IN THE DESIRED SECTOR



c. INCORRECT SITING - HIGH SCREENING CREST

Figure 134. Siting.

158. SURVEY

a. General. Accuracy of survey is important because any error in determining the location of the radar will cause corresponding errors in target locations made by that radar. Survey control is normally brought to the antenna position or to a placemark in the vicinity by survey teams.

b. Requirements. The *E*-, *N*-, and *Z*-coordinates of the radar antenna must be determined. A line of known direction (orienting azimuth) from the antenna to a prominent terrain feature or stake must also be determined. These survey requirements are the same as those for a firing battery.

c. Procedure.

(1) *Deliberate occupation of position.* As soon as the radar position has been selected, the battery commander is notified so that the radar position may be included in the battery survey plan. Wherever possible, survey control should be brought to the radar position before the radar set is emplaced. Operation is not delayed, however, while waiting for survey control. Assumed coordinates may be used to designate initial target locations. Conversion to true coordinates is made when true control becomes available.

(2) *Rapid occupation of position.* In a rapidly moving situation where observed firing charts are used by friendly artillery, it is possible to tie the radar set

in to the assumed control of an observed firing chart by the following method.

(*a*) The radar is oriented in azimuth by means of a declinated aiming circle.

(*b*) An artillery unit gives the radar section its observed-firing-chart coordinates (*E*, *N*, and *Z*) of a point in the sky which is near its base point and high enough to be observed by the radar. This point is plotted on the radar operations chart.

(*c*) The artillery unit fires six or more rounds (air bursts) with data that will cause the projectiles to burst at the designated point; the radar section observes these rounds and determines the azimuth, elevation, and range to the burst center from the radar (par. 165*d*).

(*d*) A ray is drawn on the radar operations chart from the plotted burst center toward the radar (back azimuth of the radar-to-burst-center azimuth), and the radar is plotted at the measured radar-to-burst center range. The vertical interval (radar-to-burst-center) is subtracted from the *Z*-coordinate of the burst center to determine the altitude of the radar. The radar is now located on the observed-firing-chart control.

(*e*) A less accurate alternate method is to locate the center of impact of six rounds fired at a point in the vicinity of the base point (par. 165*d*). The radar tracks the projectiles. An estimate of the vertical interval between the radar and the center of impact is made. The best available data should be used, but the effect of error in this estimate will be partly canceled by error in subsequent radar locations of enemy weapons in the same general area. The plots are interpreted and azimuth and range are determined to each of the six bursts. The radar is placed on the observed-firing-chart control as outlined in (*d*), above.

(*f*) A new radar operations chart is set up when survey control arrives, and targets located on the observed firing chart are transferred to the new operations chart.

159. CLUTTER AND COVERAGE

a. General. As soon as the radar is placed in operation, clutter diagrams and coverage diagrams should be made for the sector of search and for any area that might be an alternate sector. This will permit evaluation of the site for trajectories of various maximum ordinates. From a knowledge of the trajectories of various weapons, it will be possible to determine the effective ranges of operation against these weapons. At high screening angles and long radar ranges, the trajectories of some enemy weapons will never reach the radar beam, or only a small portion of the trajectory will be observable. Thus, a complete evaluation of the site will depend not alone upon a clutter diagram but upon a consideration of both clutter and coverage diagrams. Copies of the clutter diagrams and coverage diagrams are filed with the radar log.

b. Clutter Diagram. A clutter diagram is a reconstruction of the presentation seen on the PPI scope and shows the clutter in the area to be searched (fig. 135). In making the diagram, the reflector is set at the elevation of the screening crest, and the range that will be used in projectile detection is used (10,000-yard range on present counterbattery radar). The diagram should be made for various elevations starting at the screening elevation and increasing in increments of 50 mils up to 150 or 200 mils elevation, or to an elevation at which no clutter appears. Clutter outside the area of search normally will not affect operation. A small amount of clutter in the area will not prevent effective operation.

c. Coverage Diagram. Figure 136 shows a coverage diagram for a specific site. The center of the diagram represents the radar location. The contour lines connect points of equal altitude. The distances from the center of the diagram to the contour lines represents the maximum slant range at which a projectile at that altitude is visible to the radar. The diagram should be kept

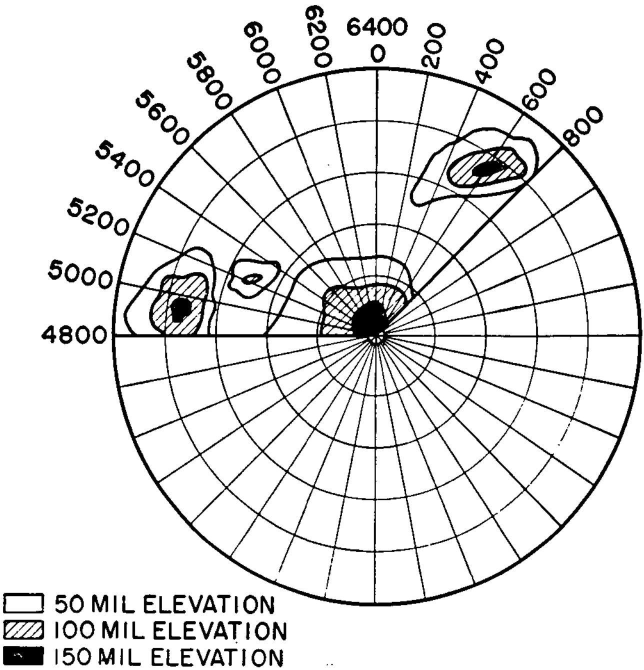


Figure 135. Clutter diagram.

as simple as possible. Steps in the construction of a coverage diagram are as follows:

(1) Elevate or depress the antenna until the horizontal crosshair of the orienting telescope is tangent to the horizon at either edge of the assigned sector of search. Record the azimuth and the angular height of the horizon.

(2) Repeat the action described in (1) above throughout the sector of search at each 200 mils in azimuth and at any other

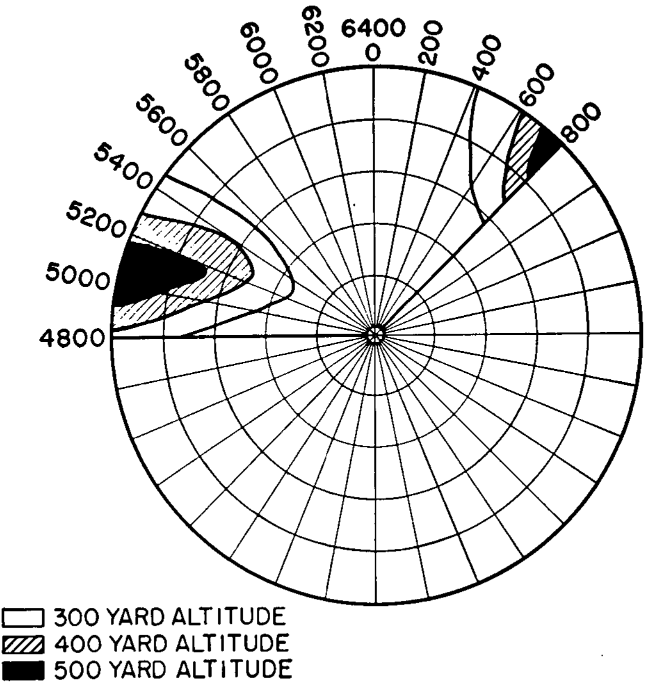


Figure 136. Coverage diagram.

azimuth where there is a sharp departure in the uniformity of the horizon.

(3) Calculate the slant ranges for each angular height measured for selected altitudes of 300, 400, and 500 yards using the formula:

$$\text{Slant range} = \frac{\text{Selected altitude}}{\text{Sine angle of elevation of the radar reflector}}$$

(The altitude levels chosen are optional and should meet existing requirements.)

(4) Plot the recorded slant range for a particular altitude on polar coordinate paper at each azimuth at which readings were taken.

(5) Draw in a contour line by connecting the plots for a particular altitude with a continuous, smooth curve and label according to altitude in feet.

(6) Plot the slant ranges for the other altitudes in the same manner. Draw in contour lines, and appropriately label each contour line.

Section III. WEAPON LOCATION

160. GENERAL

Maximum use should be made of organic observation facilities to enable the radar to search only in areas of known activity and to allow the radar operators to rest during periods of inactivity. Continuous observation of an indicator scope causes severe eyestrain and mental fatigue. This may result in failure to detect target echoes. The radar operators should alternate in observing the PPI scope during periods of search. The state of training of an operator is also an important factor in the detection of targets. Targets which return weak signals, whether because of an unfavorable aspect angle or the reflecting properties of the target, may not be noticed if the operator is not skilled. Also, because of the relatively small size of the targets normally sought by a field artillery radar, the equipment must be expertly tuned and operate at the peak of its performance. A crew should be on duty no longer than 8 hours at a time, and at least 1 hour should be devoted to maintenance of the equipment for each 8 hours of operation. Whenever electrical or mechanical difficulties render the radar inoperative, the battery commander must be notified immediately.

161. PRE-OPERATION PROCEDURE

After the radar is emplaced, it is put in operation, tuned, adjusted, and oriented as prescribed in FM 44–45. If an automatic plotter is used it must be synchronized and calibrated with the radar.

162. OPERATION WITH AUTOMATIC PLOTTER

a. Searching and Tracking Procedure. The chief radar operator designates the sector to be searched. For example: SEARCH SECTOR, AZIMUTH 3,000, 400 RIGHT, 400 LEFT. The sector of search may be outlined on the PPI scope with china marking pencil. Search is conducted at the minimum elevation where clutter will not prevent target detection. When a projectile passes through the beam, an echo in the form of a bright spot appears on the PPI scope. When this bright spot is detected on the PPI scope, search is stopped immediately. The range, azimuth, and elevation at which the projectile echo appeared are noted and recorded as a pick-up point, and the radar antenna is positioned to observe this point. Succeeding rounds from the same piece will normally pass through or very close to this pick-up point. Even though changes in elevation or deflection are made at the guns during the firing of a single mission, the effective width of the radar beam will normally permit detection and tracking of succeeding rounds. Upon the appearance of another projectile echo, the radar automatically tracks the projectile throughout that portion of the trajectory visible to the radar.

b. Locating Procedure.

(1) *General.* Data supplied by the radar must be converted to data which can be plotted on a grid sheet and weapon-location coordinates obtained. Accuracy and speed are important in this phase of the operation.

(2) *Preparation.* The location of the radar is plotted on a grid sheet, and azimuth reference lines are drawn 100 mils apart to expedite subsequent plotting of azimuths (fig. 137).

c. Plotter. An automatic plotter (fig. 138) instantaneously plots the height, slant range, and azimuth of a projectile against time, as the radar tracks the projectile through space. When an automatic plotter is used, it must be synchronized and calibrated with the radar to insure that data read from the plotter record corresponds exactly with the data produced by the radar. For detailed information concerning the automatic plotter, see *d. Plot Interpretation.*

(1) *Height plot.* The key to plot interpretation is the height plot. As three pens on the plotter record height, azimuth, and slant range versus time, a fourth pen which is fixed plots the ground line which represents the altitude of the

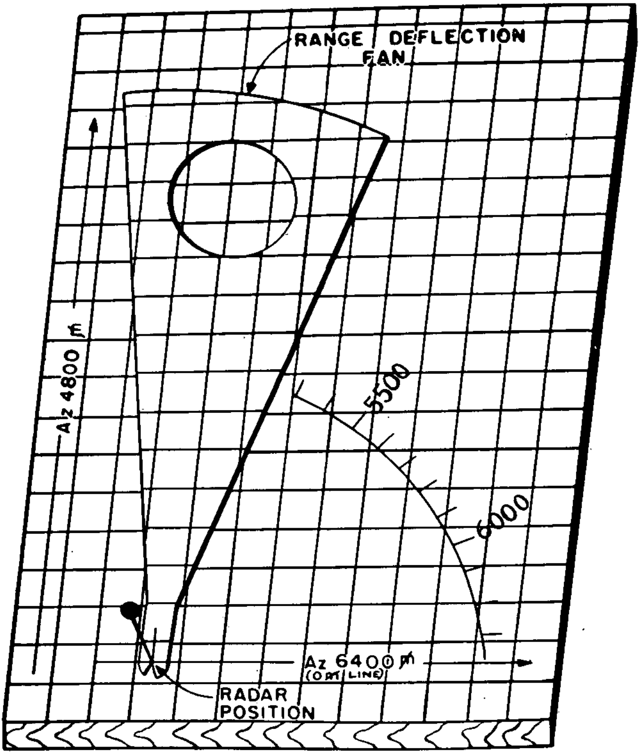


Figure 137. Radar operations chart.

radar (fig. 139). This ground line is the line of zero reference for the height, azimuth, and slant range pens; height, azimuth, and slant range are all measured as a distance above this zero-reference line. To locate a weapon after the projectile has been tracked, the range and azimuth must be read at

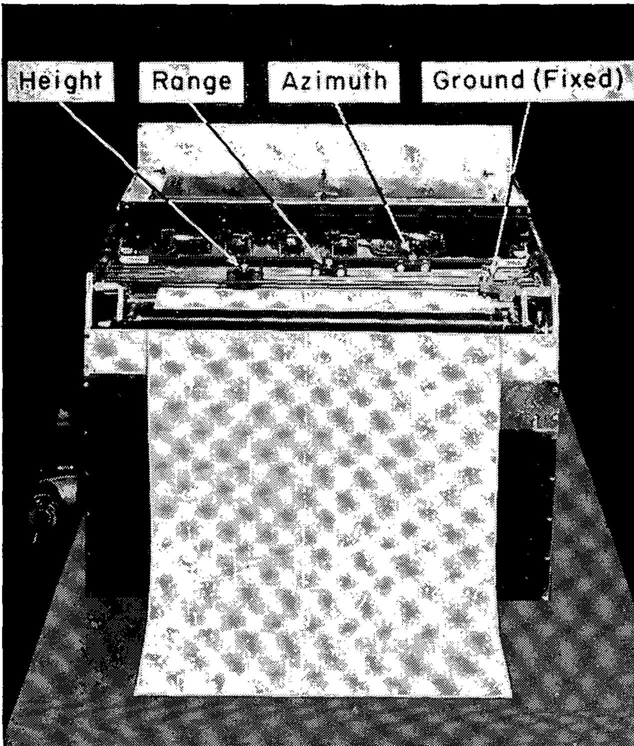


Figure 138. A type automatic plotter.

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"zero time." Assuming that the weapon and the radar are at the same altitude, this "zero time" is the instant in time at which the height of the projectile is zero. Thus, if the height plot can be extended backwards (extrapolated) accurately to the ground line, the intersection of the height plot and the ground line will indicate the point on the time axis at which the range and azimuth should be read to locate the weapon. Since the plot of height versus time for any projectile approximates some portion of a specific parabola, any two trajectories having the same maximum ordinates will have approximately the same height-time plot regardless of muzzle velocity, elevation, or range fired. Figure 140 illustrates that a mortar projectile and an artillery projectile, each attaining the same maximum ordinate, will be at the same height above the weapon at the same elapsed time after firing. It will be observed that in a trajectory plot the horizontal axis is range and in a height-time plot the horizontal axis is time. A celluloid parabola is used as a curve to extrapolate the height-time plot. This parabola may be prepared from a sheet of plexiglas. Using the maximum ordinate of the parabola as the origin, the parabola is engraved on the plexiglas by plotting y (height) equal to minus $16t^2$ (time) using the same scale for height and time which the plotter records. The parabola is cut out of the sheet and is then ready for use. In practice, this plexiglas parabola is carefully fitted against the ascending or descending branch of the plot, depending on whether extrapolation to determine the weapon or the burst location is desired. No attempt is made to fit the celluloid parabola to the entire plot. The point at which the extrapolated height plot intersects the ground line is the point of "zero time" only if the radar and weapon are at the same altitude. If vertical control of the target area is available, the first location obtained may show the terrain in the vicinity of the weapon to be considerably above or below the radar. If the weapon is below the radar, "zero time" is the point at which the extrapolated height plot intersects a line parallel to the ground line and below it by the difference in altitude (radar-weapon). If the weapon is above the radar, "zero time" is determined by the intersection of the extrapolated height plot and a line parallel to the ground line and above it by the difference in altitude (radar-weapon).

(2) *Azimuth plot.* In order to read the azimuth at "zero time," the azimuth plot

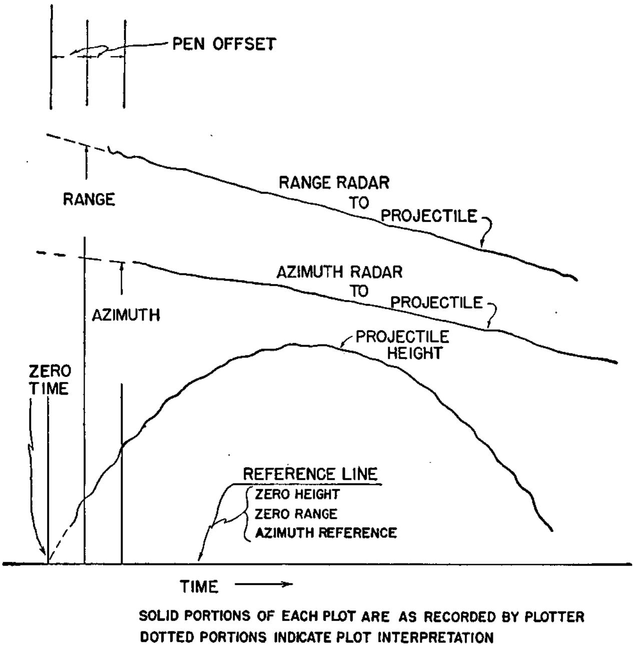

Figure 139. Record from an automatic plotter.

must also be extended backward or extrapolated. Information concerning correct extrapolation procedure may be obtained by a study of an ideal trajectory (no air resistance). Figure 141 shows the relative locations of the guns and radar. Three azimuth plots are shown representing azimuth-time plots for ideal trajectories fired by the weapons placed with respect to the radar as shown in figure 141. Plot K is the special case

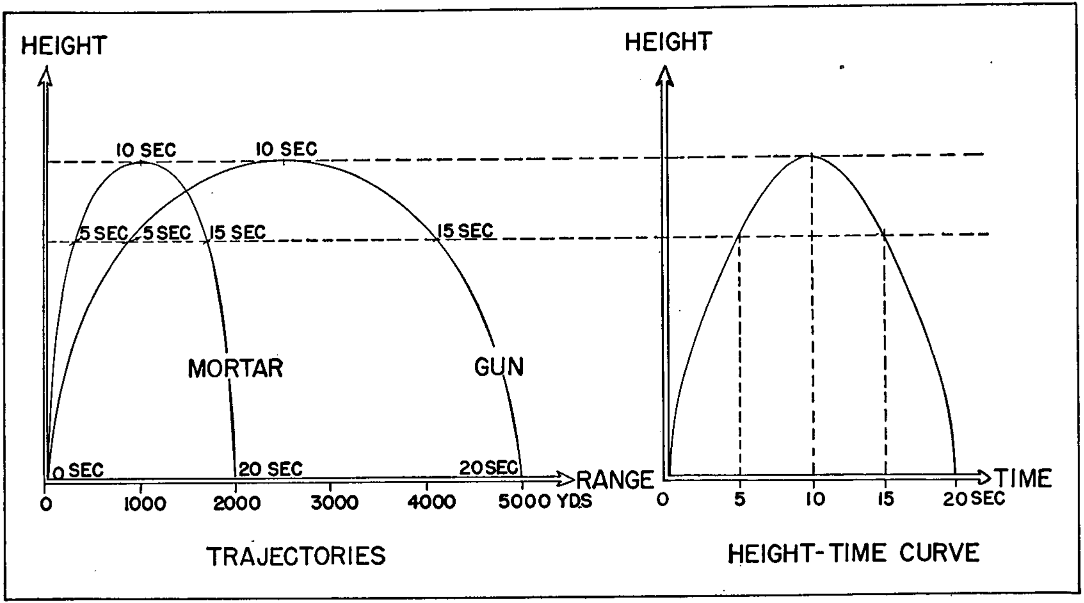

Figure 140. The relation between projectile trajectories and a height-time curve.

where the azimuth of fire is the same as the radar-weapon azimuth. In plots L and M, the weapon is shooting across the front of the radar, and the radar beam is perpendicular to the trajectory at the mid-point. Both plot L and plot M are complete plots from weapon to burst, and both are symmetrical above A, the point of inflection. However, the radar beam is not usually perpendicular to the trajectory at the mid-point. An example of the complete weapon-to-burst azimuth plot in a case where the beam is not perpendicular to the trajectory at mid-point is the plot from B to D along plot M where B is at "zero time." Normally, however, the radar only tracks a portion of the trajectory giving, for example, the plot from B' to D'. If the point of inflection (A) can be determined, the curvature from C' to C can be used as a guide in extrapolating from B' back to B because of the symmetry about point A. This guidance is only available for plots where the point of inflection occurs in the first half of the plot. Using the above information, the azimuth plot is extrapolated using a straightedge, French curve, or a curved portion of the plexiglas parabola.

(3) *Range plot.* Since this is slant range versus time, the range plot is not a regular curve even for an ideal trajec-

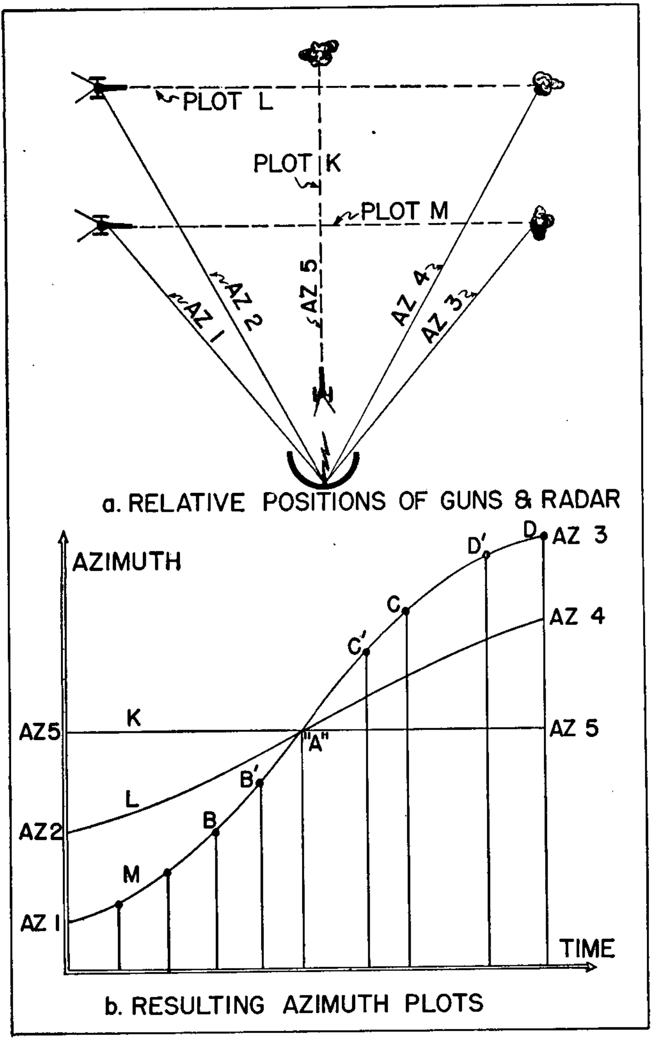

Figure 141. Relative positions of guns and radar and resulting azimuth plots.

tory. A study of the aspect angle, type of fire, and range to the weapon will aid an experienced interpreter in determining what type of plot to expect. The range plot is extrapolated by use of a French curve, straightedge, or a curved portion of the plexiglas parabola in the same manner as for the azimuth plot.

(4) *Radar plot-reading scale.* The radar plot-reading scale is a plexiglas rectangle engraved with height, range, and azimuth indices (fig. 142). These indices are vertical lines and are separated horizontally by the same distance as the horizontal offset between the respective data-recording pens. The indices are graduated vertically from a reference line which corresponds to the ground line on the plot. This reference line represents the zero height and range graduation and *any* hundred mil azimuth graduation (dependent on plotter azimuth synchronization). Radar to projectile data can be read directly from the plot. In weapon (burst) location, the radar plot-reading scale is placed with the scale reference line coincident with the plot ground line, and is moved horizontally until the height index intersects the extrapolated height plot at the relative height of the weapon (burst) with respect to the radar. With the radar plot-reading scale so placed, the azimuth and

range to the weapon (burst) are read at the point where the range and azimuth plot extrapolations intersect the range and azimuth indices.

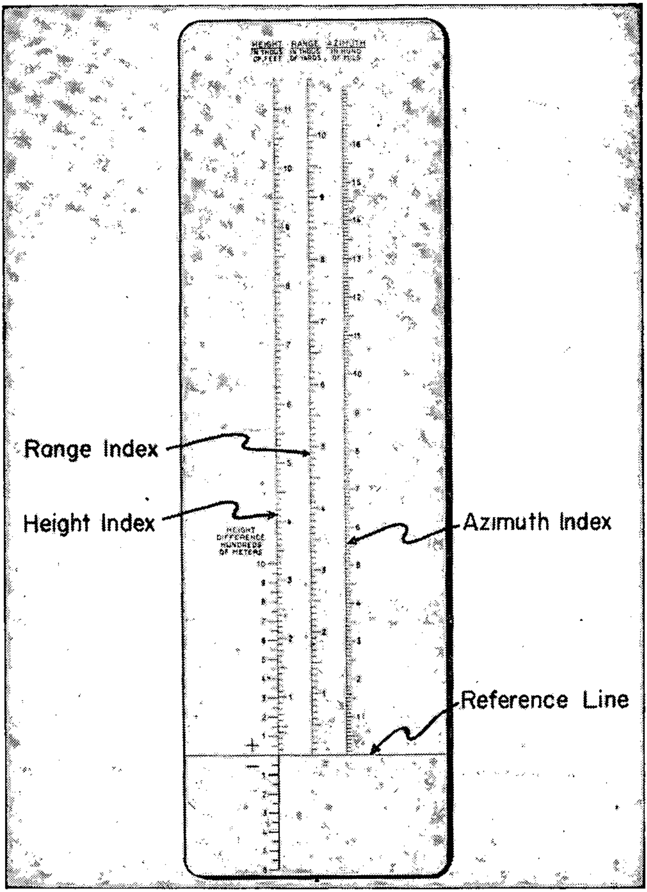

Figure 142. The radar plot-reading scale.

(5) *Ground projection of trajectory.* In some cases the portion of the trajectory tracked may be so small that an accurate location by the above methods is impossible. It may be worth while in such cases to construct the ground projection of the trajectory. Using the height and slant range at any instant, the horizontal range may be computed. This is done for four or five points along the record, and the azimuth is read at each of these points. These points are then polar-plotted on the operations chart, and the straight line that most nearly joins them is drawn. This is the line of fire; it will pass very close to the weapon. Interpretation of the remainder of the plot will give some information as to where along the line of fire the weapon is located. Such information will be valuable for photo interpretation and for other intelligence agencies.

163. OPERATION WITHOUT AUTOMATIC PLOTTER

a. General. When the automatic plotter is not employed, the determination of weapon locations is less accurate. In this case, weapon locations can be determined by interpretation of radar data read at regular time intervals.

b. Searching and Tracking Procedure. Searching and tracking procedure is the same as described in paragraph 162*a*.

c. *Locating Procedure.*

(1) *Preparation.* The draftsman prepares the grid sheet for conversion of radar data to weapon coordinates. The radar position and azimuth reference lines are plotted (fig. 137).

(2) *Determination of data.* When the control switch is thrown to AUTOMATIC by the range operator to track a shell, a stop watch is started and slant range, azimuth, and elevation are read, announced, and recorded. Readings are repeated, usually at 2- to 4-second intervals, as long as the projectile is being tracked.

(3) *Computation.* Since horizontal or ground ranges are used in determining the locations of ground installations, the slant range as read from the radar must be converted to horizontal range. This is done by multiplying the slant range by the cosine of the angle of elevation. Altitude is computed by multiplying slant range by the sine of the angle of elevation. These computations can be performed on the military slide rule.

(4) *Plotting.* After the above computations have been made, the azimuth, horizontal range, and altitude of three or more points on the trajectory are available. The azimuth and horizontal range are plotted on the grid sheet from the plotted radar position, and a straight line is

drawn through the points determined. If the location of the points is such that a straight line cannot be drawn through them, the line which most nearly includes all the points is drawn. This line is the horizontal projection of the trajectory. Perpendiculars to the projection are drawn through each of these plotted points, and computed altitudes for each point are laid off on the corresponding perpendiculars. This procedure locates the points on the trajectory, and by connecting the points with a freehand curve, the ascending or descending branch of the trajectory can be reconstructed (fig. 143). The intersections of this reconstructed trajectory with the horizontal projection will determine the location of the weapon firing or the location of the burst. Simple freehand sketching of the trajectory curve will give satisfactory results. If a straight line is drawn through the first two or last two altitude points, it will intersect the horizontal projection at some point beyond the true location of the gun or the burst. This point of intersection will serve as a limiting point in sketching a freehand trajectory curve. The lower the elevation of pickup, and, therefore, the closer the first altitude point is to the direction of fire line, the more accurate will be the determination of the weapon location. When the radar position prevents tracking the projectile from a relatively low altitude, the points will be too high to permit accurate extrapolation. It is desirable that the pickup elevation be less than 100 mils. Higher elevations are acceptable at shorter ranges. The draftsman next plots the coordinates of the weapon location, as obtained above, on a contoured map. If the altitude of this location differs materially from that of the radar, a correction may be applied by shifting the located point forward or backward along the horizontal projection of the trajectory. Unless the correction is greater than 50 yards, it will probably fall within the expected error of this method as a whole. As soon as the coordinates of the weapon are determined, they are forwarded to the battery headquarters.

Section IV. REGISTRATION AND ADJUSTMENT OF FRIENDLY FIRE

164. ADJUSTMENT OF FIRE

a. General. The adjustment of field artillery fire is discussed in FM 6–40. A radar sited for weapon location can be used to adjust friendly artillery fire on any target whose location relative to the radar is known. Using the SCR–784 for adjustment, the fire of weapons having rela-

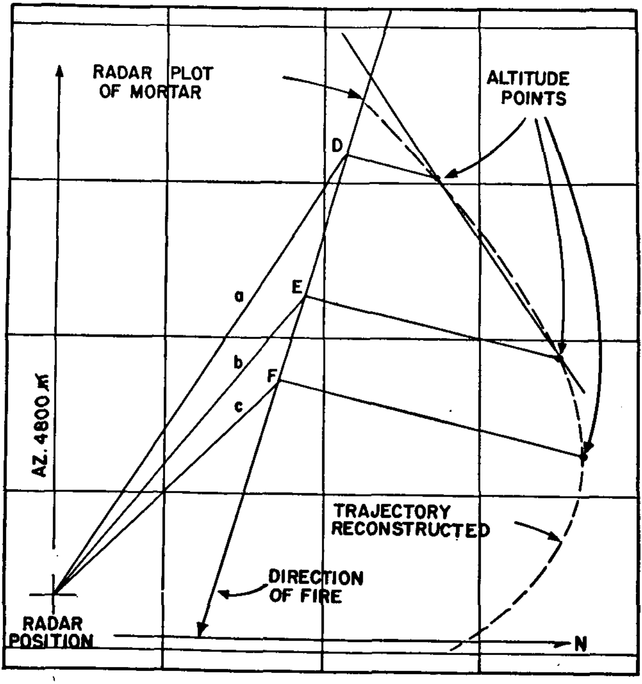

Figure 143. Trajectory plot.

tively low muzzle velocities and high maximum ordinates can be more accurately adjusted than the fire of high-velocity, flat-trajectory weapons. Operation procedure is the same for weapon location (pars. 160–162) except that the plotter record is interpreted to locate the terminus instead of the origin (fig. 144).

b. Steps in Adjustment.

(1) At the fire-direction center of the firing battalion, the target grid is centered on the target with the azimuth index of

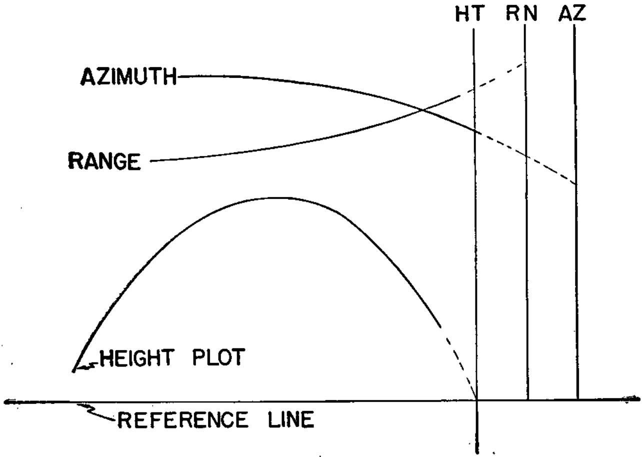

Figure 144. Record interpreted to locate a shell burst or point of impact.

the target grid oriented to coincide with the radar-target azimuth.

(2) The adjusting piece fires, using the best available data on the target to be attacked, at the command of the radar section. The radar searches for the friendly projectile to determine a pick-up point. After finding a pickup point, succeeding rounds are tracked and points of impact located.

(3) (*a*) The radar-target azimuth and range are obtained from the radar operations chart. After each round is tracked, the record is interpreted to give the range and azimuth from the radar to the point of impact or burst. Corrections in yards for direction and

range relative to the radar's line of observation are sent to the fire-direction center. The radar-burst azimuth is compared with the radar-target azimuth. The direction correction is equal to the azimuth error in mils multiplied by the radar-target range in thousands of yards. If the radar-burst azimuth is the greater of the two azimuths, the correction is left; if it is the smaller, the correction is right. The range correction is the difference between radar-target range and radar-burst range applied so as to move the burst to the target.

For example:

	Azimuth	*Direction*	*Range*
Radar to target from operations chart.	1340ɱ		6400
Radar to burst from trajectory record.	1320ɱ		6600
Correction to FDC in yards.		RIGHT 128 (20x6.4)	DROP 200

(*b*) An alternate method of determining corrections is as follows:

1. Center a target grid on the target on the radar operations chart with its azimuth index oriented to coincide with the radar-target azimuth.

2. Polar-plot each burst from the radar's chart location.

3. Read the corrections on the target grid. The adjustment is continued until corrections are small enough to warrant firing for effect (FM 6–40).

(4) Fire for effect may be tracked and locations obtained for surveillance of fire. When tracking a battery volley, the radar may jump from projectile to projectile causing inaccuracies in locations.

c. Radar and Adjusting Battery not Located on Same Control. In this case a pickup point near the adjusting piece is required. The record of the first round tracked is interpreted to determine both the location of the burst and the location of the adjusting piece. The coordinates of the target, the adjusting piece, and the radar-target azimuth are sent to the fire-direction center conducting the adjustment. After this, the procedure is that described in *b* above.

d. Radar and Adjusting Battery Located on Same Control.

(1) The radar sends the radar-target azimuth to the fire-direction center and requests the coordinates of the adjusting battery. Plotting the adjusting battery enables the radar section to compute pickup data. The procedure is that described in *b* above.

(2) In this case a low pickup point is not essential since only the descending arc

of the trajectory is interpreted. Adjustment of fire can be expedited by determining a pickup point prior to starting the adjustment. Laying the radar in azimuth, elevation, and range to the pickup point is done prior to starting the adjustment.

165. REGISTRATION OF FRIENDLY ARTILLERY

a. General. Registration of friendly artillery may be accomplished, using the SCR–784, by either the center-of-impact or high-burst method. Center-of-impact registration may be performed by the normal ground-burst procedure or by computation at a selected datum plane above the ground.

b. Center of Impact. A center-of-impact registration may be accomplished by having the adjusting weapon fire six rounds at the same elevation and deflection. Each round is tracked and the burst location obtained as described in paragraph 164. The center of impact of the rounds is determined and reported to the adjusting unit. Base point or check point registration is obtained by finding the center of impact of six rounds fired at the base point or check point.

c. Center-of-Impact Registration at Selected Datum Plane. When using an automatic plotter, a more accurate registration may be accomplished in the following manner: Six rounds are tracked to the lowest elevation possible. The records from the plotter are examined, and on each record, the height at which the radar ceased tracking the projectile is noted. The greatest of these heights (H) will be a height at which the radar was still tracking each of the six rounds. On each of the records, a line parallel to, and at height H above, the ground line is drawn to intersect the height plot (fig. 145). The slant range and azimuth are then read at this point of intersection. These data determine the points where each of the six rounds penetrated a horizontal plane at H height above the ground. The ranges and azimuths so measured are averaged and the mean point of penetration of the horizontal plane is polar-plotted on the radar operations chart with reference to the radar location. It is unnecessary to convert slant range to horizontal range. The coordinates and altitude of the mean point of penetration are reported as a center of impact to the adjusting unit. There is no extrapolation error in this method since all data are read at points where the radar was actually tracking the projectile.

d. High-burst Registration. A high-burst registration may be conducted by radar. A procedure similar to that for antiaircraft artillery trial fire spotting (FM 44–45) is used. The height of burst may be computed by the mil relation. The burst center must be visible to the radar. The radar is laid on the azimuth, elevation, and range to the expected burst center. Orienting rounds are fired to allow corrections in pointing data to be made if necessary. The azimuth and elevation deviations of succeeding bursts are read in the telescope mounted on the antenna and the range

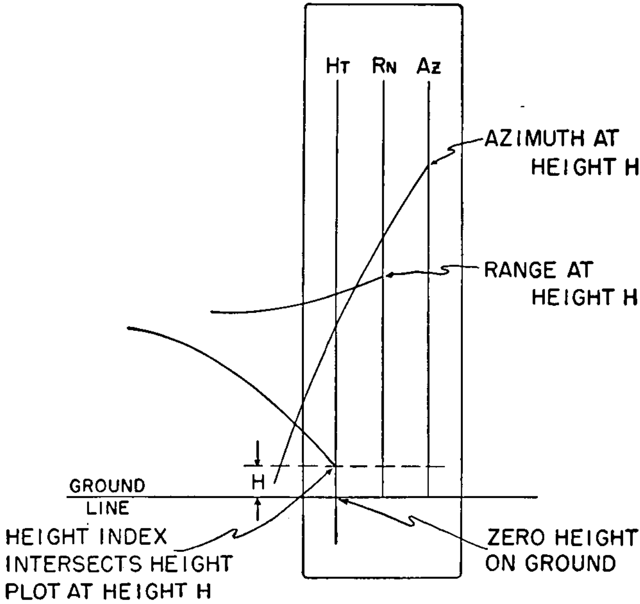

Figure 145. Interpreting the plot of one round of a center-of-impact registration at a selected datum plane.

read on the radar range scope. With the SCR–784 or similar type equipment, this is the most accurate type of registration.

Section V. OTHER MISSIONS

166. BATTLEFIELD SURVEILLANCE

a. General. Counterbattery radar can be used to detect moving targets to which it has line-of-sight observation. The nature of these targets may vary from a walking man to a moving tank column. The range at which such detection is possible will depend upon the size of the target and the speed of movement. The radar as presently developed should never be used to search the entire hostile area, but should be used to observe several small sectors of suspected activity.

b. Considerations Affecting Use of Radar for Battlefield Surveillance. This use of the radar requires that it be sited on a crest or forward slope for line-of-sight observation to the target area. So sited, the radar cannot perform its missions of hostile weapon location or the adjustment of friendly fire. Such location places very valuable equipment in a hazardous position. Certain weather conditions—wind and heat—may hamper or prohibit its use for battlefield surveillance. Considering these factors, counterbattery radar should only be used for surveillance when—

(1) Visibility is poor owing to darkness, fog, or smoke.

(2) The importance of the targets that may be detected justifies the risk to the equipment and the diversion of the radar from its mission of weapon location.

c. Selection and Occupation of Position. The only absolute requirement of a radar site for surveillance is that it have line-of-sight observation to the target area. A ground observation post that has visual observation to the target area will permit radar observation to the same area. Since radar prime movers are noisy, the site should be out of hearing distance of the enemy front lines. Radars which utilize a 10 cm. wave length (S-Band radars) can operate satisfactorily through light trees, brush, camouflage nets (non-metallic), or from within a light frame building In any of the above cases, the maximum range is decreased, the amount varying with the nature and thickness of the material through which the radar is observing. Radars of shorter wave length are less able to penetrate such materials. If such camouflage and a concealed route of approach are available, the radar may occupy the position during daylight. If the position is occupied after darkness, survey, communication, and digging of individual shelters should be completed before occupation of position.

d. Orientation. Since the position is normally occupied after dark, the selection of a suitable azimuth orienting point is important. Elevation orientation is not critical for moving target detection. If a radar with an offset beam is used, the effect of the offset may be compensated for by applying the proper corrections. Polarizing the antenna in a vertical position gives more exact azimuths, and the offset correction is made by changes in elevation of the reflector. Polarizing the antenna in a horizontal position gives more exact elevations, but corrections must be applied to all azimuth readings.

e. Preoperation Procedure. As soon as the radar is placed in operation, clutter diagrams should be made for each sector of search. The clutter diagram is made at the reflector elevation giving the strongest fixed echoes in the sector of search (par. 141).

f. Search Procedure.

(1) The assigned sectors are searched in steps of 30 to 40 mils at each azimuth setting. The operator positions the reflector in elevation for maximum fixed-echo strength and examines the indicator for targets.

(2) Once an echo on the indicator has been identified as a target, the radar range, azimuth, and elevation are adjusted to maximize the echo.

(3) After the target echo is maximized, the range and azimuth to the target are read and reported to the plotter.

(4) The target is polar-plotted from the grid sheet location of the radar, and the target location reported to the observation battery command post. For moving targets the report should include speed and direction of movement.

g. Moving Ground Targets.

(1) The detection of a target in motion requires a thorough knowledge of the type of signal to be expected. For discussion, see FM 44–44 or FM 44–45. The character and texture of the signal will identify the target as to type. The strength considered in conjunction with range will indicate the size. A moving target passing over terrain that causes fixed echoes will cause a moving target signal to appear in the top of the fixed

echo. Considerable practical experience is essential to permit an operator to correctly identify echoes of this type.

(2) Swaying grass and trees or heat waves may cause fixed echoes to have the same appearance as moving target echoes. These false moving target echoes may swell and fade in strength but will not move in range or azimuth. An experienced operator can detect a true moving target echo among false ones since the target echo moves in range, azimuth, or both.

h. Stationary Ground Targets. The location of stationary targets is based on familiarity with the clutter diagram and a study of its changes, both being tied into map and photo studies. An echo that appears where there was no fixed echo before is probably a target and should be investigated further.

167. FIRING CHART LOCATION OF FRIENDLY ELEMENTS

a. General. A radar sited for hostile weapon location can obtain the *approximate* firing chart locations of friendly elements. Any survey locations obtained by radar will be on the same control as the radar. There are two general methods of obtaining the locations of friendly batteries by radar. Both methods are expedients because neither can insure the accuracy required of field artillery survey. An advantage of survey by radar is that it offers a rapid method of locating many batteries of artillery on the same control when terrain or other conditions makes normal survey operations difficult or impossible.

b. High-Burst Method.

(1) In this method, the battery centers are actually located by three-point resection. Three-point resection requires that the angles between three points whose locations are known be measured at the point whose location is desired (par. 83).

(2) In this particular case, the radar locates three or more high air bursts. The angles between bursts are measured at the batteries to be located (fig. 146). The burst locations must be carefully chosen. The bursts must be visible to all batteries concerned and, for accurate resection, the angles between bursts, as measured at the batteries, should be as large as possible. If possible, the batteries should be given the anticipated location of each burst.

(3) In order to orient the radar on the point of burst, several bursts may be required at each point. The same bursts that orient the radar can be used to orient the observers at the firing batteries. In performing the resection, it is imperative that the firing batteries use the horizontal angles measured between the rounds that the radar actually locates. To avoid errors, the radar must have

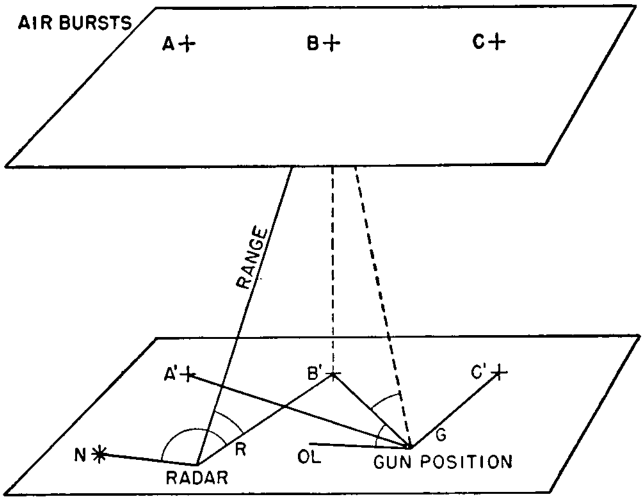

Figure 146. Locating a gun by resection using radar.

telephone or radio communication with the batteries firing and observing the bursts. Communication between the radar to ascertain that the firing batteries can observe each burst; it also enables the radar to notify the firing batteries when to shift to the next burst location. The radar locates each burst as described in paragraph 165*d*. Using range, azimuth, and elevation to each burst and the radar's coordinates, the *E*-, *N*-, and *Z*-coordinates of each burst may be computed.

(4) The radar section reports that coordinates and altitude of each of the located bursts to the firing battalions or bat-

teries concerned. The vertical angle to any one burst will give a firing battery vertical control. The firing battalion or battery survey sections perform the resection.

c. Weapon-Location Method. In this method, the radar locates the friendly weapon in the same manner that it would locate a hostile weapon. The piece to be located fires six rounds, preferably high-angle fire, at the command of the radar section. Each round is tracked, and the location is obtained as described in paragraph 162. This method has the disadvantages that only one battery may be located at a time, whereas, in the high-burst method any number of batteries can be located simultaneously. The weapon-location method requires less planning and prearrangement.

d. Location of Front Lines. Radar can locate friendly front lines by the weapon-location method. Troops that are in or near the front lines fire a bazooka or a mortar on call from the radar. Front lines are determined from the locations of these weapons.

168. DETERMINATION OF WINDS ALOFT

In emergencies, the meteorological section in headquarters battery of the observation battalion may request that a radar platoon assist in measuring the winds aloft. The radar platoon assists by tracking a radar target supended from a balloon. The meteorological section furnishes the balloon and performs all of the necessary computations, based upon elevation, azimuth, and range data furnished by the radar section (TM 20–240).

CHAPTER 10
METEOROLOGY

Section I. GENERAL

169. GENERAL

This chapter contains a general description of the operations of the meteorological section in the headquarters battery of the field artillery observation battalion, with emphasis on the mission, employment, and liaison with other units.

170. MISSION

The mission of the meteorological section is to—

a. Provide ballistic meteorological messages to artillery firing units for use in correcting firing data for existing nonstandard weather conditions.

b. Provide meteorological messages to the sound platoons of the observation battalion for determining corrections in sound ranging data resulting from existing nonstandard weather conditions.

c. Provide weather information as requested for Air Weather Service units.

171. BALLISTIC METEOROLOGICAL MESSAGES

a. Ballistic weather data for corrections in firing data are furnished to artillery firing units by the meteorological section in the form of a ballistic meteorological message. This message includes:

(1) Ballistic wind speed and direction.

(2) Ballistic air temperature.

(3) Ballistic air density.

b. For the techniques involved in obtaining raw data and computing and encoding ballistic meteorological data, see TM 20–240.

172. METEOROLOGICAL MESSAGES FOR SOUND RANGING

a. The data necessary for the correction of errors in sound plots resulting from variations in existing atmospheric conditions are furnished to sound ranging platoons by the meteorological section in the form of sound ranging meteorological messages. This message includes:

(1) Effective wind speed.

(2) Effective wind direction.

(3) Effective air temperature.

b. For the techniques involved in obtaining raw data and computing and encoding sound ranging weather data, see TM 20–240.

173. WEATHER INFORMATION FOR THE AIR WEATHER SERVICE

a. To expand the area over which it has actual measurements of atmospheric conditions aloft, the Air Weather Service uses measurements made by artillery units. Upon request from the Air Weather Service, the artillery meteorological section furnishes such data as can be employed effectively in the preparation of synoptic maps and in forecasting. These data, both for surface and for designated levels aloft, normally consist of the following:

(1) Temperature.
(2) Pressure.
(3) Relative humidity.
(4) Wind speed.
(5) Wind direction.

b. For the techniques involved in the measurement and encoding of such data for Air Weather Service use, see TM 20–240.

Section II. EMPLOYMENT

174. GENERAL

Many factors influence the employment of the meteorological section. Normally, a standard operating procedure (SOP) will be prescribed by higher authority. The meteorological warrant officer in charge of the section recommends variations from the standard procedure to the battery commander whenever technical or atmospheric conditions dictate such variation. The two primary considerations in determining the employment of the section are the size of the area to be serviced, and the existence of other meteorological sections within the same command and/or geographical limits.

175. AREA AND TROOPS TO BE SERVICED

The meteorological section should be located centrally with relation to the units which are to use messages prepared by the section; this is to insure that the measured atmospheric conditions are representative of the conditions encountered by the using units. The meteorological station should also be at or near the mean altitude of the artillery units using its data so that errors caused by arbitrary changes of data, to compensate for differences in altitude, will be minimized.

176. OTHER METEOROLOGICAL SECTIONS

a. Coordination. The existence and operation of other electronically-equipped, ballistic meteorological sections must be considered in the selection of position, and in the determination of types and frequency of messages. If more than one section operates within a given area or command, the size of the area to be serviced will dictate whether each section should prepare data for certain units in the area, or whether the various sections should set up a scheduled and alternately prepare the required data. In a small area, it may be advisable to combine the operations of the sections to eliminate duplication of installations and effort.

b. Visual Meteorological Sections.

(1) Meteorological sections which use electronic equipment (the observation battalion, antiaircraft artillery, and Air Weather Service) can obtain weather data which is much more accurate and dependable than data obtained by meteorological sections which use only

visual equipment (division artillery or electronically equipped section using visual methods as an alternative in an emergency). For this reason, sections which use only visual methods should use upper air data obtained by electronic methods whenever possible. The meteorological warrant officer in the observation battalion is responsible for recommending to visual sections how they should use the electronic messages furnished by the observation battalion. This use is dependent upon the distance between sections and upon the terrain. Techniques employed by a visual meteorological section in obtaining raw data and computing and encoding ballistic meteorological messages are found in TM 20–240.

(2) Normally, the visual section should use data obtained with its own means for the first three lines of any message. Data prepared by a section using electronic equipment should be used for higher lines. A rough rule of thumb may be used to determine how many lines of the message should be based on visually obtained data. This rule is stated as follows: Determine the highest terrain feature which might influence winds and cause local differences in air masses. For each 200 feet height of this terrain feature, employ an additional line deter-

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mined by visual methods. For example, in rough terrain, with hills mounting to 1100 feet above the meteorological stations, the first six lines (1100/200 equals 5.5) should be those determined by the visual methods. Higher lines should be based on the data determined by the electronic section. With no terrain feature higher than 200 feet, the first three lines should be taken from the visual section, and higher lines should be taken from an electronically obtained message.

(3) Employing the above method the winds obtained by electronic methods should be used unchanged. The electronically determined temperatures should not be changed. If there is a great variation between densities determined by visual and electronic methods, the surface ballistic density from the visual section should be used. The electronic densities should be used for all lines as determined by the above rule of thumb. Intermediate densities should be interpolated from the surface to the first electronically obtained density employed.

177. SELECTION OF POSITION

a. The selection of the position to be occupied by the meteorological section is influenced by the general location of the units that it serves, by the location of the headquarters battery of the observation battalion, by the availability of communications for the dissemination of messages, and by the terrain.

b. The meteorological station is located most conveniently from a command, communication, and administrative point of view in the vicinity of the command post of the observation battalion. If possible, this location is near the center of the corps artillery area so that a proper sampling of the atmosphere over the corps area can be obtained. If the observation battalion command post is not near the center of the area to be serviced, the meteorological station should be separated from it and installed nearer the center of the corps area.

c. The meteorological station must be close to a communications center, or have communications readily available, in order to expedite the distribution of meteorological messages. The corps artillery fire-direction center may distribute meteorological messages to artillery units with the corps. The messages for the sound ranging platoons are sent through the observation battalion headquarters communication system. Messages for the Air Weather Service normally are sent through corps headquarters.

d. The station must be located so that observing instruments (visual and electronic) will have a clear line of sight to balloons ascending in the direction away from the prevailing wind. Terrain masks in the direction of the prevailing wind should not be more than 3° above the horizon for best results. The station position must also have a clearing for the launching of balloons.

e. When the area to be occupied is under enemy surveillance, or the enemy has air superiority, it is extremely important that the meteorological station be located at some distance from other installations. This is essential since the technical characteristics of the equipment employed preclude the normal use of camouflage and concealment. The location of the station is indicated directly to the enemy by the release of balloons. Therefore, if the enemy has surveillance of the area, it is advisable to release the balloons at a considerable distance from the station, or to reduce to a minimum the number of releases made during daylight.

178. OCCUPATION OF POSITION

a. The initial movement or displacement of the meteorological section must be planned and executed so as to provide the uninterrupted delivery of ballistic meteorological data to firing units on a prearranged schedule.

b. A well-trained electronic section will need at least 90 minutes in which to set up the station and initiate an observation. After installation is completed, as much as two hours may be required to complete a ballistic message, depending on the maximum altitude required, and on how many types of messages must be provided. A visual section can be installed in about 30 minutes. After installation, about an hour is required to produce data in message form. Higher headquarters must consider these performance times in setting up a schedule for meteorological messages.

c. In a displacement, an advance detachment consisting of a visual crew of four men can be employed to prepare ballistic messages for forward units by the use of the theodolite, psychrometer, and barometer. If visibility will not permit the use of the theodolite in the advance position, either the radio direction finder must be moved forward or provisions must be made to obtain upper wind data from a unit equipped with radar.

d. For further information on occupation of position, loading plans, and related information, see TM 20–240.

179. TYPES OF METEOROLOGICAL MESSAGES

a. Three different sets of standard weighting factors to be applied to measured data have been determined, based upon the muzzle velocities and the broad classification of weapons. Based upon the various weighting factors used, there are three types of meteorological messages for artillery weapons. The following table lists these three types and the artillery weapon which uses each of these types:

Type 2 message	*Type 3 message*	*Type 4 message*
AA weapons firing at aerial targets.	All 75-mm howitzers and guns; 105-mm howitzers; 155-mm howitzers; 8-inch howitzers; 240-mm howitzer, M1, charge 1.	155-mm guns; 240-mm howitzer, M1, charges 2, 3, and 4; 8-inch gun; AA weapons firing at terrestrial targets.

b. In addition to the above mentioned types of ballistic meteorological messages, it will also be necessary for artillery meteorological sections to obtain sound ranging meteorological messages and meteorological messages for the Air Weather Service.

c. The meteorological section may be called upon to provide any of the above types of messages, or any combination of the above types, depending upon the using units. Normally, the section has to provide type 3 and type 4 messages to field artillery units with the corps. When more than one type of message is required, it is necessary to apply the various weighting factors to the measured data more than once. Therefore, more time must be taken for the computation of more than one type of message.

180. FREQUENCY OF METEOROLOGICAL MESSAGES

a. No fixed rule can be made as to the required frequency of meteorological messages since the rate of variation of the atmospheric conditions is never absolutely predictable. The warrant officer in charge of the meteorological section is responsible for recommending the frequency of messages, based upon the weather at any particular time. Normally, sound ranging messages are transmitted every two hours and ballistic messages every four hours. Messages for the Air Weather Service are required every six hours. During a period in which the weather conditions over the area in question are not changing, or are changing very slowly, the above time schedule is adequate to provide accurate data for using units.

b. During periods of frontal passage, great turbulence, thundershowers, or when air masses of varying characteristics are passing through or entering the area, it is the responsibility of the warrant officer in charge of the section to recommend variations in the above schedule. This recommendation should be accepted by higher authority (normally the corps artillery commander) unless other conditions outweigh the advantages to be gained by improved meteorological data.

c. The capabilities of present equipment and the lengthy computations made necessary by present techniques make it impossible to obtain and transmit a ballistic meteorological message at a frequency of more than once every 2½ hours. Sound ranging messages can be obtained every one-half hour, if necessary, but one every hour should be the maximum required frequency.

d. The meteorological section should not be held to a rigid schedule for reporting of data to Air Weather Service. When possible, the data reported to Air Weather Service should be that obtained during flights made to fulfill normal ballistic requirements. Special flights should not be made for the purpose of furnishing data to Air Weather Service.

181. LIAISON

a. General. The meteorological section can obtain much data of value by maintaining contact with other units—Air Weather Service, radar-equipped units, and other electronically equipped meteorological sections—and can improve the use made of data obtained by proper liaison with using units.

b. The Air Weather Service.

(1) The Air Weather Service is the organization responsible for obtaining, evaluating, and disseminating all weather information, except as set forth in pars. 170–172. Air Weather Service installations record and transmit data for the use of all other stations; they have available at all times a picture of the weather situation over a wide area as well as the latest forecast of weather conditions.

(2) The meteorological section should be in contact with the nearest Air Weather Service station at all times so that it can be informed of the status of the weather over its area and of the major changes that are expected. This will enable the station to recommend variations in the flight schedules or to take other necessary action. If possible the daily synoptic map should be procured for the use of the personnel of the meteorological section; the maximum forecast temperature for each day should be obtained from the Air Weather Service for employment in determining the proper pressure-height scale in evaluating ra-

diosonde flights.

(3) There may be occasions when the only meteorological data available is that which is specifically forecast for artillery by a nearby Air Weather Service station. Such data may be obtained from Air Weather Service units after direct liaison has been established.

c. Other Artillery Meteorological Sections. Close personal liaison must be maintained at all times with all ballistic meteorological sections within the same area and/or command and with adjacent meteorological units. Specific arrangements should be made for—

(1) Transmittal of messages to and receiving of messages from other units in case of equipment failure, displacement, or on a prearranged schedule where areas overlap sufficiently for messages from one unit to be valid for another unit. On occasions where metro messages are required more often than a single metro unit is capable of producing, additional messages may be obtained by prearrangement and a coordinated schedule with adjacent metro units.

(2) Variation of radiosonde frequencies when schedules are similar, locations are close, and units have not made arrangements to take alternate soundings.

(3) Employment of electronic messages by visually equipped sections.

(4) Employment of the radars in the let-

tered batteries of the observation battalion and in nearby antiaircraft battalions in emergencies to obtain winds-aloft data (par. 168).

182. DISTRIBUTION OF MESSAGES

Rapid distribution of all types of meteorological messages is essential because changing atmospheric conditions will render messages invalid. Any quick means of distribution may be used to transmit the meteorological data to the using units. Normally, the corps artillery commander will establish a standard procedure for the distribution of messages to artillery with the corps. Meteorological messages may be distributed by telephone to the using units from the meteorological station or by radio on the corps artillery fire-direction net to the using units from either the observation battalion or the corps artillery fire-direction center.

CHAPTER 11
SPECIAL OPERATIONS

183. SNOW AND EXTREME COLD (FM 70–15)

a. General. The measures to overcome handicaps of snow and extreme cold are technical rather than tactical. Heavy snow greatly decreases mobility. It is sometimes necessary to replace trucks with track-laying vehicles. The use of trail-breaking vehicles to pack roads and trails in advance of wheeled or track-laying vehicles is recommended. Hand-drawn sleds or toboggans should be available. Extreme cold weather necessitates special measures in the use of certain instruments and equipment. The lubricants used in transits, observing instruments, and in the sound recording set freeze. The use of prescribed arctic-type lubricants usually corrects this trouble although, under the worst conditions, heating may be necessary. Metal equipment must be insulated against direct contact with the bare skin. In the arctic, the magnetic needle should not be used for orienting the transit. Special measures to insure proper operation of vehicles, weapons, and instruments are included in appropriate technical manuals.

b. Sound Ranging Equipment. For operations in temperatures below 10°F., the lubricant in the reduction gear case of the paper-drive motor of the recorder unit on the Sound Ranging Set GR–8 should be replaced by a mixture of equal parts of medium weight cup grease and fuel oil. All other lubricants are those prescribed for use in the arctic. Microphones may be suspended in a hole dug in the snow or earth, or they may be used on the surface. They must be inspected frequently for frosted relay contacts. They will operate in a normal manner when the frost is removed. The sound ranging plotting board is difficult to transport because of its bulk and weight. A smaller plotting board may be improvised.

c. Radar Ranging. The operation of radar sets for counterbattery and countermortar purposes may be hampered, or the sets may be rendered ineffective, by various cold weather conditions. Heavily falling snow may reduce the range and sensitivity of radar equipment and may even make the detection of projectiles impossible. Snow on the ground may increase clutter. Excessive icing of the antenna may distort the radar beam or cause sluggish movement of the antenna.

d. Camouflage and Fortifications. Camouflage and field fortifications present special problems. Ordinary camouflage nets are sometimes worthless because the snow falls through them and the position shows as a definite dark patch. White cloth should be used to cover the nets or as drapes to cover vehicles. Digging emplacements or trenches in frozen ground usually is impossible without the use of explosives.

184. MOUNTAIN WARFARE (FM 70–10)

a. Mobility. The mobility of the observation battalion is limited in mountainous terrain. Motor travel usually is limited to roads, and speeds are considerably reduced. Frequently, equipment must be transported considerable distances by back pack or on pack animals, and installations must be made by man power or with the aid of pack animals.

b. Observation. Observation posts should be echeloned in altitude, if possible, as well as in width and depth since observation is often obscured by sudden fog. Independent short bases may be the only type flash base that can be installed because of the difficulty of establishing survey and communication and of getting multiple observation posts that provide observation in the same zone.

c. Employment. Operations are often decentralized to batteries. Oblique photos and overlapping pairs facilitate location of targets and vertical control. Generally, survey is accomplished by triangulation. Probable locations of targets are determined easily because the points that the enemy is compelled to pass and the areas in which he will most likely form for attack may be determined usually by a study of the terrain.

d. Communication. Wire is hard to install and maintain. Radio reception is usually satisfactory, but dead spaces should be expected because of the shadow effect of hill masses. These dead spaces may be overcome by making full use of the remote control unit, or in some cases, by the use of relay stations.

e. Radar Positions. In mountainous terrain, it may be impossible to find radar sites which have adequate electrical screening. This may hamper or even prevent successful radar ranging.

f. Reconnaissance and Selection of Position. Extensive reconnaissance is necessary. The selection of positions may be limited by inaccessibility and may be further limited by special requirements for flash and sound bases. Maps of mountainous regions, if available, are seldom accurate. A correct appreciation of the terrain can be gained only by ground reconnaissance, supplemented by a study of aerial photographs or maps. The employment of local guides is often advantageous.

185. DESERT WARFARE (FM 31–25)

a. The observation battalion uses its normal installations in desert warfare. The lack of landmarks increases the difficulty of survey and target identification. Movement in desert country is largely dependent on some means of land navigation; careful adherence to a predetermined compass direction for a given distance is the most common method. Celestial navigation may sometimes be useful.

b. Ground observation frequently is limited by undulations of the terrain, shimmering atmosphere, dust, and sand storms. Portable observation towers may be very valuable where the terrain offers no natural vantage points. Sound ranging, flash ranging, and radar ranging are employed to the maximum.

c. Natural concealment, except through defilade, is difficult. Protection against hostile shelling and air attack may be obtained by dispersion and field fortifications. Camouflage is used extensively. Security against hostile ground attack, especially armored attack, must be stressed.

186. JUNGLE WARFARE (FM 72–20)

a. *General*. The jungle does not change the principles of operation of the observation battalion, but it does affect its application, chiefly by restricting observation, movement, and supply.

b. *Mobility*. Motor movement in the jungle is retarded and slow, and it is usually confined to roads and trails. Equipment will often have to be backpacked; sound and flash bases will often have to be installed completely by hand without the use of vehicles. Special equipment and packboards should be provided. Organic means of transportation may be supplemented by boats and barges and by the use of sleds or carts drawn by animals or man power, tractors, and amphibious vehicles.

c. *Observation*. Flash observation in the jungle is extremely limited. Personnel must be trained to exploit available commanding ground. Careful scrutiny and the ability to identify all types of enemy installations, weapons, and transport are very important. Observation is usually difficult because of very large trees with dense interlacing foliage; the undergrowth is massive. A limited field of view can often be cut through the undergrowth with machetes or bush knives. Observation posts should always have overhead cover because overhanging foliage often causes tree bursts. Personal reconnaissance is a prime necessity in choosing the location of observation posts or other installations. All adjacent troops should always be notified before trees are climbed to gain observation. Security for the observer is important because enemy patrols may infiltrate into the position. Observers may accompany reconnaissance patrols to locate targets. Infantry patrol leaders often return by way of artillery observation posts to point out targets they have located. Sound ranging and radar ranging are often the only observation possible. The prevalence of high-angle fire in jungle operations greatly facilitates radar location of enemy weapons. Observation from boats off shore may be feasible in coastal regions. Climate, weather, insects, and animals also present problems to the observer.

d. Conduct of Fire.

(1) Registration and adjustment usually will be conducted by sound ranging or radar ranging. Difficulty of survey in jungle terrain may make deliberate occupation

of position extremely slow, especially in the initial phase of the operation. In many cases, irregular bases, located by "shooting in" or by inspection of air photos, will be used. Relative sound ranging locations (par. 116*h*) and *sound-on-sound* adjustments (par. 119) will play major roles. Where laying of wire is difficult, initial use of radio for sound data transmission may speed up early operation.

(2) Flash ranging high-burst registration and adjustment may be used advantageously. As a rule, ground bursts will be obscured by jungle growth and trees.

(3) Radar registration and adjustment will be frequent. The simplicity of the survey required for radar ranging and the fact that line-of-sight observation to the burst is not required in radar adjustments are advantages in jungle operations. Adjustment on observed-firing-chart control or by burst location on target location may be used when no survey control is available (par. 158*c*).

e. Communication.

(1) Wire is the principal means of ground communication. The supply of wire and the means of laying it are usually limited; much wire has to be laid by hand. Initially, existing trails may have to be used for line routes, but later circuits should be rerouted through the jungle

or buried along the original route. Wire parties may require protection by accompanying patrols.

(2) The range of radio is greatly reduced. Waterproofing and fungi-proofing equipment are critically important in humid areas and during rainy seasons. Dismounted messengers are used extensively. Oral messages are preferable because the danger of written matter falling into enemy hands is relatively great.

f. Position Areas. Good position areas are usually few in number and are limited to locations near existing roads or trails. In many cases it will be necessary to clear a position area, and construct a road prior to occupation.

g. Survey. Reliable maps may not be available. Aerial photographs are valuable, but important terrain features are often obscured by dense vegetation. Survey is of particular importance because of the reliance placed on unobserved fires, and it is slow because of the amount of brush cutting necessary. Usually, the target area must be tied to the position area by firing. Owing to the slowness of normal survey, hasty survey by radar will frequently be used until normal survey is complete (par. 158). Radar survey is not a substitute for normal survey. Location of front lines by radar (par. 167) is especially useful in jungles. Use of radar in the jungle necessitates considerable clearing of the jungle growth to provide clear fields of operation. When clearing the line of site, consideration must also be given to the dangers of destruction of natural camouflage.

h. Local Security. Camouflage and concealment are relatively easy. Overhead cover for personnel is necessary because bombs and other projectiles are likely to burst in the tree tops. Ground attack by infiltration is always a threat; each battery and similar installation must establish a strong perimeter defense.

187. LANDING OPERATIONS (FM 31–5)

The observation battalion is seldom in the assault waves of an amphibious operation; however, its forward echelons, battery and battalion, must be landed as early as possible in the operation. Preparation for landing operations is extremely important. Prior knowledge of terrain from intensive map study and knowledge of enemy dispositions is essential. Information on the progress and whereabouts of our own troops is also of extreme importance. Special precautions must be taken to waterproof vehicles and to protect equipment—weapons; communication equipment; sound, flash, and radar ranging equipment; etc.—from exposure—immersion, spray, or dampness—to salt water. All equipment must be carefully cleaned immediately after exposure. In loading, precautions must be taken to facilitate entry into action; equipment needed first should be readily available. Reconnaissance parties should be first ashore to reconnoiter routes and select positions for installations. Survey personnel and equipment must also be landed early. To facilitate survey, existing maps should be studied thoroughly so that prominent terrain features can be identified for orientation and for use in installations as soon as the units are landed. A minimum of 3 days' rations should be carried with the landing parties.

APPENDIX I

REFERENCES

SR 110–1–1	Index of Army Motion Pictures and Film Strips.
SR 310–20 series	List of Training Publications.
SR 320–5–1	Dictionary of United States Army Terms.
FM 5–6	Operations of Engineer Units.
FM 6–20	Field Artillery Tactics and Technique.
FM 6–40	Field Artillery Gunnery.
FM 6–101	Tactics and Technique, Battalion and Battery, Motorized.
FM 6–130	Field Artillery Intelligence.
FM 6–140	The Field Artillery Battery.
FM 21–5	Military Training.
FM 21–8	Military Training Aids.
FM 21–30	Military Symbols and Abbreviations.
FM 24–20	Field Wire Technique.
FM 31–5	Landing Operations on Hostile Shores.
FM 31–25	Desert Operations.
FM 44–44	Service of the Radio Set SCR–584.
FM 44–45	Service of the Radio Set SCR–784.
FM 70–10	Mountain Operations.
FM 70–15	Operations in Snow and Extreme Cold.

FM 72–20	Jungle Warfare.
FM 101–5	Staff Officers Field Manual, Staff Organization and Procedure.
TM 5–235	Surveying.
TM 5–241	Universal Grid Systems.
TM 5–9420	Altimeter, Surveying, 6000-foot, 10-foot Divisions, Type 6, Wallace and Tiernan, Model FA–112.
TM 6–240	Rule, Slide, Military Field Artillery, with Case, 10-Inch.
TM 6–605	Field Artillery Individual and Unit Training Standards.
TM 9–525	Graphical Firing Tables.
TM 9–575	Auxiliary Sighting and Fire Control Equipment.
TM 11–439	Flash Ranging Set GR–4–A.
TM 11–2568	Sound Ranging Set GR–8.
TM 20–240	Meteorology for Artillery.
TM 44–225	Orientation for Artillery.

APPENDIX II

MINIMUM TRAINING SCHEDULES

Section I. GENERAL

1. PURPOSE

This appendix is a general guide for the minimum training of elements of the field artillery observation battalion in the *subjects contained in this manual.*

2. SCOPE

It is designed to provide the *minimum* instruction nacessary for the performance of essential duties and for the teamwork to meet minimum training standards. *Additional training beyond the scope of this appendix is necessary to develop an efficient and well-trained unit.*

3. APPLICATION

a. Tactical training within the battalion is conducted in accordance with FM 21–5 and TM 6–605. All paragraph references in the following schedules are to paragraphs in the main text of the manual.

b. Training of individuals in technical specialties should be arranged for outside of the time allotted in these schedules. For example, instruction in the operation of the transit, the calculating machine, and the sound recorder should be given in battery or battalion schools.

c. Administrative, supply, and maintenance personnel will receive on-the-job training in these functions under the supervision of key noncommissioned officers (FM 6–140).

d. Throughout the training period, the application of prior instruction to current training must be stressed.

e. Subjects involving similar time-consuming preparations may be combined where practicable. For example, the same 105-mm howitzer may be used to fire for practical training in both sound and radar ranging concurrently.

f. The necessity for developing leadership and initiative in unit leaders must constantly be borne in mind throughout training.

4. PHASES OF TRAINING

a. The training program is divided into four phases: *section phase, platoon phase, battery phase,* and *battalion phase.*

b. For the purposes of this appendix it is assumed that basic and specialist training has been acquired elsewhere.

c. It is intended that the various phases of training for all batteries be conducted simultaneously in so far as possible taking into consideration the fact that total hours for section training do not always coincide. Sections which do not participate in the *platoon phase* should continue the section phase. *Battery* and *battalion phases* should be simultaneous for all sections.

d. The same howitzers and ammunition should be used to satisfy the requirements of the sound, flash, and radar platoons by conducting training requiring live ammunition simultaneously.

e. Two or more sections whose duties are identical may be combined during *section phase* to receive training in common subjects.

5. TRAINING AIDS, EQUIPMENT, AND PERSONNEL

The following training aids, equipment, and additional personnel are the minimum requirements for the conduct of training under the following schedule.

a. T/O&E equipment.

b. Blackboards.

c. Charts.

d. Blank forms for recording and computation.

e. Two 105-mm howitzer sections with equipment.

f. One 155-mm howitzer section with equipment.

g. Smoke puff equipment for miniature exercise for flash ranging.

h. One motor section with equipment.

i. Skeleton fire-direction center.

j. Five hundred rounds of mortar ammunition.

k. Fourteen hundred rounds of 105-mm howitzer ammunition.

l. Four hundred rounds of 155-mm howitzer ammunition.

m. Eighteen hundred pounds of TNT charges for sound platoon.

n. Demolition detail with equipment.

o. Four hundred smoke puffs.
p. Eight hundred percussion caps.
q. Four hundred and fifty electric caps.
r. Fifty high-burst signals.

Section II. SCHEDULES

6. METEOROLOGICAL SECTION (section phase) (38 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization and mission of the observation battalion and headquarters battery (conference).	Pars. 10–15.	Classroom.	Blackboard.
2	1	Organization and mission of the meteorological section (conference).	Par. 170..	...do...	Do.
3	1	Producing a visual message (conference).	Par. 176..	...do...	Do.
4	3	Producing a visual message (practical exercise).	....do....	Battery area.	T/O & E equipment.
5	1	Producing ballistic densities and temperatures from radiosonde data (conference).	Par. 171..	Classroom.	Blackboard.

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
6	7	Producing ballistic densities and temperatures from radiosonde data (practical exercise).	Par. 171. .	Battery area.	T/O & E equipment.
7	1	Determination of ballistic winds from radio direction finder and radar data (conference).	Pars. 168 and 171.	Classroom.	Blackboard.
8	5	Determination of ballistic winds from radio direction finder and radar data (practical exercise).	. . . .do. . . .	Battery area.	T/O & E equipment.
9	1	Communication and selection and occupation of position (conference).	Pars. 177–178, 182.	Classroom.	Blackboard.
10	1	Liaison (conference).	Pars. 173–176.	. . .do. . .	Do.
11	4	Preparation of sound ranging and ballistic meteorological messages (field exercise).	Pars. 171–176.	Field. . .	T/O & E equipment.
12	4	. . . .do.	. . . .do. . . .	. . .do. . .	Do.
13	4	. . . .do.	. . . .do. . . .	. . .do. . .	Do.
14	4	. . . .do.	. . . .do. . . .	. . .do. . .	Do.

[1]P—period. [2]H—hours.

7. FIRST PERIOD

a. Objective. To familiarize the personnel of the meteorogolical section with the organization and mission of the observation battalion and headquarters battery.

b. Outline. Show graphically the various organizations of the battalion, and explain how they work together to accomplish the missions of the battalion and headquarters battery.

8. SECOND PERIOD

a. Objective. To teach the personnel of the meteorological section the organization and mission of the section.

b. Outline. Show the elements of the section graphically, and explain what each does to aid in preparing a meteorological message.

9. THIRD PERIOD

a. Objective. To outline the procedure for producing a visual message.

b. Outline. Review the steps in the procedure explaining the importance of each.

10. FOURTH PERIOD

a. Objective. To practice individual skills required to produce a visual message.

b. Outline. Conduct practical exercise including release, tracking, plotting, and computation to produce a visual message.

11. FIFTH PERIOD

a. Objective. To outline the procedure for producing ballistic densities and temperatures using radiosonde data.

b. Outline. Review the steps in the computation of ballistic densities from radiosonde data.

12. SIXTH PERIOD

a. Objective. To practice individual skills required to produce ballistic densities and temperatures from radiosonde data.

b. Outline. Conduct a practical exercise including a release, tracking, interpretation of record, and computation of ballistic densities and temperatures from radiosonde data.

13. SEVENTH PERIOD

a. Objective. To review the procedure for determining ballistic winds from radio direction finder and radar data.

b. Outline. Discuss the steps in the procedure for determining ballistic winds from radio direction finder and radar data.

14. EIGHTH PERIOD

a. Objective. To practice individual skills required to produce ballistic winds from radio direction finder and radar data.

b. Outline. Conduct a practical exercise including release, tracking, plotting, and computation of ballistic winds from radio direction finder and radar data.

15. NINTH PERIOD

a. Objective. To teach the communication system required and used by the meteorological section, the method of distributing the completed messages, and the principles of selection and occupation of position.

b. Outline. Discuss the subjects mentioned under *a* above.

16. TENTH PERIOD

a. Objective. To teach the liaison responsibilities of the meteorological section.

b. Outline. Discuss liaison between the meteorological section and the Air Weather Service and other meteorological sections in the area.

17. ELEVENTH PERIOD

a. Objective. To train the section how to live in the field and how to operate continuously.

b. Outline. Move the section into the field, select and occupy position, and operate under field conditions. Conduct this exercise during daylight hours.

18. TWELFTH PERIOD

Same as paragraph 17.

19. THIRTEENTH PERIOD

Same as paragraph 17, except that the exercise is held during hours of darkness.

20. FOURTEENTH PERIOD

Same as paragraph 19.

21. METEOROLOGICAL SECTION

(battery phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Battery field exercise (daytime).	Pars. 171 and 172.	Field...	T/O & E equipment.
2	8	Battery field exercise (nighttime).	....do....	...do...	Do.

[1]P—period. [2]H—hours.

22. FIRST PERIOD

a. Objective. To train the meteorological section in the continuous production of sound ranging and ballistic meteorological messages.

b. Outline. Move the section into a tactical position and operate continuously under simulated combat conditions.

23. SECOND PERIOD

Same as paragraph 22.

24. METEOROLOGICAL SECTION

(battalion phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Continuous field operation in battalion field exercise (daytime).	Pars. 171 and 172.	Field...	T/O & E equipment.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
2	8	Continuous field operation in battalion field exercise (nighttime).	....do....	...do...	Do.

[1]P—period. [2]H—hours.

25. FIRST PERIOD

Same as paragraph 22.

26. SECOND PERIOD

Same as paragraph 22.

27. OPERATIONS SECTION, HEADQUARTERS BATTERY

(Section phase) (17 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization of the observation battalion (conference).	Pars. 10–15.	Classroom.	Blackboard.
2	3	Missions and capabilities of the observation batallion (conference).	Pars. 3–9.	...do...	Do.
3	2	Communication in the observation battalion (conference).	Pars. 42–50.	...do...	Do.

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
4	2	Equipment of the observation battalion (demonstration).	Pars. 70, 108–110, 112–113, 117, 129, 139, 142, 150–182.	Battery area.	T/O & E equipment.
5	3	Duties and responsibilities of operations section (practical) exercise).	Pars. 14*a*, 54–55.	Section area.	Do.
6	3	Duties of intelligence sergeant (practical excise).	Pars. 14*e*, 54–55.	...do...	T/O & E equipment and examples of the reports and charts.
7	3	Duties of operations sergeant (practical exercise).	....do....	...do...	Do.

[1]P—period.
[2]H—hours.

28. FIRST PERIOD

a. Objective. To teach the organization of the observation battalion and batteries.

b. Outline. Show graphically the various organizations in the batteries and how they are welded together into an organization through command channels.

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29. SECOND PERIOD

a. Objective. To explain the six missions of the observation battalion and its limitations and capabilities in performing these missions.

b. Outline. Show graphically which agency or agencies within the battalion are responsible for the accomplishment of each of the six missions which the battalion is capable of performing.

30. THIRD PERIOD

a. Objective. To familiarize the personnel of the operations section with the communications system available within the observation battalion.

b. Outline. Show the radio and wire communication nets graphically, and explain the use of the various nets and basic wire and radio procedure.

31. FOURTH PERIOD

a. Objective. To acquaint the personnel of the operations section with the major items of equipment operated by the agencies of the observation battalion.

b. Outline. Arrange to have each major item of the equipment available for the personnel of the operations section to look at; explain the function of each item.

32. FIFTH PERIOD

a. Objective. To outline duties and responsibilities of the operations section.

b. Outline. Explain the purpose of the specific reports, records, maps, and charts processed by the operations section.

33. SIXTH PERIOD

a. Objective. To teach the personnel of the operations section the duties of the intelligence sergeant.

b. Outline. Explain in detail how to produce the reports and records and to keep the maps and charts required by the intelligence officer of the battalion.

34. SEVENTH PERIOD

a. Objective. To teach the personnel of the operations section the duties of the operations sergeant.

b. Outline. Explain in detail how to produce the reports and records and how to keep the maps and charts required by the operations officer of the battalion.

35. RADIO SECTION

(section phase) (12 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization of the observation battalion (conference).	Pars. 10–15.	Classroom.	Blackboard.
2	1	Principles of communication (conference).	Pars. 42–50.	...do...	Do.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
3	1	Duties of communication personnel (conference).	Pars. 14–15.	...do...	Do.
4	1	Battalion radio system (conference).	Pars. 47–50.	...do...	Blackboard, radio diagrams.
5	4	Battery radio system (practical exercise).	Par. 49...	Field...	Battery radio equipment.
6	2	Wire equipment (practical exercise).	Pars. 44–46.	Classroom and field.	Battery wire equipment.
7	2	Switchboard and telephone operating procedure (practical exercise).	Pars. 43–46.	Classroom or field.	Do.

[1]P—period. [2]H—hours.

36. FIRST PERIOD

a. Objective. To familiarize the radio section with the organization of the observation battalion.

b. Outline. Stress the communication elements of the observation battalion organization.

37. SECOND PERIOD

a. Objective. To teach the radio section the principles of communication, means of communication, and the mission of the observation battalion as it affects communication.

b. Outline. Stress the importance of principles of communication as they dictate the responsibility for the installation or establishment of radio circuits. Show how the means of communication available in the radio section are employed to accomplish the mission of the observation battalion.

38. THIRD PERIOD

a. Objective. To point out the duties of the communication personnel in the observation battalion.

b. Outline. List the duties of all communication personnel to include communication officers, radio men, wiremen, and message center personnel.

39. FOURTH PERIOD

a. Objective. To teach the radio systems employed by an observation battalion.

b. Outline. Emphasize nets, types of radios in each net, composition of the net, and use of each net.

40. FIFTH PERIOD

a. Objective. To give the radio section practice in the establishment of the battery radio system.

b. Outline. Select battery installations and a skeleton battalion headquarters on a reduced scale. Require the radio section to establish battery stations. Arrange messages to give practice in handling normal battery radio traffic.

41. SIXTH PERIOD

a. Objective. To familiarize the radio section with the wire equipment employed by the observation battalion.

b. Outline. Display and demonstrate the different items of wire equipment and the use and location of this equipment in the observation battalion. Stress the use of wire communication and the importance of radio men trained in wire communication.

42. SEVENTH PERIOD

a. Objective. To familiarize the radio section with telephone and switchboard procedure, operation, rules, words, and phrases.

b. Outline. The first part of the period should be a conference in which procedures, operation, rules, words, and phrases are discussed. The remainder of the period should be used for practical application.

43. WIRE SECTION

(section phase) (10 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization of the observation battalion (conference).	Pars. 10–15.	Class-room.	Blackboard.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
2	1	Principles of communication (conference).	Pars. 42–50.	...do...	Do.
3	1	Duties of communication personnel (conference).	Pars. 14–15.	...do...	Do.
4	1	Battery wire system (conference).	Pars. 43–46.	...do...	Blackboard, wire, diagram.
5	4	Battery wire system (practical exercise).	....do....	Field...	Battery wire equipment.
6	2	Radio equipment (practical exercise).	Pars. 47–50.	Classroom or field.	Battery radio equipment.

[1]P—period.
[2]H—hours.

44. FIRST PERIOD

a. Objective. To familiarize the wire section with the organization of the observation battalion.

b. Outline. Stress the organization of the communication elements of the observation battalion organization.

45. SECOND PERIOD

a. Objective. To teach the wire section the principles of communication, means of communication, and the mission of the observation battalion as it affects communication.

b. Outline. Stress the importance of principles of communication as they dictate the responsibility for the installation of wire circuits. Show how the means of communication in the wire section are employed to accomplish the mission of the observation battalion.

46. THIRD PERIOD

a. Objective. To point out the duties of the communication personnel in the observation battalion.

b. Outline. List the duties of all communication personnel to include communication officers, radio men, wiremen, and message center personnel.

47. FOURTH PERIOD

a. Objective. To teach the wire system employed by an observation battery.

b. Outline. Point out each trunk and local circuit to be installed and the unit responsible for installing each circuit in the observation battery wire system.

48. FIFTH PERIOD

a. Objective. To give the wire section practice in the installation of an observation battery wire system.

b. Outline. Select battery installations on the ground on a full scale. The wire section working in crews should install a complete observation battery wire net.

49. SIXTH PERIOD

a. Objective. To familiarize the wire section with the radio equipment employed by the observation battalion.

b. Outline. Display and demonstrate the different items of radio equipment and the use and location of radio sets in the observation battalion. Stress the use of radio communication to supplement wire communication and the importance of wiremen trained in radio communication.

50. COMMUNICATION PLATOON (platoon phase) (2 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	2	Integrated wire and radio nets of the observation battalion (conference).	Pars. 42–50.	Classroom.	Blackboard, wire and radio diagrams.

[1]P—period.
[2]H—hours.

51. FIRST PERIOD

a. Objective. To teach the communication platoon the integrated wire and radio systems employed by the observation battery.

b. Outline. Point out each wire circuit and radio net established by the observation battery and the phases of installation of the combined systems for rapid and deliberate occupations of position.

52. OBSERVATION BATTERY, AND HEADQUARTERS BATTERY

(battery phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Command posts (conference).	Par. 43 . . .	Class-room.	Blackboard.
2	1	Command post communication (conference).	. . . .do. . . .	. . .do. . .	Do.
3	2	Communication systems of associated arms (conference).	Par. 42 . . .	. . .do. . .	Do.
4	4	Battery field exercise.	Pars. 42–50.	Field. . .	Battery communication equipment.
5	8	. . . .do.	. . . .do. . . .	do. . .	Do.

[1]P—period.
[2]H—hours.

53. FIRST PERIOD

a. Objective. To teach the considerations required in the selection and organization of field artillery command posts and considerations in the selection of locations for elements within the command post.

b. Outline. Stress the selection of the elements of the command post. Selection requirements and considerations should include communication.

54. SECOND PERIOD

a. Objective. To teach the selection of the several elements of the command post with regard to communication, and to teach the communication systems employed in field artillery command posts.

b. Outline. Stress the communication requirements and considerations in the selection of the command post and its elements. A typical command post is displayed to show the communication systems employed within the command post.

55. THIRD PERIOD

a. Objective. To familiarize observation personnel with the communication systems employed by associated arms.

b. Outline. Discuss communication systems and equipment of various units, stressing the fact that observation units may be attached or supporting these units and knowledge of their systems and equipment is essential. The discussion should cover corps artillery, group artillery, division artillery, and separate artillery battalions.

56. FOURTH PERIOD

a. Objective. To give practice in the installation of a complete battery communication system.

b. Outline. Select battery installations on the ground on a reduced scale, and issue appropriate orders requiring the battery to install complete battery wire and radio systems.

57. FIFTH PERIOD

a. Objective. To give practice in the installation of a complete battery communication system.

b. Outline. Select battery installations on the ground on a full scale, and require the battery to install complete battery wire and radio systems.

58. OBSERVATION BATTALION
(battalion phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Battalion field exercise.	Pars. 43–50.	Field...	Battalion communication equipment.
2	8	....do..........	....do....	...do...	Do.

[1]P—period.
[2]H—hours.

59. FIRST PERIOD

a. Objective. To give practice in the installation of a complete battalion communication system.

b. Outline. Install communications required when the battalion is in the field. The instructor will act as an umpire checking all communication installations during the battalion exercise and will hold a critique immediately following the exercise.

60. SECOND PERIOD

Same as paragraph 59.

61. TOPOGRAPHICAL SECTION
(section phase) (32 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Corps artillery survey and the military grid system (conference).	Pars. 59–61, 64, 67, 69.	Classroom.	Map with UTM Grid.
2	1	Field notes (conference).	Pars. 71, 73.	...do...	Field notebooks (sample notes).
3	2	Measuring, checking, and computing angles (conference and demonstration).	Par. 71.	Classroom or field	Transit.
4	1	Care and use of transit (demonstration).	Par. 70*b*.	...do...	Do.
5	2	Measuring angles with transit (practical exercise).	Par. 71.	Field...	Do.
6	1	Horizontal taping (conference and practical exercise).	Pars. 70*c*, 72*a*.	...do...	Tape and accessories.
7	2	Traverse methods and computations (conference and practical exercise).	Pars. 74–76.	Classroom.	DA AGO Form 6–2, Vega tables.
8	2	Triangulation methods and computations (conference and	Pars. 77–82.	...do...	DA AGO Form 6–2, DA AGO Form 6–8,

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
		practical exercise).			Vega tables.
9	2	Three-point resection (conference).	Pars. 83–87.	...do...	Blackboard.
10	1	Two-point resection (conference).	Pars. 88 and 89.	...do...	Do.
11	1	Vertical control (conference).	Pars. 90 and 91.	...do...	Do.
12	1	Stadia traverse (conference).	Par. 72*b*.	...do...	Blackboard, stadia board.
13	1	Method of sound base survey (conference).	Pars. 104–106, app. VII	...do...	Blackboard.
14	2	Survey methods for rapid and deliberate flash installations (conference).	Pars. 132, 141.	Classroom.	Blackboard.
15	3	Astronomic orientation (conference).	Pars. 92 and 93.	do...	Do.
16	1	Use of American Ephemeris in computations (conference).	Par. 94*c*.	...do...	American Ephemeris.
17	2	Computations of azimuth, altitude method (conference).	Par. 94...	...do...	Blackboard, DA AGO Form 6–11.

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
18	2	Azimuth determination, sun altitude method (conference).	....do....	...do...	Do.
19	2	Computation of azimuth, hour angle method (conference).	....do....	...do...	Blackboard, DA, AGO Form 6–10.
20	2	Azimuth determination, Polaris, hour angle method (conference).	....do....	...do...	Do.

[1]P—period.
[2]H—hours.

62. FIRST PERIOD

a. Objective. To give a general outline of the application of survey as performed by the observation battalion, and to outline the grid system that is used in this survey work. To explain the accuracies to be obtained in corps survey and the operation of the survey information center (SIC).

b. Outline. Stress the survey mission of the observation battalion and its application in the first half of the period. Use the last half of the period to explain the Universal Transverse Mercator Grid and Referencing System.

63. SECOND PERIOD

a. Objective. To teach the method and importance of keeping proper field notes.

b. Outline. Show the materials used. Give the organization of the notebook. Pass out sample notes. Discuss how to keep good notes.

64. THIRD PERIOD

a. Objective. To show the method of measuring angles and how to compute, check, and adjust them.

b. Outline. Go through the steps in the measurement of an angle using the transit to demonstrate the procedure. Explain bar angles and horizon closure. Discuss how to compute and adjust an angle.

65. FOURTH PERIOD

a. Objective. To teach the care and use of the transit.

b. Outline. Demonstrate the proper method of setting up the transit; explain the various parts, the methods of measuring angles, and the precautions in the use and care of the transit.

66. FIFTH PERIOD

a. Objective. To give the members of the section experience in measuring a set of angles at a point and closing the horizon.

b. Outline. Have the men set up transit and measure the horizontal and vertical angles to designated points. They should make at least one direct and one reversed measurement of all horizontal angles and close the horizon; they should make at least one direct and one reversed measurement of the vertical angles. Have the men act as recorders.

67. SIXTH PERIOD

a. Objective. To teach a methodical procedure for horizontal taping.

b. Outline. Give the rules for taping, and explain the use of the accessories. Have members of the section tape over assigned courses.

68. SEVENTH PERIOD

a. Objective. To teach the purpose, methods, standards, and computations of a traverse.

b. Outline. Explain the purpose, methods, and standards of traverse. Show how to compute a traverse. Have the men compute a simple one leg traverse.

69. EIGHTH PERIOD

a. Objective. To teach the purpose, methods, standards, and computations of triangulation.

b. Outline. Explain the purpose, methods, and standards of triangulation. Show how to compute a triangulation problem. Have the men compute a single triangle.

70. NINTH PERIOD

a. Objective. To teach the employment of three-point resection and the mathematical solution of the three-point resection problem.

b. Outline. Stress the use of three-point resection. Point out three different cases of its application. Solve one problem.

71. TENTH PERIOD

a. Objective. To teach the employment of two-point resection and the mathematical solution of the two-point problem.

b. Outline. Stress the use of two-point resection. Explain the two methods used in the solution of this problem.

72. ELEVENTH PERIOD

a. Objective. To teach the methods and computations for carrying vertical control.

b. Outline. Go through the steps used in an observation battalion when carrying control by trigonometric leveling. Solve a problem on the blackboard.

73. TWELFTH PERIOD

a. Objective. To teach the use of stadia in carrying control and its use in the observation battalion.

b. Outline. Explain the equipment used in stadia work. Point out the limitations of stadia, and discuss its employment in the observation battalion.

74. THIRTEENTH PERIOD

a. Objective. To teach the planning and execution of a survey to establish straight and curved sound bases.

b. Outline. Stress the importance of proper planning and reconnaissance. Explain how the coordinates of the microphone positions are determined; explain the methods of establishing microphone positions on the ground.

75. FOURTEENTH PERIOD

a. Objective. To teach special applications of survey for the location of observation posts in rapid and deliberate flash installations.

b. Outline. Explain the various methods of internal survey for rapid flash installations. Spend a short time on the location of observation posts for a deliberate flash installation.

76. FIFTEENTH PERIOD

a. Objective. To teach the application of astronomy to artillery survey.

b. Outline. Explain the celestial sphere, celestial terminology, horizon and equatorial system, and units of measure of arc and time.

77. SIXTEENTH PERIOD

a. Objective. To teach the section how to use the tables in the American Ephemeris.

b. Outline. Have the men locate the necessary tables in the American Ephemeris, and have them explain how to use these tables.

78. SEVENTEENTH PERIOD

a. Objective. To teach the methods of observing, the accuracy required, and the computation of azimuths from data obtained in the altitude method.

b. Outline. Explain how to observe using the altitude method, and lead the men step by step through DA AGO Form 6–11.

79. EIGHTEENTH PERIOD

a. Objective. To teach the principles and the practices—corrections, computations, and checks—involved in observing the sun by the altitude method.

b. Outline. Explain step by step the observing of the sun in the altitude method. Give a problem to be solved by individuals during their free time.

80. NINETEENTH PERIOD

a. Objective. To teach the methods of observing, the accuracy required, and the computation of azimuths from data obtained in the hour angle method.

b. Outline. Explain how to observe in the hour angle method and lead the men step by step through DA AGO Form 6–10.

81. TWENTIETH PERIOD

a. Objective. To teach the hour angle method of observation on Polaris to obtain an azimuth;

to teach the corrections, computations, and checks involved in this method.

b. Outline. Explain step by step the observing of Polaris. Give a problem to be solved by individuals during their free time.

82. TOPOGRAPHICAL SECTION (platoon phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	4	Traverse (practical exercise).	Pars. 74–76.	Field...	Section survey equipment.
2	4	Triangulation (practical exercise).	Pars. 77–82.	...do...	Do.
3	4	Resection (practical exercise).	Pars. 83–89.	...do...	Do.
4	4	Traverse with check of azimuth by sun observation (practical exercise).	Pars. 74–76, 94.	...do...	Do.

[1]P—period.
[2]H—hours.

83. FIRST PERIOD

a. Objective. To give the survey parties training in surveying by traverse.

b. Outline. Have the section conduct a field survey by transit and tape traverse.

84. SECOND PERIOD

a. Objective. To give the survey parties training in triangulation.

b. Outline. Have the section solve a field triangulation problem.

85. THIRD PERIOD

a. Objective. To give the survey parties training in resection.

b. Outline. Have the section solve a field resection problem.

86. FOURTH PERIOD

a. Objective. To give the survey parties training in surveying by traverse and the checking of azimuths by sun observations.

b. Outline. Have the section solve a field traverse and a sun observation problem.

87. TOPOGRAPHICAL SECTION (battery phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Sound base survey (practical exercise).	Pars. 104 and 105.	Field...	Section survey equipment.
2	8	Flash rapid installation survey with expansion to flash deliberate installation (practical exercise).	Pars. 132, 141.	...do...	Do.

[1]P—period.
[2]H—hours.

88. FIRST PERIOD

a. Objective. To give the survey parties training in establishing a straight sound base.

b. Outline. Have the section establish a straight sound base. The sound base should be selected to provide a good tactical problem.

89. SECOND PERIOD

a. Objective. To give the survey parties training in performing the survey for a rapid flash installation and then expanding it to a deliberate flash installation.

b. Outline. Have the section establish a rapid flash installation and then expand it to a deliberate flash installation. Provide a tactical situation for this field problem.

90. TOPOGRAPHICAL SECTION (battalion phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Comprehensive survey (practical exercise).	Pars. 62–94.	Field...	Section survey equipment.
2	8	....do..........	....do....	...do...	Do.

[1]P—period.
[2]H—hours.

91. FIRST PERIOD

a. Objective. To provide training for all of the survey parties in their normal survey mission.

b. Outline. Have the topographical sections conduct a battalion field problem with all survey parties necessary to complete the survey. This problem should include all types of survey.

92. SECOND PERIOD

Same as paragraph 91.

93. OPERATIONS SECTION, SOUND PLATOON (section phase) (32 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization and missions of the observation battalion (conference).	Par. 1–15.	Classroom.	Blackboard.
2	2	Organization, missions, and duties of personnel (conference).	Par. 15	...do...	Do.
3	1	Description of equipment (conference and demonstration).	Par. 108–110, 112–113, 115–117.	...do...	T/O & E equipment.
4	2	Principles of sound ranging (conference).	Par. 95–96, 114–115.	...do...	Blackboard.
5	4	Sound installations (conference).	Par. 96–110.	...do...	Do.
6	4	Sound record reading (conference and practical exercise).	Par. 96, 113–114, 125*b*, 126.	...do...	Sample records.

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
7	4	Sound plotting (demonstration and practical exercise).	Par. 96*f*, 116–117, 123–125.	Classroom.	Sound base fans, plotting board.
8	2	Correction charts (demonstration and practical exercise).	Par. 104, 115.	...do...	Correction charts and wind correction DA AGO Form 6–4.
9	4	Gridding plotting board (demonstration and practical exercise).	Par. 116*f*.	...do...	Plotting board, M1.
10	4	Command post exercise (practical exercise).	Par. 116..	Classroom or field.	Regular base and irregular base fan.
11	4	....do..........	....do....	...do...	Plotting board M1.

[1]P—period. [2]H—hours.

94. FIRST PERIOD

a. Objective. To discuss the organization and missions of the observation battalion.

b. Outline. Stress how the sound platoon fits into the organization of the battalion and how the platoon does its part in carrying out the overall missions of the battalion.

95. SECOND PERIOD

a. Objective. To show the organization of the sound platoon, its missions, and how each individual fits into the organization, and what he does in accomplishing the mission by his own action.

b. Outline. Discuss in detail the organization and mission of the sound platoon during the first part of this period. During the second part, cover the duties of the individual soldier in accomplishing the mission.

96. THIRD PERIOD

a. Objective. To demonstrate the operation of the sound platoon equipment.

b. Outline. Discuss in detail, during the demonstration, the primary purpose of each piece of equipment and in general how each part helps to accomplish the mission of the platoon.

97. FOURTH PERIOD

a. Objective. To give a basic background in sound by discussing the theory of sound ranging to include fundamentals of sound, sound travel and audibility, and principles of artillery sound ranging.

b. Outline. Stress fundamentals and basic concepts of sound ranging.

98. FIFTH PERIOD

a. Objective. To teach the different types of sound bases, the advantages and disadvantages of each type, and the methods and factors affecting the selection of each type.

b. Outline. Review the various elements of a sound ranging installation, and then discuss in detail the following:

(1) Length of bases.
(2) Type of bases.
(3) Comparison of bases.
(4) Direction of bases.
(5) Location of bases.
(6) Method of installation.
(7) Deliberate and hasty bases.

99. SIXTH PERIOD

a. Objective. To teach the procedures for interpreting and reading sound ranging records.

b. Discuss the purpose of the sound record; give a description of the sound record, the form for recording, and the relation of patterns to sound-source locations. Advance the class from elementary records to difficult records.

100. SEVENTH PERIOD

a. Objective. To teach the use of the regular and irregular base plotting fans.

b. Outline. Describe the regular and irregular base fans, their construction, and preparation of the plotting boards to use with them; follow up with practical work in using the fans.

101. EIGHTH PERIOD

a. Objective. To teach the theory of sound corrections and the necessity for those corrections.

b. Outline. Explain standard weather conditions; explain the application of corrections for wind, temperature, and curvature, and how to enter them on the form.

102. NINTH PERIOD

a. Objective. To teach the procedures for using prepared grids and for gridding the M1 board.

b. Outline. Explain the necessity for using grid sheets for plotting charts and how they are placed on the M1 board. Conduct a demonstration of gridding the M1 board, followed by a practical exercise for the class in gridding the board.

103. TENTH PERIOD

a. Objective. To form the section into a team by a command post exercise in which the regular and irregular base fans are used in plotting.

b. Outline. Explain the duties of each man in the section during the first part of the period; process a record slowly so each man sees exactly how he fits into the team. Assign duties and have the men process missions.

104. ELEVENTH PERIOD

a. Objective. To form the section into a team by a command post exercise using the M1 board.

b. Outline. Have the section process missions using the section equipment. Critique each position of the team.

105. SOUND PLATOON

(platoon phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	4	Command post exercise.	Par. 116–117.	Class-room.	Calculator and plotting board, M1.
2	4	....do..........	Par. 116*f*.	Field...	T/O & E equipment and 200 lbs. TNT and 50 electric caps.
3	8	Field exercise.	Par. 117..	...do...	T/O & E equipment and 400 lbs. TNT and 100 electric caps.

[1]P—period.
[2]H—hours.

106. FIRST PERIOD

a. Objective. To weld the members into an efficient operating team in the platoon by a command post exercise using the calculator method and M1 board.

b. Outline. Demonstrate the use of the calculator in speeding up a mission during the first part of the period. Have the platoon process missions. Try to develop accuracy and speed.

107. SECOND PERIOD

a. Objective. To teach the platoon to work as a team.

b. Outline. Have the platoon locate sound sources, process by standard methods, and report locations in a field exercise. (Use TNT to stimulate enemy guns.) Correct procedure should be checked along with accuracy and speed. Coordinate problem with battery.

108. THIRD PERIOD

a. Objective. To have a platoon field exercise.

b. Outline. Have the platoon install a hasty base and operate it and then expand to a deliberate base, emphasizing the use of special methods. Check on procedure and accuracy and try to increase speed in processing missions.

109. SOUND PLATOON

(battery phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Field exercise—sound locations.	Par. 95–126.	Field...	T/O & E equipment and one 155-mm howitzer section with 50 rds. of ammunition.
2	8	Field exercise—sound locations and adjustments.	....do....	...do...	Do.

[1]P—period.
[2]H—hours.

110. FIRST PERIOD

a. Objective. To coordinate the platoon into the battery team by a field exercise.

b. Outline. Coordinate this period with the battery in a tactical problem. The first part of the exercise should be devoted to use of the plotting fans and the latter portion to the M1 plotting board.

111. SECOND PERIOD

a. Objective. To coordinate the platoon into the battery team by a field exercise combining sound locations and adjustments.

b. Outline. Use the first part of the period to work on standard plotting methods and the second part to work on the calculator method.

112. SOUND PLATOON
(battalion phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Field exercise—sound locations.	Par. 95–126.	Field...	T/O & E equipment and one 155-mm howitzer section with 40 rds. of ammunition.
2	8	Field exercise—sound locations (calculator method).	....do....	...do...	Do.

[1]P—period.
[2]H—hours.

113. FIRST PERIOD

a. Objective. To have the platoon working through the battery in a tactical battalion field exercise.

b. Outline. Devote the entire period to standard plotting methods. Emphasize procedure, accuracy, and speed.

114. SECOND PERIOD

a. Objective. To have the platoon work as part of the battery in accomplishing the battalion missions in a tactical field exercise.

b. Outline. Devote the entire period to the calculator method.

115. OPERATIONS SECTION, FLASH PLATOON (section phase) (32 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization, missions, and principles of employment of the observation battalion (conference).	Par. 3–21	Classroom.	Blackboard.
2	2	Organization, missions, methods, and duties of personnel of the flash platoon (conference).	Par. 15, 127–130, 139.	...do...	Do.
3	1	Description of equipment (con-	Par. 129, 139, 142.	Classroom	Spotting scope, out-

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
		ference and demonstration).		or field.	post unit, switchboard. plotting board.
4	2	Flash spotting instrument (conference and practical exercise).	Par. 129	Field	Spotting scopes.
5	2	Flash switchboard (conference and practical exercise).	Par. 139	Classroom or field.	Switchboard.
6	2	Flash plotting board (conference and practical exercise).	Par. 142	...do...	M5 board.
7	2	Survey methods (conference).	Par. 132, 141.	Classroom.	Blackboard.
8	2	Types of plotting charts (demonstration).	Par. 134–135, 142.	...do...	M5 board, grid sheet, maps, air photos.
9	2	Operating procedure (conference and practical exercise).	Par. 136–137, 144–149.	...do...	Blackboard.
10	4	*Observers:* Care and operation of flash spotting instrument (conference and practical exercise).	Par. 129, 131, 139–140.	Field	Spotting scopes, 15 charges of smoke puffs, 30 percussion caps and 15 high-burst signals.

[1]P—period. [2]H—hours.

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P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
		Plotting central personnel: General plotting M5 board (conference and practical exercise).	Par. 134–135, 142.	Classroom or field.	M5 plotting board.
11	4	*Observers:* Flash spotting instrument (practical exercise).	Par. 129–131, 139–140.	Field. . .	Spotting scopes and 15 smoke puffs and 30 percussion caps.
		Plotting central personnel: Resection, three-point, M5 board (conference and practical exercise).	Par. 143. .	Classroom or field.	M5 plotting board.
12	4	Flash ranging exercise (miniature) using a deliberate installation (practical exercise).	Par. 139–144.	Field. . .	All flash equipment and 20 smoke puffs and 40 percussion caps.
13	4	Flash ranging exercise (miniature) using a rapid installation (practical exercise).	Par. 130–138.	. . .do. . .	Do.

[1]P—period. [2]H—hours.

116. FIRST PERIOD

a. Objective. To teach members of the flash platoon the organization of the observation battalion, its missions, and how they fit into the overall picture.

b. Outline. Discuss the organization of the battalion and its missions so that the soldier in the platoon will see exactly why he is needed in his job to carry out the missions and why the battalion is organized as it is.

117. SECOND PERIOD

a. Objective. To teach the organization of the flash platoon, its mission, its methods, and duties of each individual in the platoon.

b. Outline. Discuss how the platoon is formed, what it is trying to do, and what each member does to accomplish the mission.

118. THIRD PERIOD

a. Objective. To show the equipment of the flash ranging platoon with a brief discussion of each major item and a short demonstration of the entire platoon equipment in operation.

b. Outline. Start this discussion and demonstration with the spotting scope and outpost equipment, and work back from the OP through the flash switchboard to the plotting board.

119. FOURTH PERIOD

a. Objective. To teach the nomenclature, care, and use of the flash spotting instrument.

b. Outline. Stress the care and use of the instrument during the first half of this period, including setting up and the nomenclature of the principal parts. During the second half, have the section set the instruments up and practice reading the scales.

120. FIFTH PERIOD

a. Objective. To acquaint all the members of the platoon with the flash switchboard, including its nomenclature and operation.

b. Outline. Discuss the main parts of the switchboard after the men have set it up. The switchboard should then be put in operation, and each man should operate it for a short time.

121. SIXTH PERIOD

a. Objective. To show the set-up and operation of the M5 board, and to show the plotting equipment for a rapid flash ranging installation.

b. Outline. Set up and operate the M5 board during the first part of this period. Discuss the various parts of the board. Near the close of the period, compare the accuracy of plotting on the M5 board with that obtained using the plotting equipment for rapid installations.

122. SEVENTH PERIOD

a. Objective. To teach the various survey methods used in locating flash ranging bases for both rapid and deliberate installations.

b. Outline. Discuss location by traverse, resection for use with deliberate flash installations, and the various triangulation methods used for rapid installations.

123. EIGHTH PERIOD

a. Objective. To show the various types of plotting charts and methods of reporting targets including the use of the target grid.

b. Outline. Demonstrate the use of grid sheets, maps, and aerial photos as plotting charts. Also demonstrate the use of the target grid.

124. NINTH PERIOD

a. Objective. To teach the operating procedure including installation, observers, plotters, and switchboard operators.

b. Outline. Cover all phases of operating procedure very thoroughly and then conduct an exercise with members processing data back and forth until each member of the platoon can process missions with both accuracy and speed.

125. TENTH PERIOD

a. Objective.

(1) *Observers.* To give detailed instruction in the care and use of the flash spotting instrument.

(2) *Plotting central personnel.* To give the plotting section detailed work on the plotting board.

b. Outline.

(1) *Observers.* Discuss and demonstrate the nomenclature, care, and use of the flash spotting instrument. After the demonstration, the men should be required to take the instruments out of the cases,

set them up, measure angles, and set off azimuths on the instruments.

(2) *Plotting central personnel.* Review the nomenclature and use of the plotting board. After providing complete plotting data, have the plotters set up the board, plot the OP's, and run through several problems, including the reporting of data.

126. ELEVENTH PERIOD

a. Objective.

(1) *Observers.* To give additional practice in the care and use of instruments.

(2) *Plotting central personnel.* To give the plotters additional practice in the operation of the M5 board, including the solving of a three-point resection problem.

b. Outline.

(1) *Observers.* Have the observers set up the instruments, practice measuring angles, and practice setting off readings on the instruments.

(2) *Plotting central personnel.* Have the plotters set up the equipment and plot the location provided. Verify the location of the plotted OP's, and have the men go into a regular problem, obtaining locations and processing the data.

127. TWELFTH PERIOD

a. Objective. To drill all individuals in their duties and develop coordination in the platoon acting as a team on a miniature long base.

b. Outline. Conduct a field exercise in an area small enough so that all members of the team can see the complete set-up, yet large enough to have a reduced scale plot of OP's and target area. The instructor should have a detail to handle the smoke puffs and should require correct procedure in processing the missions fired.

128. THIRTEENTH PERIOD

a. Objective. To drill all individuals in their duties and coordinate the work of the platoon divided into teams for rapid installations on a miniature scale.

b. Outline. Same as paragraph 127*b*.

129. FLASH PLATOON

(platoon phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	4	Flash ranging exercise using a deliberate installation (practical exercise).	Par. 139..	Field...	All flash equipment and 20 smoke puffs and 40 percussion caps.
2	4	Flash ranging exercise using a rapid installation (practical exercise).	Par. 130..	...do...	Do.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
3	8	Flash ranging exercise using a deliberate installation (practical exercise).	Par. 139..	Field...	T/O & E equipment and one 105-mm howitzer section with 50 rds. of ammunition.

[1]P—period. [2]H—hours.

130. FIRST PERIOD

a. Objective. To train the platoon as a team on a deliberate flash installation.

b. Outline. Conduct a field exercise on terrain so selected that the various critical points are available for checking and control. Use smoke puffs to simulate firing. A critique should be held in the field following the problem.

131. SECOND PERIOD

a. Objective. To train the platoon as a team in operating rapid flash installations.

b. Outline. Conduct a field exercise on terrain so selected that the various critical points are available for checking and control. If possible, the targets on this field exercise should be the same as those used during the previous period. (This should be done to provide a comparison of the results.) Use smoke puffs to simulate firing. A critique should be held following the problem.

132. THIRD PERIOD

a. Objective. To train the platoon as a team to increase accuracy and speed in the operation of a deliberate flash installation.

b. Outline. Have the platoon conduct a registration, a location, and an adjustment using one section of a field artillery firing battery. If a gun section is not available, have a detail fire smoke puffs. The instructor should stress accuracy, speed, and correct procedure in the exercise and should critique the problem in the field.

133. FLASH PLATOON
(battery phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Flash ranging exercise using both rapid and deliberate installations (practical exercise).	Par. 130, 139.	Field...	T/O & E equipment and one 105-mm howitzer section with 40 rds. of ammunition.
2	8	Flash ranging exercise using a deliberate installation (practical exercise).	Par. 139..	...do...	Do.

[1]P—period.
[2]H—hours.

134. FIRST PERIOD

a. Objective. To conduct a battery field exercise in which the flash platoon is coordinated with the remainder of the battery.

b. Outline. Require the platoon to install a rapid flash installation and expand it to a deliberate flash installation. The instructor should coordinate this period with the battery in a tactical situation.

135. SECOND PERIOD

a. Objective. To train the platoon as an element of the battery team in a deliberate flash installation.

b. Outline. Require the platoon to install a deliberate flash installation. The instructor should coordinate this period with the battery in a tactical situation.

136. FLASH PLATOON
(battalion phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Field exercise—deliberate flash installation (practical exercise).	Par. 139, 143.	Field...	T/O & E equipment and one 105-mm howitzer section with 40 rds. of ammunition.
2	8	....do..........	Par. 130, 139.	...do...	Do.

[1]P—period.
[2]H—hours.

137. FIRST PERIOD

a. Objective. To train the platoon as a part of the battalion team in deliberate flash installation.

b. Outline. Conduct a field exercise requiring a battalion to establish a deliberate flash installation. Coordinate the flash platoon with the battery in the battalion tactical situation; if possible, have the OP's locate themselves by resection.

138. SECOND PERIOD

a. Objective. To train the platoon in the battalion team in establishing a rapid flash installation and expanding it to a deliberate flash installation.

b. Outline. Conduct a field exercise requiring the platoon to establish a rapid flash installation and expand it into a deliberate flash installation. Coordinate the platoon with the battery in the battalion tactical situation.

139. RADAR PLATOON
(section phase) (40 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	1	Organization and mission of the observation battalion and batteries (conference).	Par. 10–15.	Classroom.	Blackboard.
2	1	Organization and mission of radar platoon and section (conference).	Par. 151, 153.	...do...	Do.
3	2	Plotting central operation (dem-	Par. 153, 162–163.	Battery area.	T/O & E equipment.

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
		onstration and practical exercise).			
4	4	Individual duties in emplacement, start-stop, and march order (demonstration and practical exercise).	Par. 153, 160–163.	Battery area.	T/O & E equipment.
5	2	Plotting central operation (practical exercise).	Par. 153, 162–163.	...do...	Do.
6	2	Individual duties in emplacement, start-stop, and march order (practical exercise).	Par. 153, 160–163.	...do...	Do.
7	4	Mortar location (field exercise).	Par. 158–160, 162–163.	Field...	T/O & E equipment and one mortar w/ crew and 60 rds. of ammunition.
8	8	....do..........	....do....	...do...	T/O & E equipment and one mortar w/ crew and 100 rds. of ammunition.
9	8	Howitzer location (field exercise).	....do....	...do...	T/O & E equipment

[1]P—period. [2]H—hours.

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
					and one 105-mm howitzer w/crew and 75 rds. of ammunition.
10	4	Registration and adjustment of friendly artillery (field exercise).	Par. 164–165.	...do...	T/O & E equipment and one 105-mm howitzer w/crew and 40 rds. of ammunition.
11	4	Battlefield surveillance (field exercise).	Par. 166...	Area where frequently traveled road is within sight.	T/O & E equipment.

[1]P—period.
[2]H—hours.

140. FIRST PERIOD

a. Objective. To familiarize the personnel of the radar section with the organization and mission of the observation battalion and its batteries.

b. Outline. Show graphically the various organizations of the battalion and batteries, and explain how they work together to accomplish the missions of the battalion.

141. SECOND PERIOD

a. Objective. To teach the personnel of the radar section the organization and mission of the radar platoons and sections.

b. Outline. Show the elements of the platoons and sections, and explain what each man does in weapon location.

142. THIRD PERIOD

a. Objective. To teach the functioning of the personnel of the plotting central as a team.

b. Outline. Demonstrate each man's duty, and then have the group practice as a team, using predetermined data.

143. FOURTH PERIOD

a. Objective. To review individual duties of the members of the radar section, and to show the men how to work together.

b. Outline. Demonstrate each man's duties; require individual practice to improve individual skills.

144. FIFTH PERIOD

a. Objective. To improve individual skills in operating the plotting central.

b. Outline. Practice operating as a team, using predetermined data.

145. SIXTH PERIOD

a. Objective. To gain skill in individual duties in emplacement, start-stop, and march order.

b. Outline. Practice emplacing, starting, stopping, and march order with a radar.

146. SEVENTH PERIOD

a. Objective. To teach and practice pickup, tracking, plotting, and plot interpretation procedure in locating mortars.

b. Outline. Conduct a field exercise in which the radar section practices mortar location using a mortar firing live ammunition.

147. EIGHTH PERIOD

Same as paragraph 146.

148. NINTH PERIOD

a. Objective. To teach and practice pickup, tracking, plotting, and plot interpretation procedure in locating howitzers.

b. Outline. Conduct a field exercise in which the radar section practices locating a howitzer firing live ammunition.

149. TENTH PERIOD

a. Objective. To teach the techniques and procedures required to register and adjust friendly artillery.

b. Outline. Conduct a field exercise in which the radar section practices registering and adjusting the actual fire of a howitzer.

150. ELEVENTH PERIOD

a. Objective. To teach the techniques and procedure of locating moving ground targets.

b. Outline. Conduct a field exercise in which the radar section carries on surveillance of a frequently traveled road or roads and reports traffic movements thereon.

151. RADAR PLATOON

(battery phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Field exercise including fire adjustment.	Par. 32–41, 164–165.	Field...	One 105-mm howitzer, 80 rds., skeleton FDC.
2	8	Field exercise in weapon location to include a forward displacement.	Par. 32–41, 160–163.	...do...	One 105-mm howitzer, 80 rds.

[1]P—period.
[2]H—hours.

152. FIRST PERIOD

a. Objective. To teach the operation of the observation battery as a team.

b. Outline. Include the following:

(1) Selection and occupation of position.

(2) Survey location of all battery elements.

(3) Adjustment of fire by radar.

(4) Communications exercise stressing the means and nets available in the battery.

153. SECOND PERIOD

a. Objective. To teach the operation of the observation battery as a team.

b. Outline. Include the following:

(1) Selection and occupation of position.
(2) Survey location of all battery elements.
(3) Location of hostile artillery by radar.
(4) Forward displacement by echelon.

154. RADAR PLATOON (battalion phase) (16 hrs.)

P[1]	H[2]	Subject	Text references	Area	Training aids and equipment
1	8	Battalion RSOP to include fire adjustment (field exercise).	Par. 32–41, 164–165.	Field...	One 105-mm howitzer, 80 rds. HE, skeleton FDC.
2	8	Battalion RSOP to include weapon location and forward displacement (field exercise).	Par. 32–41, 160–163.	...do...	One 105-mm howitzer, 80 rds. HE.

[1]P—period.
[2]H—hours.

155. FIRST PERIOD

a. Objective. To teach the tactical employment of the observation battalion.

b. Outline. Include the following:

(1) Selection and occupation of position.
(2) Survey location of all elements of the battalion.

(3) Adjustment of fire by radar.
(4) Communications exercise.

156. SECOND PERIOD

a. Objective. To teach the tactical employment of the observation battalion.

b. Outline. Include the following:

(1) Selection and occupation of position.
(2) Survey location of all elements of the battalion.
(3) Location of hostile artillery by radar.
(4) Communications exercise.
(5) Forward displacement.

APPENDIX III
REFERENCE DATA

1. GENERAL

Azimuths and angles of site must be measured accurately in order to obtain acceptable locations or adjustments. It is necessary that intruments be in adjustment or that the error of the instrument be known and a correction applied. The adjustment of transits or observing instruments may be made or the error may be determined by methods described in TM 5–235. An instrument can be checked by comparison with other instruments, by multiple measurement of the same angle, or by closing the horizon, as discussed in chapter 6.

2. ANGLE-OF-SITE ADJUSTMENT

a. Since cross-country movement makes it difficult to keep instruments in adjustment the angle-of-site adjustment, must be made frequently. The adjustment can be made by the "peg" method described in TM 5–235.

b. A quick method of checking the angle-of-site error in an instrument is by calibration as follows:

(1) Two instruments, A and B, are set up at approximately the same height, facing each other with their objective lenses about 2 feet apart, and adjusted so that the cross hairs of each instrument can be seen in the other. The bubbles are carefully leveled, and a reading is taken

on each instrument to the horizontal cross hair of the other. If the two instruments are in perfect adjustment, the readings will be the same. If the readings are different, their algebraic sum is the algebraic sum of the errors in the two instruments. Both instruments are then laid on the same distant object and the angle of site to this distant object is read on each instrument. The difference between these two readings is the algebraic difference of the errors of the two instruments. Having found the algebraic sum and the algebraic difference of the two errors, these errors may be determined by solution of a pair of algebraic equations, as illustrated in the example in (2) below.

(2) Let a be the error in instrument A, and b the error in instrument B. When reading on the horizontal cross hair of the other, instrument A reads —6 mils, and instrument B reads 0 mils.

Then: $a + b = -6$ mils (1)

When reading to the distant object, A reads 45 mils and B reads 43 mils.

Then: $a - b = +2$ mils (2)

Adding equations (1) and (2):

$$2a = -4$$

$$a = -2 \text{ mils}$$

Substitutions of this value of a in either (1) or (2) gives:

$$b = -4 \text{ mils}$$

(3) This means that the vertical angle scale of instrument A reads 2 mils too low. The correction to be applied to any angle of site measured by this instrument is therefore + 2 mils. Similarly, the correction for instrument B is + 4 mils.

(4) The error found for each instrument and the instrument number should be reported to the plotting central. Care must be taken to avoid confusing the instrument error with the correction. In the example, instrument A has an *error* of —2 mils; the *correction* is + mils.

c. Before departing for the observation post, each observer will, if time permits, ascertain his instrument error by the method described above. If possible, instrument adjustment will be performed independently by each observer, and the results will be compared.

3. MOUNTING DRAWING PAPER ON IMPROVISED SOUND RANGING PLOTTING BOARD

The drawing board on which paper is to be mounted should be 3/4-inch plywood or 3/4-inch hardwood, reinforced by strips on the back to prevent warping. All varnish or shellac is removed from the top surface, the edges, and from a 3-inch margin all the way around the back surface of the board; these surfaces are then smoothed with a fine grade of sandpaper. A good grade of fine-grained (high-surfaced) drawing paper (medium thickness) is cut to a size 6 inches larger in length and width than the board. The paper is saturated with water and allowed to stand about 5 minutes. The surplus water is then wiped off. The prepared surface of the board is dampened and covered with a thin coat of good glue. The wet paper is placed on and stretched over the board, and the edges turned over, saw-toothed, and glued to the edges and back of the board. Thus, the drawing paper is glued to the board at every point. The board is then weighted down to hold the paper in position until dry (about 48 hours).

4. LAYING OFF TIME SCALES FOR SOUND PLOTTING ON IMPROVISED PLOTTING BOARD

A convenient way to lay off time scales for sound plotting is by the tangent method. Tables for this purpose are included in appendix VII. Similar tables may be made up for other lengths of subbases by determining from trigonometric tables the tangents of the angles D whose sines are equal to t/s for various values of t. To lay off a time scale for a subbase M_1M_2 (fig. 147), the perpendicular bisector CO of the subbase is drawn. An arc, along which the time scale graduations are to be drawn, is constructed at a convenient place. This arc is not necessarily concentric about C. At K, a convenient distance from C (for example, 10,000 meters at the scale of the plot), a line KE is drawn perpendicular to CO. To lay off the graduation for a time interval t, the corresponding tangent is found in the proper table. This tangent is multiplied by the distance CK (10,000 meters) and the resulting distance is scaled off from K along the line KE. Points are located to the right for positive values t, and to the left for negative values of t. A straightedge is laid from C to each point so located on KE, and the line extended to locate a corresponding point are the arc. Referring to figure 147, the subbase s is 4 sound-seconds. Assuming a time interval t of 1 second, tan D, from table XVI in appendix VII, is 0.25820. If CK is 10,000 meters, the point for $t =$ + is laid off $0.25820 \times 10{,}000 = 2582.0$ meters at the scale of the plot, along KE to the right of K. This point, projected in line with C to the arc, locates the graduation for $t = +1$ second. Graduations for

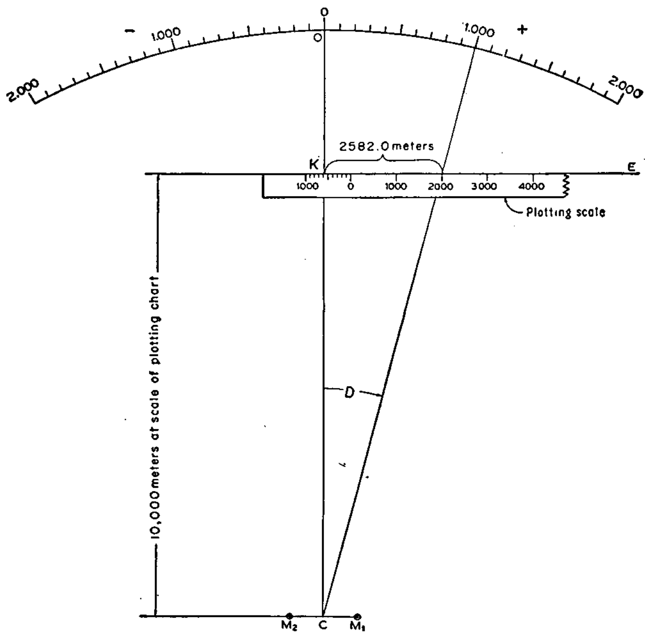

Figure 147. Laying off time scales.

other values of t are located in a similar manner; positive time intervals are laid off to the right of K; negative time intervals, to the left of K. After completing graduations corresponding to the time intervals listed in the tables, the scales are further subdivided by interpolation, usually to one-hundredth-second intervals.

5. FORMULAS FOR SOLUTION OF RIGHT TRIANGLES

In the right triangle ABC (fig. 148):

$$c^2 = a^2 + b^2$$

$$\text{sine (sin) } A = \frac{a}{c} = \cos B$$

$$\text{cosine (cos) } A = \frac{b}{c} = \sin B$$

$$\text{tangent (tan) } A = \frac{a}{b} = \cot B$$

$$\text{cotangent (cot) } A = \frac{b}{a} = \tan B$$

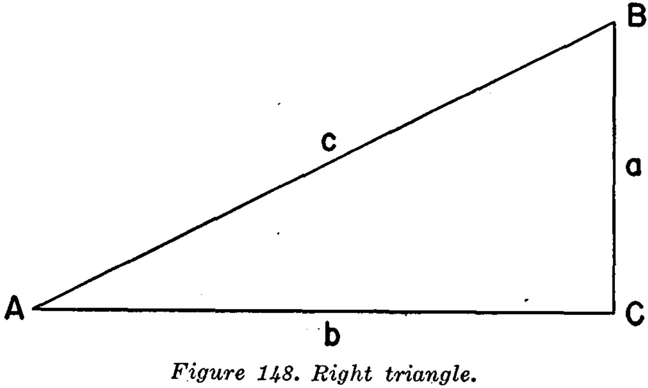

Figure 148. Right triangle.

6. FORMULAS FOR SOLUTION OF OBLIQUE TRIANGLES

In the oblique triangle ABC (fig. 149):

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \text{ (law of sines)}$$

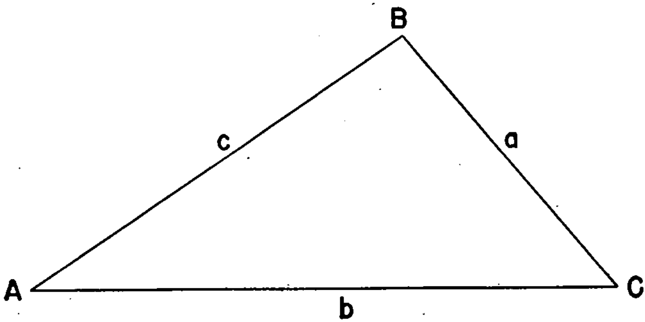

Figure 149. Oblique triangle.

$$c^2 = a^2 + b^2 - 2ab \cos C \text{ (law of cosines)}$$

$$\frac{a - b}{a + b} = \frac{\tan \frac{1}{2} (A - B)}{\tan \frac{1}{2} (A + B)} \text{ (law of tangents)}$$

$$\tan A = \frac{a \sin C}{b - (a \cos C)} \text{ (short tangent formula)}$$

7. FORMULAS FOR SOLUTION OF ASTRONOMIC TRIANGLES

In the astronomic triangle North celestial pole — Zenith — sun (fig. 48):

$$\tan \tfrac{1}{2} A = \sqrt{\frac{\sin (s - h) \sin (s - \text{latitude})}{\cos s \cos (s - p)}}$$

(altitude method)

$$\tan A = \frac{\sin t}{\cos \text{lat.} \tan \text{decl.} - \sin \text{lat.} \cos t} \quad \text{(hour angle method)}$$

where O = position of observer
Z = zenith
S = position of celestial body
A = azimuth to celestial body (east or west of true north)
h = altitude of celestial body
p = polar distance (90° − declination)
$s = \frac{1}{2}$ (latitude + h + p)
t = hour angle of celestial body in arc

8. FUNCTIONS OF ANGLES

Functions of angles in any quadrant in terms of angles in the first quadrant are given in the following table (b stands for Bearing):

	$-b$	$90° \pm b$	$180° \pm b$	$270° \pm b$
sin	$-\sin b$	$+\cos b$	$\mp \sin b$	$-\cos b$
cos	$+\cos b$	$\mp \sin b$	$-\cos b$	$\pm \sin b$
tan	$-\tan b$	$\mp \cot b$	$\pm \tan b$	$\mp \cot b$
cot	$-\cot b$	$\mp \tan b$	$\pm \cot b$	$\mp \tan b$

9. APPEARANCE OF OBJECTS AT DIFFERENT DISTANCES

a. An object appears nearer—

(1) When looking over water, or over a large

ravine or depression.

(2) When the sun is behind the observer.

(3) When air is clear, especially after a rain.

(4) When the background is in contrast with the color of the object.

(5) When using field glasses.

(6) When trees are leafless, as in winter.

(7) When trees or branches are silhouetted against a clear skyline or contrasting background.

b. An object appears more distant—

(1) When looking over rolling country.

(2) When the sun is in front of the observer.

(3) When air is not clear due to fog, smoke, rain, etc.

(4) When background is similar in color to that of an object.

(5) On hot days, especially when the ground is moist, an object will appear more distant if observed from a kneeling or sitting position. (Owing to heat radiation.)

c. Objects appear as indicated at ranges (in yards) of—

Range in yards	Trees	Troops	Buildings
1,000	Minor branches distinguishable. Foliage blends into cluster-like shapes with sky as background; daylight can be seen through the branches.	. . . .	

Range in yards	Trees	Troops	Buildings
1,200	....	Infantry column can be distinguished.	Sign posts and national insignias distinguishable.
1,500	Foliage densely clustered, presenting a rough surface. Outlines of large branch or group of branches distinguishable.	Dismounted, in small masses; mounted outlines of horses become distinguishable. Vehicles in column distinguishable.	
3,000	Lower half of trunks visible; main branches blend with foliage.	Truck columns and horse-drawn artillery can be distinguished.	
4,000	Trunks blend with foliage; surface of clusters smooth.	....	Ordinary houses distinguishable.
5,000	Entire area covered by trees appears like a bushy area at about 100 yards, except that surface is smoother and blacker.	....	Ordinary factory chimneys and steel water towers become distinguishable.
16,000	....	....	Churches, castles, and prominent buildings distinguishable.

APPENDIX IV

CONVERSION FACTORS AND CONVERSION TABLES

Table I. Conversion Factors

To convert	To	Multiply by	Logarithm
Degrees (angle)	Grads	1.1111111	0.045 7575
Degrees	Mils	17.777778	1.249 8775
Feet	Meters	0.30480061	9.484 0158
Feet	Miles	0.00018939	6.277 3661
Feet	Sound-seconds	0.00090285	6.955 6171
Gallons (Imperial)	Gallons (U. S.)	1.2009	0.079 5219
Gallons (U. S.)	Gallons (Imperial)	0.83268	9.920 4781
Gallons	Liters	3.7853	0.578 1040
Gallons	Ounces (fluid)	128	2.107 2100
Gallons	Pints	8	0.903 0900
Grads	Degrees	0.9	9.954 2425
Grads	Mils	16	1.204 1200
Grads	Minutes	54	1.732 3938
Grads	Seconds	3240	3.510 5450
Grams	Ounces (Av.)	0.035274	8.547 4537
Grams	Pounds (Av.)	0.0022046	7.343 3337
Inches	Millimeters	25.400	1.404 8346
Inches of mercury	Millibars	33.864	1.529 7377
Liters	Gallons (U. S.)	0.26418	9.421 9860
Liters	Ounces (fluid)	33.815	1.529 1060
Liters	Pints	2.1134	0.324 9860
Meters	Feet	3.2808333	0.515 9842
Meters	Miles	0.00062137	6.793 3502
Meters	Sound-seconds	0.0029621	7.471 6012
Meters	Yards	1.0936111	0.038 8629

To convert	To	Multiply by	Logarithm
Meters per second	Miles per hour . . .	2.2369	0.349 6527
Miles.	Feet.	5280	3.722 6339
Miles.	Meters.	1609.3	3.206 6498
Miles.	Sound-seconds . . .	4.7671	0.678 2510
Miles.	Yards.	1760	3.245 5127
Miles per hour. . .	Meters per second	0.44704	9.650 3473
Miles.	Yards per second.	0.48889	9.689 2102
Millibars.	Inches of mercury	0.029530	8.470 2623
Millibars.	Millimeters of mercury	0.75006	9.875 0969
Millimeters.	Inches.	0.03937	8.595 1654
Millimeters of mercury	Millibars.	1.3332	0.124 9031
Mils.	Degrees.	0.05625	8.750 1225
Mils.	Grads.	0.0625	8.795 8800
Mils.	Minutes.	3.375	0.528 2738
Mils.	Seconds.	202.5	2.306 4250
Minutes (angle) . .	Grads.	0.018518519	8.267 6062
Minutes.	Mils.	0.29629630	9.471 7262
Ounces (weight, Av.)	Grams.	28.350	1.452 5463
Ounces (fluid). . . .	Gallons.	0.0078125	7.892 7900
Ounces.	Liters.	0.029573	8.470 8940
Ounces.	Pints.	0.0625	8.795 8800
Pints.	Gallons.	0.125	9.096 9100
Pints.	Liters.	0.47317	9.675 0140
Pints.	Ounces (fluid). . . .	16	1.204 1200
Pounds (Av.). . . .	Grams.	453.59	2.656 6663
Seconds (angle). . .	Grads.	0.00030864198	6.489 4550
Seconds.	Mils.	0.0049382716	7.693 5750
Sound-seconds . . .	Feet.	1107.6	3.044 3829
Sound.	Meters.	337.60	2.528 3988
Sound.	Miles.	0.20977	9.321 7490

To convert	To	Multiply by	Logarithm
Sound...........	Yards...........	369.2	2.567 2617
Yards...........	Meters..........	0.91440183	9.961 1371
Yards...........	Miles...........	0.00056818	6.754 4873
Yards...........	Sound-seconds...	0.0027086	7.432 7383
Yards per second.	Miles per hour...	2.0455	0.310 7898

Table II. Conversion of Mils to Degrees, Minutes, and Seconds

Hundreds of mils

Mils	Degrees	Mils	Degrees	Mils	Degrees
100	05°37′30″	800	45°00′00″	1,500	84°22′30″
200	11°15′00″	900	50°37′30″	1,600	90°00′00″
300	16°52′30″	1,000	56°15′00″		
400	22°30′00″	1,100	61°52′30″	3,200	180°00′00″
500	28°07′30″	1,200	67°30′00″	4,800	270°00′00″
600	33°45′00″	1,300	73°07′30″	6,400	360°00′00″
700	39°22′30″	1,400	78°45′00″		

Tens and units

Mils	Degrees	Mils	Degrees	Mils	Degrees
1	00°03′22″	36	02°01′30″	71	03°59′38″
2	00°06′45″	37	02°04′52″	72	04°03′00″
3	00°10′08″	38	02°08′15″	73	04°06′22″
4	00°13′30″	39	02°11′38″	74	04°09′45″
5	00°16′52″	40	02°15′00″	75	04°13′08″
6	00°20′15″	41	02°18′22″	76	04°16′30″
7	00°23′38″	42	02°21′45″	77	04°19′52″
8	00°27′00″	43	02°25′08″	78	04°23′15″
9	00°30′22″	44	02°28′30″	79	04°26′38″
10	00°33′45″	45	02°31′52″	80	04°30′00″
11	00°37′08″	46	02°35′15″	81	04°33′22″
12	00°40′30″	47	02°38′38″	82	04°36′45″
13	00°43′52″	48	02°42′00″	83	04°40′08″
14	00°47′15″	49	02°45′22″	84	04°43′30″
15	00°50′38″	50	02°48′45″	85	04°46′52″

Mils	Degrees	Mils	Degrees	Mils	Degrees
16	00°54′00″	51	02°52′08″	86	04°50′15″
17	00°57′22″	52	02°55′30″	87	04°53′38″
18	01°00′45″	53	02°58′52″	88	04°57′00″
19	01°04′08″	54	03°02′15″	89	05°00′22″
20	01°07′30″	55	03°05′38″	90	05°03′45″
21	01°10′52″	56	03°09′00″	91	05°07′08″
22	01°14′15″	57	03°12′22″	92	05°10′30″
23	01°17′38″	58	03°15′45″	93	05°13′52″
24	01°21′00″	59	03°19′08″	94	05°17′15″
25	01°24′22″	60	03°22′30″	95	05°20′38″
26	01°27′45″	61	03°25′52″	96	05°24′00″
27	01°31′08″	62	03°29′15″	97	05°27′22″
28	01°34′30″	63	03°32′38″	98	05°30′45″
29	01°37′52″	64	03°36′00″	99	05°34′08″
30	01°41′15″	65	03°39′22″	100	05°37′30″
31	01°44′38″	66	03°42′45″		
32	01°48′00″	67	03°46′08″		
33	01°51′22″	68	03°49′30″		
34	01°54′45″	69	03°52′52″		
35	01°58′08″	70	03°56′15″		

Tenths and hundredths

Mils	Degrees	Mils	Degrees	Mils	Degrees
0.01	00°00′02″	0.36	00°01′13″	0.71	00°02′24″
0.02	00°00′04″	0.37	00°01′15″	0.72	00°02′26″
0.03	00°00′06″	0.38	00°01′17″	0.73	00°02′28″
0.04	00°00′08″	0.39	00°01′19″	0.74	00°02′30″
0.05	00°00′10″	0.40	00°01′21″	0.75	00°02′32″
0.06	00°00′12″	0.41	00°01′23″	0.76	00°02′34″
0.07	00°00′14″	0.42	00°01′25″	0.77	00°02′36″
0.08	00°00′16″	0.43	00°01′27″	0.78	00°02′38″
0.09	00°00′18″	0.44	00°01′29″	0.79	00°02′40″
0.10	00°00′20″	0.45	00°01′31″	0.80	00°02′42″

Mils	Degrees	Mils	Degrees	Mils	Degrees
0.11	00°00′22″	0.46	00°01′33″	0.81	00°02′44″
0.12	00°00′24″	0.47	00°01′35″	0.82	00°02′46″
0.13	00°00′26″	0.48	00°01′37″	0.83	00°02′48″
0.14	00°00′28″	0.49	00°01′39″	0.84	00°02′50″
0.15	00°00′30″	0.50	00°01′41″	0.85	00°02′52″
0.16	00°00′32″	0.51	00°01′43″	0.86	00°02′54″
0.17	00°00′34″	0.52	00°01′45″	0.87	00°02′56″
0.18	00°00′36″	0.53	00°01′47″	0.88	00°02′58″
0.19	00°00′38″	0.54	00°01′49″	0.89	00°03′00″
0.20	00°00′40″	0.55	00°01′51″	0.90	00°03′02″
0.21	00°00′43″	0.56	00°01′53″	0.91	00°03′04″
0.22	00°00′45″	0.57	00°01′55″	0.92	00°03′06″
0.23	00°00′47″	0.58	00°01′57″	0.93	00°03′08″
0.24	00°00′49″	0.59	00°01′59″	0.94	00°03′10″
0.25	00°00′51″	0.60	00°02′02″	0.95	00°03′12″
0.26	00°00′53″	0.61	00°02′04″	0.96	00°03′14″
0.27	00°00′55″	0.62	00°02′06″	0.97	00°03′16″
0.28	00°00′57″	0.63	00°02′08″	0.98	00°03′18″
0.29	00°00′59″	0.64	00°02′10″	0.99	00°03′20″
0.30	00°01′01″	0.65	00°02′12″	1.00	00°03′22″
0.31	00°01′03″	0.66	00°02′14″		
0.32	00°01′05″	0.67	00°02′16″		
0.33	00°01′07″	0.68	00°02′18″		
0.34	00°01′09″	0.69	00°02′20″		
0.35	00°01′11″	0.70	00°02′22″		

Table III. Conversion of Degrees, Minutes and Seconds to Mils

Degrees to mils

Degrees	Mils	Degrees	Mils	Degrees	Mils
1	17.78	36	640.00	71	1,262.22
2	35.56	37	657.78	72	1,280.00
3	53.33	38	675.56	73	1,297.78
4	71.11	39	693.33	74	1,315.56
5	88.89	40	711.11	75	1,333.33

948797°—51—31

Degrees	Mils	Degrees	Mils	Degrees	Mils
6	106.67	41	728.89	76	1,351.11
7	124.44	42	746.67	77	1,368.89
8	142.22	43	764.44	78	1,386.67
9	160.00	44	782.22	79	1,404.44
10	177.79	45	800.00	80	1,422.22
11	195.56	46	817.78	81	1,440.00
12	213.33	47	835.56	82	1,457.78
13	231.11	48	853.33	83	1,475.56
14	248.89	49	871.11	84	1,493.33
15	266.67	50	888.89	85	1,511.11
16	284.44	51	906.67	86	1,528.89
17	302.22	52	924.44	87	1,546.67
18	320.00	53	942.22	88	1,564.44
19	337.78	54	960.00	89	1,582.22
20	355.56	55	977.78	90	1,600.00
21	373.33	56	995.56		
22	391.11	57	1,013.33		
23	408.89	58	1,031.11		
24	426.67	59	1,048.89		
25	444.44	60	1,066.67		
26	462.22	61	1,084.44		
27	480.00	62	1,102.22		
28	497.78	63	1,120.00	180	3,200.00
29	515.56	64	1,137.78	270	4,800.00
30	533.33	65	1,155.56	360	6,400.00
31	551.11	66	1,173.33		
32	568.89	67	1,191.11		
33	586.67	68	1,208.89		
34	604.44	69	1,226.67		
35	622.22	70	1,244.44		

Minutes to mils

Minutes	Mils	Minutes	Mils	Minutes	Mils
1	0.30	21	6.22	41	12.15
2	0.59	22	6.52	42	12.44
3	0.89	23	6.81	43	12.74
4	1.19	24	7.11	44	13.04
5	1.48	25	7.41	45	13.33
6	1.78	26	7.70	46	13.63
7	2.07	27	8.00	47	13.93
8	2.37	28	8.30	48	14.22
9	2.67	29	8.59	49	14.52
10	2.96	30	8.89	50	14.81
11	3.26	31	9.19	51	15.11
12	3.56	32	9.48	52	15.41
13	3.85	33	9.78	53	15.70
14	4.15	34	10.07	54	16.00
15	4.44	35	10.37	55	16.30
16	4.74	36	10.67	56	16.59
17	5.04	37	10.96	57	16.89
18	5.33	38	11.26	58	17.19
19	5.63	39	11.56	59	17.48
20	5.93	40	11.85	60	17.78

Seconds to mils

Seconds	Mils	Seconds	Mils	Seconds	Mils
2	0.01	22	0.11	42	0.21
4	0.02	24	0.12	44	0.22
6	0.03	26	0.13	46	0.23
8	0.04	28	0.14	48	0.24
10	0.05	30	0.15	50	0.25
12	0.06	32	0.16	52	0.26
14	0.07	34	0.17	54	0.27
16	0.08	36	0.18	56	0.28
18	0.09	38	0.19	58	0.29
20	0.10	40	0.20	60	0.30

Table IV. Conversion of Yards to Meters

Yards	Meters	Yards	Meters	Yards	Meters
100	91.44	3,600	3,291.85	7,100	6,492.25
200	182.88	3,700	3,383.29	7,200	6,583.69
300	274.32	3,800	3,474.73	7,300	6,675.13
400	365.76	3,900	3,566.17	7,400	6,766.57
500	457.20	4,000	3,657.61	7,500	6,858.01
600	548.64	4,100	3,749.05	7,600	6,949.45
700	640.08	4,200	3,840.49	7,700	7,040.89
800	731.52	4,300	3,931.93	7,800	7,132.33
900	822.96	4,400	4,023.37	7,900	7,223.77
1,000	914.40	4,500	4,114.81	8,000	7,315.21
1,100	1,005.84	4,600	4,206.25	8,100	7,406.65
1,200	1,097.28	4,700	4,297.69	8,200	7,498.09
1,300	1,188.72	4,800	4,389.13	8,300	7,589.54
1,400	1,280.16	4,900	4,480.57	8,400	7,680.98
1,500	1,371.60	5,000	4,572.01	8,500	7,772.42
1,600	1,463.04	5,100	4,663.45	8,600	7,863.86
1,700	1,554.48	5,200	4,754.89	8,700	7,955.30
1,800	1,645.92	5,300	4,846.33	8,800	8,046.74
1,900	1,737.36	5,400	4,937.77	8,900	8,138.18
2,000	1,828.80	5,500	5,029.21	9,000	8,229.62
2,100	1,920.24	5,600	5,120.65	9,100	8,321.06
2,200	2,011.68	5,700	5,212.09	9,200	8,412.50
2,300	2,103.12	5,800	5,303.53	9,300	8,503.94
2,400	2,194.56	5,900	5,394.97	9,400	8,595.38
2,500	2,286.00	6,000	5,486.41	9,500	8,686.82
2,600	2,377.44	6,100	5,577.85	9,600	8,778.26
2,700	2,468.88	6,200	5,669.29	9,700	8,869.70
2,800	2,560.33	6,300	5,760.73	9,800	8,961.14
2,900	2,651.77	6,400	5,852.17	9,900	9,052.58
3,000	2,743.21	6,500	5,943.61	10,000	9,144.02
3,100	2,834.65	6,600	6,035.05		
3,200	2,926.09	6,700	6,126.49		
3,300	3,017.53	6,800	6,217.93		
3,400	3,108.97	6,900	6,309.37		
3,500	3,200.41	7,000	6,400.81		

Example: Find the number of meters corresponding to 7,391.40 yards.

7,300	yards	=	6,675.13	meters
91	yards	=	83.21	meters
0.40	yards	=	0.37	meters
7,391.40	yards	=	6,758.71	meters

Table V. Conversion of Meters to Yards

Meters	Yards	Meters	Yards	Meters	Yards
100	109.36	3,600	3,937.00	7,100	7,764.64
200	218.72	3,700	4,046.36	7,200	7,874.00
300	328.08	3,800	4,155.72	7,300	7,983.36
400	437.44	3,900	4,265.08	7,400	8,092.72
500	546.81	4,000	4,374.44	7,500	8,202.08
600	656.17	4,100	4,483.81	7,600	8,311.44
700	765.53	4,200	4,593.17	7,700	8,420.81
800	874.89	4,300	4,702.53	7,800	8,530.17
900	984.25	4,400	4,811.89	7,900	8,639.53
1,000	1,093.61	4,500	4,921.25	8,000	8,748.89
1,100	1,202.97	4,600	5,030.61	8,100	8,858.25
1,200	1,312.33	4,700	5,139.97	8,200	8,967.61
1,300	1,421.69	4,800	5,249.33	8,300	9,076.97
1,400	1,531.06	4,900	5,358.69	8,400	9,186.33
1,500	1,640.42	5,000	5,468.06	8,500	9,295.69
1,600	1,749.78	5,100	5,577.42	8,600	9,405.06
1,700	1,859.14	5,200	5,686.78	8,700	9,514.42
1,800	1,968.50	5,300	5,796.14	8,800	9,623.78
1,900	2,077.86	5,400	5,905.50	8,900	9,733.14
2,000	2,187.22	5,500	6,014.86	9,000	9,842.50
2,100	2,296.58	5,600	6,124.22	9,100	9,951.86
2,200	2,405.95	5,700	6,233.58	9,200	10,061.22
2,300	2,515.31	5,800	6,342.94	9,300	10,170.58
2,400	2,624.67	5,900	6,452.31	9,400	10,279.94
2,500	2,734.03	6,000	6,561.67	9,500	10,389.31
2,600	2,843.39	6,100	6,671.03	9,600	10,498.67
2,700	2,952.75	6,200	6,780.39	9,700	10,608.03
2,800	3,062.11	6,300	6,889.75	9,800	10,717.39

Meters	Yards	Meters	Yards	Meters	Yards
2,900	3,171.47	6,400	6,999.11	9,900	10,826.75
3,000	3,280.83	6,500	7,108.47	10,000	10,936.11
3,100	3,390.19	6,600	7,217.83		
3,200	3,499.56	6,700	7,327.19		
3,300	3,608.92	6,800	7,436.56		
3,400	3,718.28	6,900	7,545.92		
3,500	3,827.64	7,000	7,655.28		

Example: Find the number of yards corresponding to 6758.71 meters.

$$\begin{array}{rl} 6{,}700 \text{ meters} = & 7{,}327.19 \text{ yards} \\ 58 \text{ meters} = & 63.43 \text{ yards} \\ 0.71 \text{ meters} = & 0.78 \text{ yards} \\ \hline 6{,}758.71 \text{ meters} = & 7{,}391.40 \text{ yards} \end{array}$$

Table VI. Conversion of Yards to Sound-seconds

Yards	Seconds	Yards	Seconds	Yards	Seconds
100	0.271	3,600	9.751	7,100	19.231
200	0.542	3,700	10.022	7,200	19.502
300	0.813	3,800	10.293	7,300	19.772
400	1.083	3,900	10.563	7,400	20.043
500	1.354	4,000	10.834	7,500	20.314
600	1.625	4,100	11.105	7,600	20.585
700	1.896	4,200	11.376	7,700	20.856
800	2.167	4,300	11.647	7,800	21.127
900	2.438	4,400	11.918	7,900	21.398
1,000	2.709	4,500	12.189	8,000	21.668
1,100	2.979	4,600	12.459	8,100	21.939
1,200	3.250	4,700	12.730	8,200	22.210
1,300	3.521	4,800	13.001	8,300	22.481
1,400	3.792	4,900	13.272	8,400	22.752
1,500	4.063	5,000	13.543	8,500	23.023
1,600	4.334	5,100	13.814	8,600	23.294
1,700	4.605	5,200	14,085	8,700	23.564

Yards	Seconds	Yards	Seconds	Yards	Seconds
1,800	4.875	5,300	14.355	8,800	23.835
1,900	5.146	5,400	14.626	8,900	24.106
2,000	5.417	5,500	14.897	9,000	24.377
2,100	5.688	5,600	15.168	9,100	24.648
2,200	5.959	5,700	15.439	9,200	24.919
2,300	6.230	5,800	15.710	9,300	25.190
2,400	6.501	5,900	15.980	9,400	25.460
2,500	6.771	6,000	16.251	9,500	25.731
2,600	7.042	6,100	16.522	9,600	26.002
2,700	7.313	6,200	16.793	9,700	26.273
2,800	7.584	6,300	17.064	9,800	26.544
2,900	7.855	6,400	17.335	9,900	26.815
3,000	8.126	6,500	17.606	10,000	27.086
3,100	8.397	6,600	17.876		
3,200	8.667	6,700	18.147		
3,300	8.938	6,800	18.418		
3,400	9.209	6,900	18.689		
3,500	9.480	7,000	18.960		

Example: Find the number of sound-seconds corresponding to 4485.4 yards.

$$\begin{array}{rl}
4{,}400 \text{ yards} = & 11.918 \text{ seconds} \\
85 \text{ yards} = & 0.230 \text{ seconds} \\
0.4 \text{ yards} = & 0.001 \text{ seconds} \\
\hline
4{,}485.4 \text{ yards} = & 12.149 \text{ seconds}
\end{array}$$

Table VII. Conversion of Sound-seconds to Yards.

(To find the distance which sound travels in a given time under other than standard atmospheric conditions, the time interval must first be corrected to standard conditions.)

Seconds	Yards	Seconds	Yards	Seconds	Yards
0.1	36.9	3.6	1,329.1	7.1	2,621.3
0.2	73.8	3.7	1,366.0	7.2	2,658.2
0.3	110.8	3.8	1,403.0	7.3	2,695.2
0.4	147.7	3.9	1,439.9	7.4	2,732.1
0.5	184.6	4.0	1,476.8	7.5	2,769.0
0.6	221.5	4.1	1,513.7	7.6	2,805.9
0.7	258.4	4.2	1,550.6	7.7	2,842.8
0.8	295.4	4.3	1,587.6	7.8	2,879.8
0.9	332.3	4.4	1,624.5	7.9	2,916.7
1.0	369.2	4.5	1,661.4	8.0	2,953.6
1.1	406.1	4.6	1,698.3	8.1	2,990.5
1.2	443.0	4.7	1,735.2	8.2	3,027.4
1.3	480.0	4.8	1,772.2	8.3	3,064.4
1.4	516.9	4.9	1,809.1	8.4	3,101.3
1.5	553.8	5.0	1,846.0	8.5	3,138.2
1.6	590.7	5.1	1,882.9	8.6	3,175.1
1.7	627.6	5.2	1,919.8	8.7	3,212.0
1.8	664.6	5.3	1,956.8	8.8	3,249.0
1.9	701.5	5.4	1,993.7	8.9	3,285.9
2.0	738.4	5.5	2,030.6	9.0	3,322.8
2.1	775.3	5.6	2,067.5	9.1	3,359.7
2.2	812.2	5.7	2,104.4	9.2	3,396.6
2.3	849.2	5.8	2,141.4	9.3	3,433.6
2.4	886.1	5.9	2,178.3	9.4	3,470.5
2.5	923.0	6.0	2,215.2	9.5	3,507.4
2.6	959.9	6.1	2,252.1	9.6	3,544.3
2.7	996.8	6.2	2,289.0	9.7	3,581.2
2.8	1,033.8	6.3	2,326.0	9.8	3,618.2
2.9	1,070.7	6.4	2,362.9	9.9	3,655.1
3.0	1,107.6	6.5	2,399.8	10.0	3,692.0

Seconds	Yards	Seconds	Yards	Seconds	Yards
3.1	1,144.5	6.6	2,436.7		
3.2	1,181.4	6.7	2,473.6		
3.3	1,218.4	6.8	2,510.6		
3.4	1,255.3	6.9	2,547.5		
3.5	1,292.2	7.0	2,584.4		

Example: Find the distance in yards corresponding to 12.149 sound-seconds.

$$
\begin{array}{rl}
10 \text{ seconds} = & 3{,}692.0 \text{ yards} \\
2.1 \text{ seconds} = & 775.3 \text{ yards} \\
0.049 \text{ seconds} = & 18.1 \text{ yards} \\
\hline
12.149 \text{ seconds} = & 4{,}485.4 \text{ yards}
\end{array}
$$

Table VIII. Conversion of Meters to Sound-seconds

Meters	Seconds	Meters	Seconds	Meters	Seconds
100	0.296	3,600	10.664	7,100	21.031
200	0.592	3,700	10.960	7,200	21.327
300	0.889	3,800	11.256	7,300	21.623
400	1.185	3,900	11.552	7,400	21.920
500	1.481	4,000	11.848	7,500	22.216
600	1.777	4,100	12.145	7,600	22.512
700	2.073	4,200	12.441	7,700	22.808
800	2.370	4,300	12.737	7,800	23.104
900	2.666	4,400	13.033	7,900	23.401
1,000	2.962	4,500	13.329	8,000	23.697
1,100	3.258	4,600	13.626	8,100	23.993
1,200	3.555	4,700	13.922	8,200	24.289
1,300	3.851	4,800	14.218	8,300	24.586
1,400	4.147	4,900	14.514	8,400	24.882
1,500	4.443	5,000	14.811	8,500	25.178
1,600	4.739	5,100	15.107	8,600	25.474
1,700	5.036	5,200	15.403	8,700	25.770
1,800	5.332	5,300	15.699	8,800	26.067
1,900	5.628	5,400	15.995	8,900	26.363
2,000	5.924	5,500	16.292	9,000	26.659

Meters	Seconds	Meters	Seconds	Meters	Seconds
2,100	6.220	5,600	16.588	9,100	26.955
2,200	6.517	5,700	16.884	9,200	27.251
2,300	6.813	5,800	17.180	9,300	27.548
2,400	7.109	5,900	17.476	9,400	27.844
2,500	7.405	6,000	17.773	9,500	28.140
2,600	7.701	6,100	18.069	9,600	28.436
2,700	7.998	6,200	18.365	9,700	28.732
2,800	8.294	6,300	18.661	9,800	29.029
2,900	8.590	6,400	18.958	9,900	29.325
3,000	8.886	6,500	19.254	10,000	29.621
3,100	9.183	6,600	19.550		
3,200	9.479	6,700	19.846		
3,300	9.775	6,800	20.142		
3,400	10.071	6,900	20.439		
3,500	10.367	7,000	20.735		

Example: Find the number of sound-seconds corresponding to 4,101.5 meters.

4,100 meters = 12.145 seconds
01 meters = 0.003 seconds
0.5 meters = 0.001 seconds
4,101.5 meters = 12.149 seconds

Table IX. Conversion of Sound-seconds to Meters

(To find the distance which sound travels in a given time under other than standard atmospheric conditions, the time interval must first be corrected to standard conditions.)

Seconds	Meters	Seconds	Meters	Seconds	Meters
0.1	33.8	3.6	1,215.3	7.1	2,396.9
0.2	67.5	3.7	1.249.1	7.2	2,430.7
0.3	101.3	3.8	1,282.9	7.3	2,464.5
0.4	135.0	3.9	1,316.6	7.4	2,498.2
0.5	168.8	4.0	1,350.4	7.5	2,532.0

Seconds	Meters	Seconds	Meters	Seconds	Meters
0.6	202.6	4.1	1,384.1	7.6	2,565.7
0.7	236.3	4.2	1,417.9	7.7	2,599.5
0.8	270.1	4.3	1,451.7	7.8	2,633.3
0.9	303.8	4.4	1,485.4	7.9	2,667.0
1.0	337.6	4.5	1,519.2	8.0	2,700.8
1.1	371.4	4.6	1,552.9	8.1	2,734.5
1.2	405.1	4.7	1,586.7	8.2	2,768.3
1.3	438.9	4.8	1,620.5	8.3	2,802.1
1.4	472.6	4.9	1,654.2	8.4	2,835.8
1.5	506.4	5.0	1,688.0	8.5	2,869.6
1.6	540.2	5.1	1,721.7	8.6	2,903.3
1.7	573.9	5.2	1,755.5	8.7	2,937.1
1.8	607.7	5.3	1,789.3	8.8	2,970.9
1.9	641.4	5.4	1,823.0	8.9	3,004.6
2.0	675.2	5.5	1,856.8	9.0	3,038.4
2.1	709.0	5.6	1,890.5	9.1	3,072.1
2.2	742.7	5.7	1,924.3	9.2	3,105.9
2.3	776.5	5.8	1,958.1	9.3	3,139.7
2.4	810.2	5.9	1,991.8	9.4	3,173.4
2.5	844.0	6.0	2,025.6	9.5	3,207.2
2.6	877.8	6.1	2,059.3	9.6	3,240.9
2.7	911.5	6.2	2,093.1	9.7	3,274.7
2.8	945.3	6.3	2,126.9	9.8	3,308.5
2.9	979.0	6.4	2,160.6	9.9	3,342.2
3.0	1,012.8	6.5	2,194.4	10.0	3,376.0
3.1	1,046.6	6.6	2,228.1		
3.2	1,080.3	6.7	2,261.9		
3.3	1,114.1	6.8	2,295.7		
3.4	1,147.8	6.9	2,329.4		
3.5	1,181.6	7.0	2,363.2		

Example: Find the distance in meters corresponding to 12.149 sound-seconds.

$$
\begin{array}{rlr}
10 & \text{seconds} = & 3{,}376.0 \text{ meters} \\
2.1 & \text{seconds} = & 709.0 \text{ meters} \\
0.049 & \text{seconds} = & 16.5 \text{ meters} \\
\hline
12.149 & \text{seconds} = & 4{,}101.5 \text{ meters}
\end{array}
$$

Table X. Temperature-time Conversion

$$\frac{\text{Conversion number}}{\dfrac{\text{Length of subbase in meters}}{1000}} = \text{Factor}$$

Factor x Time interval = Time interval converted to 4-second equivalent, temperature corrected.

Temp. °F.	Conversion No.	Temp. °F.	Conversion No.	Temp. °F.	Conversion No.
−70	1.1809	−35	1.2327	0	1.2825
−69	1.1824	−34	1.2342	1	1.2839
−68	1.1839	−33	1.2356	2	1.2853
−67	1.1854	−32	1.2371	3	1.2867
−66	1.1869	−31	1.2385	4	1.2881
−65	1.1884	−30	1.2400	5	1.2894
−64	1.1899	−29	1.2414	6	1.2908
−63	1.1914	−28	1.2429	7	1.2922
−62	1.1929	−27	1.2443	8	1.2936
−61	1.1944	−26	1.2457	9	1.2950
−60	1.1959	−25	1.2472	10	1.2964
−59	1.1974	−24	1.2486	11	1.2977
−58	1.1989	−23	1.2500	12	1.2991
−57	1.2004	−22	1.2515	13	1.3005
−56	1.2019	−21	1.2529	14	1.3019
−55	1.2034	−20	1.2543	15	1.3032
−54	1.2049	−19	1.2557	16	1.3046
−53	1.2064	−18	1.2572	17	1.3060
−52	1.2078	−17	1.2586	18	1.3073
−51	1.2093	−16	1.2600	19	1.3087
−50	1.2108	−15	1.2614	20	1.3101
−49	1.2123	−14	1.2628	21	1.3114
−48	1.2137	−13	1.2642	22	1.3128
−47	1.2152	−12	1.2657	23	1.3142
−46	1.2167	−11	1.2671	24	1.3155

Temp. °F.	Conversion No.	Temp. °F.	Conversion No.	Temp. °F.	Conversion No.
−45	1.2182	−10	1.2685	25	1.3169
−44	1.2196	− 9	1.2699	26	1.3182
−43	1.2211	− 8	1.2713	27	1.3196
−42	1.2225	− 7	1.2727	28	1.3210
−41	1.2240	− 6	1.2741	29	1.3223
−40	1.2255	− 5	1.2755	30	1.3237
−39	1.2269	− 4	1.2769	31	1.3250
−38	1.2284	− 3	1.2783	32	1.3264
−37	1.2298	− 2	1.2797	33	1.3277
−36	1.2313	− 1	1.2811	34	1.3290
35	1.3304	76	1.3844	117	1.4364
36	1.3317	77	1.3857	118	1.4376
37	1.3331	78	1.3870	119	1.4389
38	1.3344	79	1.3883	120	1.4401
39	1.3358	80	1.3895	121	1.4413
40	1.3371	81	1.3908	122	1.4426
41	1.3384	82	1.3921	123	1.4438
42	1.3398	83	1.3934	124	1.4451
43	1.3411	84	1.3947	125	1.4463
44	1.3424	85	1.3960	126	1.4475
45	1.3438	86	1.3972	127	1.4488
46	1.3451	87	1.3985	128	1.4500
47	1.3464	88	1.3998	129	1.4512
48	1.3477	89	1.4011	130	1.4525
49	1.3491	90	1.4024	131	1.4537
50	1.3504	91	1.4036	132	1.4549
51	1.3517	92	1.4049	133	1.4561
52	1.3530	93	1.4062	134	1.4574
53	1.3544	94	1.4074	135	1.4586
54	1.3557	95	1.4087	136	1.4598
55	1.3570	96	1.4100	137	1.4610
56	1.3583	97	1.4113	138	1.4623
57	1.3596	98	1.4125	139	1.4635
58	1.3609	99	1.4138	140	1.4647
59	1.3623	100	1.4150		
60	1.3636	101	1.4163		
61	1.3649	102	1.4176		

Temp. °F.	Conversion No.	Temp. °F.	Conversion No.	Temp. °F.	Conversion No.
62	1.3662	103	1.4188		
63	1.3675	104	1.4201		
64	1.3688	105	1.4214		
65	1.3701	106	1.4226		
66	1.3714	107	1.4239		
67	1.3727	108	1.4251		
68	1.3740	109	1.4264		
69	1.3753	110	1.4276		
70	1.3766	111	1.4289		
71	1.3779	112	1.4301		
72	1.3792	113	1.4314		
73	1.3805	114	1.4326		
74	1.3818	115	1.4339		
75	1.3831	116	1.4351		

APPENDIX V

CORRECTIONS FOR CURVATURE AND REFRACTION

Table XI. Curvature and Refraction

(The corrections in the table are always to be added to the altitude of the point as determined from the vertical angle from a station of known altitude.)

Range (meters or yards)	Correction in feet (meters)	Correction in feet (yards)
1,000	0.2	0.2
2,000	0.9	0.7
3,000	2.0	1.7
4,000	3.5	3.0
5,000	5.5	4.6
6,000	8.0	6.6
7,000	10.9	9.0
8,000	14.2	11.8
9,000	17.9	15.0
10,000	22.2	18.5
11,000	26.8	22.3
12,000	31.9	26.6
13,000	37.4	31.2
14,000	43.4	36.2
15,000	49.9	41.6
16,000	56.7	47.3
17,000	64.0	53.4
18,000	71.8	59.8
19,000	80.0	66.7
20,000	88.6	73.9
21,000	97.7	81.4
22,000	107.2	89.4
23,000	117.2	97.7
24,000	127.6	106.4
25,000	138.5	115.4

Range (meters or yards)	Correction in feet (meters)	Correction in feet (yards)
26,000	149.8	124.8
27,000	161.5	134.6
28,000	173.7	144.8
29,000	186.4	155.3
30,000	199.4	166.2

Formula $H = R^2 \times .1847$ (yards)

$H = R^2 \times .2216$ (meters)

$H =$ Correction in feet

$R =$ Range or surveyed distance in thousands of yards or meters; that is for 10,000 yards or meters $R = 10$.

APPENDIX VI

LENGTHS OF SUBBASES EXPRESSED IN YARDS, METERS, AND MILES

Table XII. Lengths of Subbases

Sound seconds	Length of subbase		
	Yards	Meters	Miles
2.0	738.40	675.19	0.4195
2.5	923.00	843.99	0.5244
3.0	1107.60	1012.79	0.6293
3.5	1292.20	1181.59	0.7342
4.0	1476.80	1350.39	0.8391
4.5	1661.40	1519.19	0.9440
5.0	1846.00	1687.99	1.0489
5.5	2030.60	1856.78	1.1538

948797°—51—32

APPENDIX VII

TIME SCALE VALUES

Table XIII. Two-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.050	0.02500	1°26′	25.5	0.02501
0.100	0.05000	2°52′	51.0	0.05006
0.150	0.07500	4°18′	76.5	0.07521
0.200	0.10000	5°44′	102.0	0.10050
0.250	0.12500	7°11′	127.7	0.12599
0.300	0.15000	8°38′	153.4	0.15172
0.350	0.17500	10°05′	179.2	0.17774
0.400	0.20000	11°32′	205.1	0.20412
0.450	0.22500	13°00′	231.2	0.23092
0.500	0.25000	14°29′	257.4	0.25820
0.550	0.27500	15°58′	283.8	0.28603
0.600	0.30000	17°27′	310.4	0.31449
0.650	0.32500	18°58′	337.2	0.34366
0.700	0.35000	20°29′	364.2	0.37363
0.750	0.37500	22°01′	391.5	0.40452
0.800	0.40000	23°35′	419.2	0.43644
0.850	0.42500	25°09′	447.1	0.46951
0.900	0.45000	26°45′	475.4	0.50390
0.950	0.47500	28°22′	504.2	0.53978
1.000	0.50000	30°00′	533.3	0.57735
1.050	0.52500	31°40′	563.0	0.61685
1.100	0.55000	33°22′	593.2	0.65855
1.150	0.57500	35°06′	624.0	0.70280
1.200	0.60000	36°52′	655.5	0.75000
1.250	0.62500	38°41′	687.7	0.80064
1.300	0.65000	40°32′	720.7	0.85534
1.350	0.67500	42°27′	754.7	0.91486
1.400	0.70000	44°26′	789.8	0.98020
1.450	0.72500	46°28′	826.1	1.05263
1.500	0.75000	48°35′	863.8	1.13389

t Seconds	Sin D	D Degrees	D Mils	Tan D
1.550	0.77500	50°48′	903.2	1.22634
1.600	0.80000	53°08′	944.5	1.33333
1.650	0.82500	55°35′	988.2	1.45983
1.700	0.85000	58°13′	1,034.9	1.61357
1.750	0.87500	61°03′	1,085.2	1.80739
1.800	0.90000	64°09′	1,140.6	2.06474
1.850	0.92500	67°40′	1,203.0	2.43442
1.900	0.95000	71°48′	1,276.5	3.04243
1.950	0.97500	77°10′	1,371.8	4.38784
2.000	1.00000	90°00′	1,600.0	Infinity

Table XIV. Three-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.100	0.03333	1°55′	34.0	0.03335
0.200	0.06667	3°49′	68.0	0.06682
0.300	0.10000	5°44′	102.0	0.10050
0.400	0.13333	7°40′	136.2	0.13453
0.500	0.16667	9°36′	170.6	0.16903
0.600	0.20000	11°32′	205.1	0.20412
0.700	0.23333	13°30′	239.9	0.23996
0.800	0.26667	15°28′	275.0	0.27669
0.900	0.30000	17°27′	310.4	0.31449
1.000	0.33333	19°28′	346.2	0.35355
1.100	0.36667	21°31′	382.4	0.39412
1.200	0.40000	23°35′	419.2	0.43644
1.300	0.43333	25°41′	456.5	0.48082
1.400	0.46667	27°49′	494.5	0.52764
1.500	0.50000	30°00′	533.3	0.57735
1.600	0.53333	32°14′	573.0	0.63049
1.700	0.56667	34°31′	613.7	0.68775
1.800	0.60000	36°52′	655.5	0.75000
1.900	0.63333	39°18′	698.6	0.81839
2.000	0.66667	41°49′	743.3	0.89443

t Seconds	Sin D	D Degrees	D Mils	Tan D
2.100	0.70000	44°26′	789.8	0.98020
2.200	0.73333	47°10′	838.5	1.07864
2.300	0.76667	50°03′	889.9	1.19410
2.400	0.80000	53°08′	944.5	1.33333
2.500	0.83333	56°27′	1,003.4	1.50756
2.600	0.86667	60°04′	1,068.0	1.73720
2.700	0.90000	64°09′	1,140.6	2.06474
2.800	0.93333	68°58′	1,226.0	2.59973
2.900	0.96667	75°10′	1,336.3	3.77548
3.000	1.00000	90°00′	1,600.0	Infinity

Table XV. Three and One-half-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.10	0.0286	1°38′	29	0.0285
0.20	0.0571	3°16′	58	0.0571
0.30	0.0858	4°55′	87	0.0860
0.40	0.1143	6°34′	117	0.1151
0.50	0.1429	8°13′	146	0.1444
0.60	0.1714	9°52′	175	0.1739
0.70	0.2000	11°32′	205	0.2041
0.80	0.2286	13°13′	235	0.2349
0.90	0.2571	14°54′	265	0.2661
1.00	0.2857	16°36′	295	0.2981
1.10	0.3143	18°19′	326	0.3310
1.20	0.3429	20°03′	357	0.3650
1.30	0.3714	21°48′	388	0.4000
1.40	0.4000	23°35′	419	0.4365
1.50	0.4286	25°23′	451	0.4745
1.60	0.4571	27°12′	484	0.5139
1.70	0.4857	29°03′	517	0.5555
1.80	0.5142	30°57′	550	0.5997
1.90	0.5428	32°52′	584	0.6461
2.00	0.5714	34°51′	620	0.6963

t Seconds	Sin D	D Degrees	D Mils	Tan D
2.10	0.6000	36°52′	655	0.7499
2.20	0.6286	38°57′	693	0.8083
2.30	0.6571	41°05′	730	0.8718
2.40	0.6857	43°18′	770	0.9424
2.50	0.7142	45°34′	810	1.0200
2.60	0.7428	47°58′	853	1.1093
2.70	0.7714	50°29′	898	1.2124
2.80	0.8000	53°08′	945	1.3335

Table XVI. Four-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.100	0.02500	1°26′	25.5	0.02501
0.200	0.05000	2°52′	51.0	0.05006
0.300	0.07500	4°18′	76.5	0.07521
0.400	0.10000	5°44′	102.0	0.10050
0.500	0.12500	7°11′	127.7	0.12599
0.600	0.15000	8°38′	153.4	0.15172
0.700	0.17500	10°05′	179.2	0.17774
0.800	0.20000	11°32′	205.1	0.20412
0.900	0.22500	13°00′	231.2	0.23092
1.000	0.25000	14°29′	257.4	0.25820
1.100	0.27500	15°58′	283.8	0.28603
1.200	0.30000	17°27′	310.4	0.31449
1.300	0.32500	18°58′	337.2	0.34366
1.400	0.35000	20°29′	364.2	0.37363
1.500	0.37500	22°01′	391.5	0.40452
1.600	0.40000	23°35′	419.2	0.43644
1.700	0.42500	25°09′	447.1	0.46951
1.800	0.45000	26°45′	475.4	0.50390
1.900	0.47500	28°22′	504.2	0.53978
2.000	0.50000	30°00′	533.3	0.57735
2.100	0.52500	31°40′	563.0	0.61685
2.200	0.55000	33°22′	593.2	0.65855
2.300	0.57500	35°06′	624.0	0.70280
2.400	0.60000	36°52′	655.5	0.75000
2.500	0.62500	38°41′	687.7	0.80064

t Seconds	Sin D	D Degrees	D Mils	Tan D
2.600	0.65000	40°32′	720.7	0.85534
2.700	0.67500	42°27′	754.7	0.91486
2.800	0.70000	44°26′	789.8	0.98020
2.900	0.72500	46°28′	826.1	1.05263
3.000	0.75000	48°35′	863.8	1.13389
3.100	0.77500	50°48′	903.2	1.22634
3.200	0.80000	53°08′	944.5	1.33333
3.300	0.82500	55°35′	988.2	1.45983
3.400	0.85000	58°13′	1,034.9	1.61357
3.500	0.87500	61°03′	1,085.2	1.80739
3.600	0.90000	64°09′	1,140.6	2.06474
3.700	0.92500	67°40′	1,203.0	2.43442
3.800	0.95000	71°48′	1,276.5	3.04243
3.900	0.97500	77°10′	1,371.8	4.38785
4.000	1.00000	90°00′	1,600.0	Infinity

Table XVII. Four and One-half-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.100	0.02222	1°16′	22.6	0.02223
0.200	0.04444	2°33′	45.3	0.04449
0.300	0.06667	3°49′	68.0	0.06682
0.400	0.08889	5°06′	90.7	0.08924
0.500	0.11111	6°23′	113.4	0.11180
0.600	0.13333	7°40′	136.2	0.13453
0.700	0.15556	8°57′	159.1	0.15747
0.800	0.17778	10°14′	182.1	0.18066
0.900	0.20000	11°32′	205.1	0.20412
1.000	0.22222	12°50′	228.3	0.22792
1.100	0.24444	14°09′	251.5	0.25209
1.200	0.26667	15°28′	275.0	0.27669
1.300	0.28889	16°47′	298.5	0.30175
1.400	0.31111	18°08′	322.2	0.32736
1.500	0.33333	19°28′	346.2	0.35355
1.600	0.35556	20°50′	370.3	0.38041
1.700	0.37778	22°12′	394.6	0.40801

t Seconds	Sin D	D Degrees	D Mils	Tan D
1.800	0.40000	23°35′	419.2	0.43644
1.900	0.42222	24°58′	444.0	0.46578
2.000	0.44444	26°23′	469.1	0.49614
2.100	0.46667	27°49′	494.5	0.52764
2.200	0.48889	29°16′	520.3	0.56043
2.300	0.51111	30°44′	546.5	0.59465
2.400	0.53333	32°14′	573.0	0.63049
2.500	0.55556	33°45′	600.0	0.66815
2.600	0.57778	35°18′	627.5	0.70789
2.700	0.60000	36°52′	655.5	0.75000
2.800	0.62222	38°29′	684.1	0.79483
2.900	0.64444	40°07′	713.3	0.84280
3.000	0.66667	41°49′	743.3	0.89443
3.100	0.68889	43°33′	774.1	0.95037
3.200	0.71111	45°20′	805.8	1.01142
3.300	0.73333	47°10′	838.5	1.07864
3.400	0.75556	49°04′	872.4	1.15337
3.500	0.77778	51°03′	907.7	1.23744
3.600	0.80000	53°08′	944.5	1.33333
3.700	0.82222	55°18′	983.3	1.44461
3.800	0.84444	57°37′	1,024.2	1.57651
3.900	0.86667	60°04′	1,068.0	1.73720
4.000	0.88889	62°44′	1,115.3	1.94029
4.100	0.91111	65°40′	1,167.3	2.21057
4.200	0.93333	68°58′	1,226.0	2.59973
4.300	0.95556	72°51′	1,295.2	3.24125
4.400	0.97778	77°54′	1,384.9	4.66399
4.500	1.00000	90°00′	1,600.0	Infinity

Table XVIII. Five-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.100	0.02000	1°09′	20.4	0.02000
0.200	0.04000	2°18′	40.8	0.04003
0.300	0.06000	3°26′	61.2	0.06011
0.400	0.08000	4°35′	81.6	0.08026
0.500	0.10000	5°44′	102.0	0.10050

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.600	0.12000	6°54′	122.5	0.12087
0.700	0.14000	8°03′	143.1	0.14139
0.800	0.16000	9°12′	163.7	0.16209
0.900	0.18000	10°22′	184.4	0.18299
1.000	0.20000	11°32′	205.1	0.20412
1.100	0.22000	12°43′	225.9	0.22553
1.200	0.24000	13°53′	246.9	0.24723
1.300	0.26000	15°04′	267.9	0.26926
1.400	0.28000	16°16′	289.1	0.29167
1.500	0.30000	17°27′	310.4	0.31449
1.600	0.32000	18°40′	331.8	0.33776
1.700	0.34000	19°53′	353.4	0.36154
1.800	0.36000	21°06′	375.1	0.38587
1.900	0.38000	22°20′	397.0	0.41082
2.000	0.40000	23°35′	419.2	0.43644
2.100	0.42000	24°50′	441.5	0.46280
2.200	0.44000	26°06′	464.1	0.48998
2.300	0.46000	27°23′	486.9	0.51807
2.400	0.48000	28°41′	510.0	0.54715
2.500	0.50000	30°00′	533.3	0.57735
2.600	0.52000	31°20′	557.0	0.60878
2.700	0.54000	32°41′	581.0	0.64159
2.800	0.56000	34°03′	605.4	0.67593
2.900	0.58000	35°27′	630.2	0.71199
3.000	0.60000	36°52′	655.5	0.75000
3.100	0.62000	38°19′	681.2	0.79021
3.200	0.64000	39°48′	707.4	0.83293
3.300	0.66000	41°18′	734.2	0.87852
3.400	0.68000	42°51′	761.7	0.92743
3.500	0.70000	44°26′	789.8	0.98020
3.600	0.72000	46°03′	818.7	1.03750
3.700	0.74000	47°44′	848.6	1.10020
3.800	0.76000	49°28′	879.4	1.16937

t Seconds	Sin D	D Degrees	D Mils	Tan D
3.900	0.78000	51°16′	911.3	1.24645
4.000	0.80000	53°08′	944.5	1.33333
4.100	0.82000	55°05′	979.3	1.43266
4.200	0.84000	57°08′	1,015.8	1.54814
4.300	0.86000	59°19′	1,054.5	1.68530
4.400	0.88000	61°39′	1,095.9	1.85273
4.500	0.90000	64°09′	1,140.6	2.06474
4.600	0.92000	66°56′	1,189.8	2.34743
4.700	0.94000	70°03′	1,245.4	2.75519
4.800	0.96000	73°44′	1,310.9	3.42857
4.900	0.98000	78°31′	1,395.9	4.92469
5.000	1.00000	90°00′	1,600.0	Infinity

Table XIX. Five and One-half-second Subbase

t Seconds	Sin D	D Degrees	D Mils	Tan D
0.100	0.01818	1°03′	18.5	0.01818
0.200	0.03636	2°05′	37.0	0.03639
0.300	0.05455	3°08′	55.6	0.05463
0.400	0.07273	4°10′	74.1	0.07292
0.500	0.09091	5°13′	92.7	0.09129
0.600	0.10909	6°16′	111.3	0.10975
0.700	0.12727	7°19′	130.0	0.12832
0.800	0.14545	8°22′	148.7	0.14702
0.900	0.16364	9°25′	167.4	0.16587
1.000	0.18182	10°29′	186.2	0.18490
1.100	0.20000	11°32′	205.1	0.20412
1.200	0.21818	12°36′	224.0	0.22357
1.300	0.23636	13°40′	243.1	0.24326
1.400	0.25455	14°45′	262.2	0.26322
1.500	0.27273	15°50′	281.4	0.28347
1.600	0.29091	16°55′	300.7	0.30406
1.700	0.30909	18″00′	320.1	0.32501
1.800	0.32727	19°06′	339.6	0.34635
1.900	0.34545	20°13′	359.3	0.36812
2.000	0.36364	21°19′	379.1	0.39036

t Seconds	Sin D	D Degrees	D Mils	Tan D
2.100	0.38182	22°27′	399.0	0.41312
2.200	0.40000	23°35′	419.2	0.43644
2.300	0.41818	24°43′	439.5	0.46037
2.400	0.43636	25°52′	459.9	0.48497
2.500	0.45455	27°02′	480.6	0.51031
2.600	0.47273	28°13′	501.5	0.53645
2.700	0.49091	29°24′	522.7	0.56348
2.800	0.50909	30°36′	544.1	0.59148
2.900	0.52727	31°49′	565.7	0.62054
3.000	0.54545	33°03′	587.7	0.65079
3.100	0.56364	34°18′	609.9	0.68235
3.200	0.58182	35°35′	632.5	0.71536
3.300	0.60000	36°52′	655.5	0.75000
3.400	0.61818	38°11′	678.8	0.78646
3.500	0.63636	39°31′	702.6	0.82496
3.600	0.65455	40°53′	726.8	0.86577
3.700	0.67273	42°17′	751.6	0.90923
3.800	0.69091	43°42′	776.9	0.95569
3.900	0.70909	45°10′	802.9	1.00564
4.000	0.72727	46°39′	829.5	1.05963
4.100	0.74545	48°12′	856.9	1.11837
4.200	0.76364	49°47′	885.1	1.18275
4.300	0.78182	51°26′	914.3	1.25391
4.400	0.80000	53°08′	944.5	1.33333
4.500	0.81818	54°54′	976.1	1.42302
4.600	0.83636	56°45′	1,009.0	1.52572
4.700	0.85455	58°43′	1,043.7	1.64533
4.800	0.87273	60°47′	1,080.5	1.78761
4.900	0.89091	62°59′	1,119.8	1.96157
5.000	0.90909	65°23′	1,162.3	2.18218

t Seconds	Sin D	D Degrees	D Mils	Tan D
5.100	0.92727	68°01′	1,209.1	2.47678
5.200	0.94545	70°59′	1,262.0	2.90236
5.300	0.96364	74°30′	1,324.5	3.60619
5.400	0.98182	79°03′	1,405.5	5.17226
5.500	1.00000	90°00′	1,600.0	Infinity

APPENDIX VIII

TYPE SOUND RANGING CORRECTION CHARTS

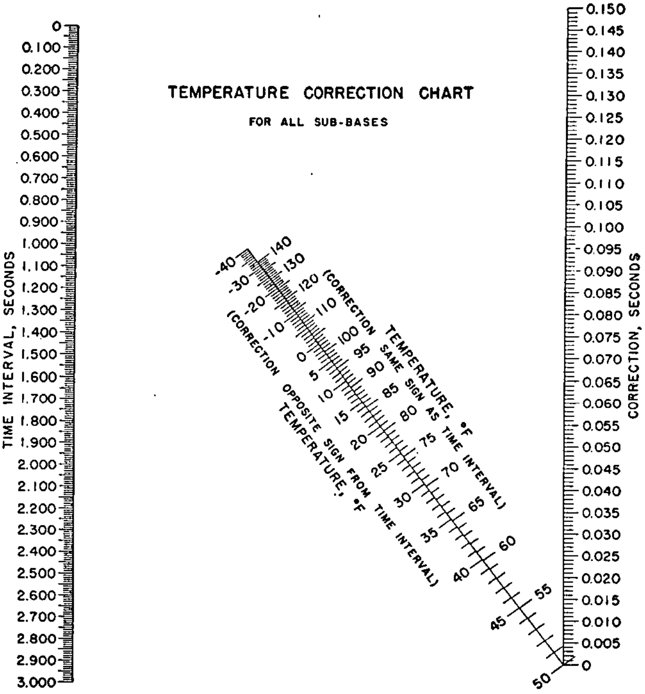

Figure 150. Temperature correction chart for all subbases.

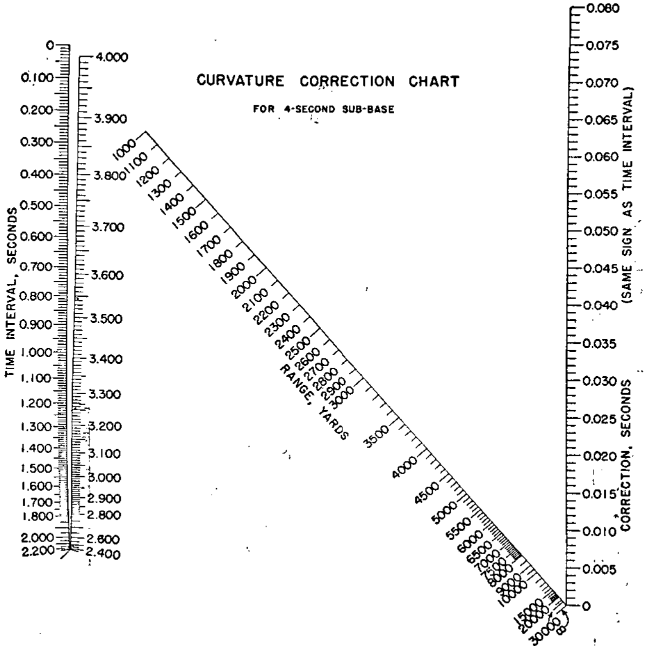

Figure 151. Curvature correction chart, 4-second subbase.

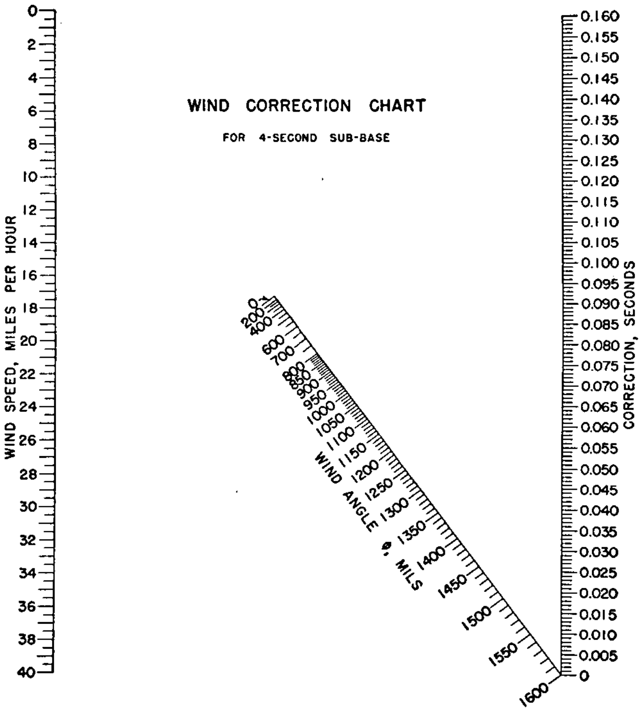

Figure 152. Wind correction chart, 4-second subbase.

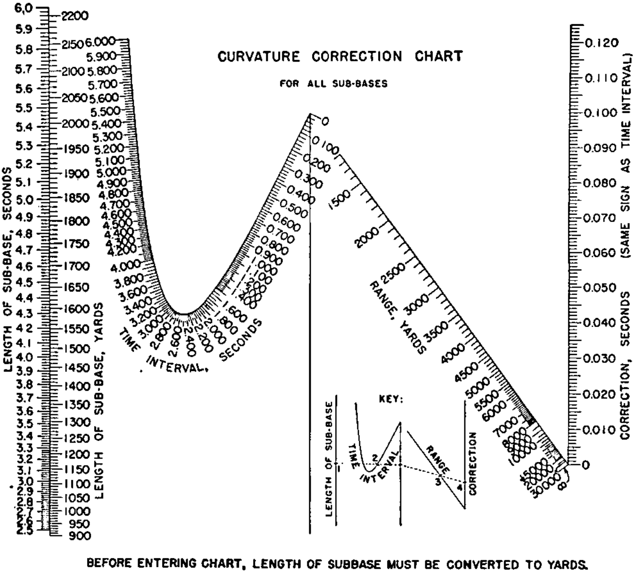

Figure 153. Curvature correction chart, any length subbase.

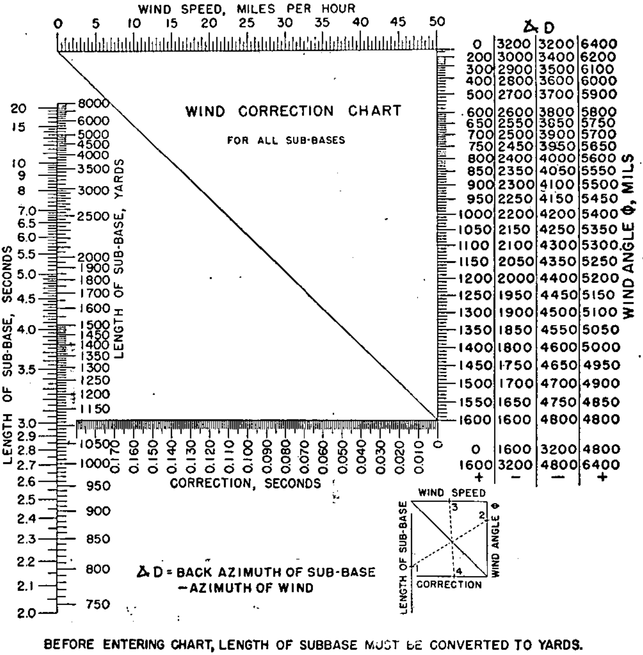

Figure 154. Wind correction chart, any length subbase.

APPENDIX IX

VELOCITY OF SOUND IN AIR

The velocity of sound in air for a specific temperature may be determined from the formula—

$$V_x = 337.6 \quad \frac{X + 458.5}{508.5} \text{ meters per second}$$

Where X = effective temperature in °F. taken from Weather Data for Sound Ranging Form (fig. 73). Effects of both temperature and humidity are taken into account.

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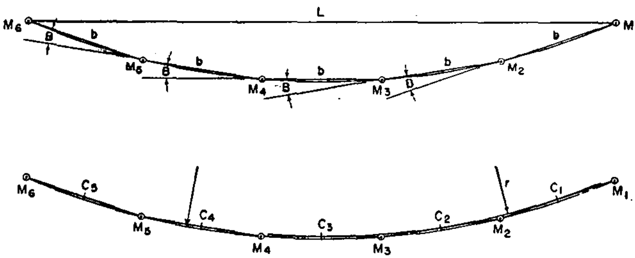
APPENDIX X

SURVEY AND COMPUTATION TABLES FOR CURVED BASE



M_1, M_2, etc.- Microphone positions
C_1, C_2, etc.- Midpoints of subbases
s = Length of subbase (sound seconds)
b = Length of subbases

L = Length of long chord (M_1 to M_6)
B = Angular offset between adjacent subbases
r = Radius of arc passing through midpoints

Center of curvature - Center of arcs on which microphones and midpoints lie; this is also the point where the perpendicular bisectors of the subbases converge.

Figure 155. Elements of curved sound ranging bases.

Table XX. Values for Elements of Curved Sound Bases

s Sound seconds	r Sound seconds	b Yards	Log b Yards	b Meters	Log b Meters	$\frac{B}{2}$	B	$2B$
3.5	25	1292.20	3.1113297	1181.59	3.0724668	4°00′15″	8°00′30″	16°01′00″
4.0	25	1476.80	3.1693217	1350.39	3.1304592	4°34′26″	9°08′52″	18°17′44″
4.5	25	1661.40	3.2204742	1519.19	3.1816093	5°08′34″	10°17′08″	20°34′16″
4.0	30	1476.80	3.1693217	1350.39	3.1304592	3°48′51″	7°37′41″	15°15′23″
4.5	30	1661.40	3.2204742	1519.19	3.1816093	4°17′21″	8°34′42″	17°09′24″
5.0	30	1846.00	3.2662317	1687.99	3.2273698	4°45′49″	9°31′38″	19°03′16″
4.5	35	1661.40	3.2204742	1519.19	3.1816093	3°40′42″	7°21′23″	14°42′47″
5.0	35	1846.00	3.2662317	1687.99	3.2273698	4°05′08″	8°10′16″	16°20′33″
5.5	35	2030.60	3.3076244	1856.78	3.2687604	4°29′33″	8°59′07″	17°58′13″

Table XX. Values for Elements of Curved Sound Bases—Continued

s Sound seconds	r Sound seconds	L Meters	Log L Meters	Log sin B	Log cos B	Log sin $2B$	Log cos $2B$
3.5	25	5793.16	3.7629155	9.1440045	9.9957439	9.4407784	9.9828054
4.0	25	6581.08	3.8182972	9.2013462	9.9944410	9.4968173	9.9774720
4.5	25	7353.38	3.8664870	9.2517700	9.9929643	9.5457642	9.9713858
4.0	30	6632.87	3.8217015	9.1230075	9.9961397	9.4201848	9.9844184
4.5	30	7426.76	3.8707994	9.1736565	9.9951141	9.4698008	9.9802315
5.0	30	8208.38	3.9142574	9.2188406	9.9939681	9.5138387	9.9755277
4.5	35	7471.30	3.8733962	9.1073482	9.9964105	9.4047966	9.9855207
5.0	35	8269.27	3.9174671	9.1526850	9.9955685	9.4492910	9.9820889
5.5	35	9057.19	3.9569935	9.1936272	9.9946376	9.4892884	9.9782795

APPENDIX XI

TABLES FOR COMPUTATION OF GRID CONVERGENCE AND SCALE FACTORS

Table XXI. UTM Scale Factors for Artillery Use

E	*E*	Log Scale *Factor*
500,000	500,000	9.99983-10
510,000	490,000	9.99983
520,000	480,000	9.99983
530,000	470,000	9.99983
540,000	460,000	9.99984
550,000	450,000	9.99984
560,000	440,000	9.99985
570,000	430,000	9.99985
580,000	420,000	9.99986
590,000	410,000	9.99987
600,000	400,000	9.99988
610,000	390,000	9.99989
620,000	380,000	9.99990
630,000	370,000	9.99992
640,000	360,000	9.99993
650,000	350,000	9.99995
660,000	340,000	9.99996
670,000	330,000	9.99998-10
680,000	320,000	0.00000
690,000	310,000	0.00002
700,000	300,000	0.00004
710,000	290,000	0.00006
720,000	280,000	0.00009
730,000	270,000	0.00011
740,000	260,000	0.00013
750,000	250,000	0.00016
760,000	240,000	0.00019
770,000	230,000	0.00022

E	E	Log Scale *Factor*
780,000	220,000	0.00025
790,000	210,000	0.00028
800,000	200,000	0.00031
810,000	190,000	0.00034
820,000	180,000	0.00037
830,000	170,000	0.00041
840,000	160,000	0.00044
850,000	150,000	0.00048
860,000	140,000	0.00052

Example: The point A in the northern hemisphere has the approximate coordinates:

$$E = 634{,}000 \text{ meters}$$
$$N = 4{,}879{,}000 \text{ meters}$$

A sun azimuth to B is observed as 45° 18′ from the south.

$$E' = 134{,}000 \text{ meters, } q = .134$$

$$\begin{aligned}
\log\ q &= 9.1271 \\
\log \text{ Function } XV &= 4.4951 \\
\log\ C'' &= \overline{3.6222} \\
C'' &= 4{,}190'' \\
&= 1^\circ\ 9'\ 50''
\end{aligned}$$

$$\begin{aligned}
\text{Astronomic azimuth (from } S.) &= 45^\circ\ 18' \\
\text{Convergence } &- 1^\circ\ 10' \\
&+180^\circ\ 00' \\
\text{Plane azimuth (from } N.) &\ \ \overline{224^\circ\ 08'}
\end{aligned}$$

(The log of Function XV is obtained from Table XXII below.)

Table XXII. Auxiliary Table for Convergence Computation

Northing (meters)	Log of (XV)	Northing (meters)	Log of (XV)	Northing (meters)	Log of (XV)
2 650 000	4.1575	3 000 000	4.2191	3 350 000	4.2759
2 660 000	4.1593	3 010 000	4.2208	3 360 000	4.2775
2 670 000	4.1612	3 020 000	4.2224	3 370 000	4.2790
2 680 000	4.1630	3 030 000	4.2241	3 380 000	4.2806
2 690 000	4.1648	3 040 000	4.2258	3 390 000	4.2822
2 700 000	4.1666	3 050 000	4.2275	3 400 000	4.2837
2 710 000	4.1685	3 060 000	4.2291	3 410 000	4.2853
2 720 000	4.1703	3 070 000	4.2308	3 420 000	4.2868
2 730 000	4.1721	3 080 000	4.2324	3 430 000	4.2884
2 740 000	4.1739	3 090 000	4.2341	3 440 000	4.2899
2 750 000	4.1757	3 100 000	4.2357	3 450 000	4.2915
2 760 000	4.1775	3 110 000	4.2374	3 460 000	4.2930
2 770 000	4.1792	3 120 000	4.2390	3 470 000	4.2945
2 780 000	4.1810	3 130 000	4.2407	3 480 000	4.2961
2 790 000	4.1828	3 140 000	4.2423	3 490 000	4.2976
2 800 000	4.1846	3 150 000	4.2439	3 500 000	4.2991
2 810 000	4.1863	3 160 000	4.2456	3 510 000	4.3007
2 820 000	4.1881	3 170 000	4.2472	3 520 000	4.3022
2 830 000	4.1899	3 180 000	4.2488	3 530 000	4.3037
2 840 000	4.1916	3 190 000	4.2504	3 540 000	4.3052
2 850 000	4.1934	3 200 000	4.2520	3 550 000	4.3068
2 860 000	4.1951	3 210 000	4.2537	3 560 000	4.3083
2 870 000	4.1968	3 220 000	4.2553	3 570 000	4.3098
2 880 000	4.1986	3 230 000	4.2569	3 580 000	4.3113
2 890 000	4.2003	3 240 000	4.2585	3 590 000	4.3128
2 900 000	4.2020	3 250 000	4.2601	3 600 000	4.3143
2 910 000	4.2038	3 260 000	4.2617	3 610 000	4.3158
2 920 000	4.2055	3 270 000	4.2633	3 620 000	4.3173
2 930 000	4.2072	3 280 000	4.2649	3 630 000	4.3188
2 940 000	4.2089	3 290 000	4.2664	3 640 000	4.3203
2 950 000	4.2106	3 300 000	4.2680	3 650 000	4.3218
2 960 000	4.2123	3 310 000	4.2696	3 660 000	4.3233
2 970 000	4.2140	3 320 000	4.2712	3 670 000	4.3248
2 980 000	4.2157	3 330 000	4.2728	3 680 000	4.3263
2 990 000	4.2174	3 340 000	4.2743	3 690 000	4.3278

Northing (meters)	Log of (XV)	Northing (meters)	Log of (XV)	Northing (meters)	Log of (XV)
3 700 000	4.3293	4 050 000	4.3801	4 400 000	4.4293
3 710 000	4.3307	4 060 000	4.3816	4 410 000	4.4307
3 720 000	4.3322	4 070 000	4.3830	4 420 000	4.4321
3 730 000	4.3337	4 080 000	4.3844	4 430 000	4.4334
3 740 000	4.3352	4 090 000	4.3858	4 440 000	4.4348
3 750 000	4.3367	4 100 000	4.3872	4 450 000	4.4362
3 760 000	4.3381	4 110 000	4.3887	4 460 000	4.4376
3 770 000	4.3396	4 120 000	4.3901	4 470 000	4.4390
3 780 000	4.3411	4 130 000	4.3915	4 480 000	4.4404
3 790 000	4.3425	4 140 000	4.3929	4 490 000	4.4417
3 800 000	4.3440	4 150 000	4.3943	4 500 000	4.4431
3 810 000	4.3455	4 160 000	4.3957	4 510 000	4.4445
3 820 000	4.3469	4 170 000	4.3971	4 520 000	4.4459
3 830 000	4.3484	4 180 000	4.3985	4 530 000	4.4473
3 840 000	4.3499	4 190 000	4.4000	4 540 000	4.4486
3 850 000	4.3513	4 200 000	4.4014	4 550 000	4.4500
3 860 000	4.3528	4 210 000	4.4028	4 560 000	4.4514
3 870 000	4.3542	4 220 000	4.4042	4 570 000	4.4528
3 880 000	4.3557	4 230 000	4.4056	4 580 000	4.4541
3 890 000	4.3571	4 240 000	4.4070	4 590 000	4.4555
3 900 000	4.3586	4 250 000	4.4084	4 600 000	4.4569
3 910 000	4.3600	4 260 000	4.4098	4 610 000	4.4583
3 920 000	4.3615	4 270 000	4.4112	4 620 000	4.4596
3 930 000	4.3629	4 280 000	4.4126	4 630 000	4.4610
3 940 000	4.3644	4 290 000	4.4140	4 640 000	4.4624
3 950 000	4.3658	4 300 000	4.4154	4 650 000	4.4637
3 960 000	4.3672	4 310 000	4.4168	4 660 000	4.4651
3 970 000	4.3687	4 320 000	4.4182	4 670 000	4.4665
3 980 000	4.3701	4 330 000	4.4196	4 680 000	4.4678
3 990 000	4.3715	4 340 000	4.4210	4 690 000	4.4692
4 000 000	4.3730	4 350 000	4.4223	4 700 000	4.4706
4 010 000	4.3744	4 360 000	4.4237	4 710 000	4.4720
4 020 000	4.3758	4 370 000	4.4251	4 720 000	4.4733
4 030 000	4.3773	4 380 000	4.4265	4 730 000	4.4747
4 040 000	4.3787	4 390 000	4.4279	4 740 000	4.4761

Northing (meters)	Log of (XV)	Northing (meters)	Log of (XV)	Northing (meters)	Log of (XV)
4 750 000	4.4774	5 050 000	4.5183	5 350 000	4.5593
4 760 000	4.4788	5 060 000	4.5197	5 360 000	4.5607
4 770 000	4.4802	5 070 000	4.5211	5 370 000	4.5620
4 780 000	4.4815	5 080 000	4.5224	5 380 000	4.5634
4 790 000	4.4829	5 090 000	4.5238	5 390 000	4.5648
4 800 000	4.4843	5 100 000	4.5251	5 400 000	4.5662
4 810 000	4.4856	5 110 000	4.5265	5 410 000	4.5675
4 820 000	4.4870	5 120 000	4.5279	5 420 000	4.5689
4 830 000	4.4883	5 130 000	4.5292	5 430 000	4.5703
4 840 000	4.4897	5 140 000	4.5306	5 440 000	4.5717
4 850 000	4.4911	5 150 000	4.5320	5 450 000	4.5730
4 860 000	4.4924	5 160 000	4.5333	5 460 000	4.5744
4 870 000	4.4938	5 170 000	4.5347	5 470 000	4.5758
4 880 000	4.4952	5 180 000	4.5361	5 480 000	4.5772
4 890 000	4.4965	5 190 000	4.5374	5 490 000	4.5785
4 900 000	4.4979	5 200 000	4.5388	5 500 000	4.5799
4 910 000	4.4993	5 210 000	4.5401	5 510 000	4.5813
4 920 000	4.5006	5 220 000	4.5415	5 520 000	4.5827
4 930 000	4.5020	5 230 000	4.5429	5 530 000	4.5841
4 940 000	4.5033	5 240 000	4.5442		
4 950 000	4.5047	5 250 000	4.5456		
4 960 000	4.5061	5 260 000	4.5470		
4 970 000	4.5074	5 270 000	4.5483		
4 980 000	4.5088	5 280 000	4.5497		
4 990 000	4.5102	5 290 000	4.5511		
5 000 000	4.5115	5 300 000	4.5524		
5 010 000	4.5129	5 310 000	4.5538		
5 020 000	4.5142	5 320 000	4.5552		
5 030 000	4.5156	5 330 000	4.5566		
5 040 000	4.5170	5 340 000	4.5579		

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