Supers. by FM 6-2 (June 70)



# FM 6-2

DEPARTMENT OF THE ARMY FIELD MANUAL

# ARTILLERY SURVEY



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FIELD MANUAL No. 6–2

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., *12 August 1965*

# ARTILLERY SURVEY



* This manual supersedes FM 6–2, 7 August 1961 and Chapter 3, FM 6–125, 23 April 1963.

# PART ONE

# ARTILLERY SURVEY OPERATIONS AND PLANNING

## CHAPTER 1

## GENERAL

### 1. Purpose

This manual is a guide for commanders, survey officers, and personnel engaged in the conduct of artillery surveys. It provides a basis for instruction, guidance, and reference in surveying principles and procedures and in the operation and care of surveying instruments. Procedures covering all situations cannot be prescribed; therefore, these instructions should be used as a guide in developing suitable techniques. The material presented herein is applicable without modification to both nuclear and nonnuclear warfare.

### 2. Scope

This manual discusses the survey personnel and equipment available to artillery units, the measurement of angles and distances, and the determination of relative locations on a rectangular grid system.

### 3. References

Publications used as references for the manual and those offering further technical information are listed in appendix I.

### 4. Changes and Corrections

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to Commandant, U. S. Army Artillery and Missile School, ATTN: AKPSIPL, Fort Sill, Okla.

### 5. Mission of Artillery Survey

The mission of artillery survey is to provide a common grid which will permit the massing of fires, the delivery of surprise observed fires, the delivery of effective unobserved fires, and the transmission of target data from one unit to another. The establishment of a common grid is a command responsibility.

### 6. Fundamental Operations of Survey

Survey results are obtained from the following:

*a. Planning.* A thorough plan which includes reconnaissance and gives full consideration to the factors affecting survey and conforms to basic essentials contributes to successful accomplishment of the survey mission.

*b. Fieldwork.* Survey fieldwork consists of:

(1) Measuring distances.

(2) Measuring horizontal and/or vertical angles.

(3) Recording all pertinent data.

*c. Computations.* Computations are performed simultaneously with the fieldwork. Known data and the fieldwork data are combined to produce the location and/or height of a point and/or the direction of a certain line.

### 7. Responsibilities of the Corps of Engineers

*a. Responsibility.* The survey responsibilities of the Corps of Engineers are described in AR 117–5 and TM 5–231. The Corps of Engineers is responsible for the establishment and extension of basic geodetic control in support of artillery and missile units. Close coordination between engineer and artillery and missile survey units must be maintained because exact methods and procedures for joint operations and boundaries of responsibility can be established only after careful analysis of each survey problem.

*b. Functions.* Corps of Engineers topographic units will—

(1) Extend all geodetic control required to the area of operation of artillery and missiles, perform all geodetic surveys to an accuracy of third order or higher as required for control of artillery and missile fire and assist, when required, in making astronomic observations to obtain azimuths for the control system of missile launching units.

(2) Carry an adequate azimuth from primary (first- or second-order accuracy) geodetic control stations to the area of operations of the missile unit, regardless of the zone of operations, when conditions prevent the unit from obtaining an astronomic azimuth of the required accuracy.

(3) When required for artillery and missile units operating outside of the corps zone, extend existing control to the unit area.

(4) Furnish existing control data. Whenever practicable, the control data will be furnished on the prescribed military grid.

*c. Division of Effort.* The establishment and extension of control into the corps area are functions of the engineer topographic unit. The surveyors of the field artillery target acquisition battalion extend control throughout the corps area and into the division areas.

## 8. General Responsibilities of Artillery Units

Each artillery commander is responsible for seeing that required survey control, consisting of position location and an orienting line of known direction, is furnished to subordinate units as soon as possible.

# CHAPTER 2

# FIELD ARTILLERY BATTALION AND BATTERY SURVEY OPERATIONS

## Section I. GENERAL

### 9. General

*a.* This section covers survey operations for all field artillery battalions and batteries which have survey requirements, except field artillery target acquisition battalions and batteries. Survey operations for field artillery target acquisition units are discussed in chapter 3.

*b.* Survey operations are performed by survey personnel in the field artillery battalions and smaller units to obtain the horizontal and vertical locations of points to be used in determining firing data to provide a means of orienting weapons, instruments, radars, and such other equipment or positions requiring this control. Survey operations of separate or detached batteries are performed for the same purpose.

### 10. Battalion Survey Control

*a.* Battalion installations must be located with respect to a common grid to permit massing of the fires of two or more battalions. This grid should be the grid of the next higher echelon whenever survey control points on that grid are available or when it is desired to mass the fires of more than one battalion.

*b.* A battalion survey control point (BnSCP) is a point established by a higher survey echelon for the purpose of furnishing survey control to the battalion. One or more such points may be established for a battalion.

### 11. Survey Control Points on Grid of Next Higher Echelon

Survey control points on the grid of the next higher echelon may be available in the form of—

*a.* One or more trig points in the vicinity of the battalion installations. When available, trig points should be used as the basis for battalion survey operations if survey control points for the battalion have not been established by the next higher echelon.

*b.* One or more survey control points which have been established between 1,500 and 2,000 meters of the battalion installations by the next higher echelon. These survey control points should be used as the basis for battalion survey operations.

### 12. Use of Assumed Data

When neither trig points nor survey control points exist in the vicinity of the battalion (battery) installations, the battalion (battery) survey officer must establish a point and assume data for that point. The assumed data should closely approximate the correct data. This point (and its assumed data) establishes the battalion (battery) grid and is used as the basis for the battalion (battery) survey operations. When the next higher echelon establishes control in the battalion (battery) area, the assumed data must be converted to that control.

### 13. Converting to Grid of Next Higher Echelon

*a.* The methods of converting survey data are described in chapter 15. Unless the tactical situation causes the commander to decide otherwise, battalion (battery) data are converted to those of the next higher echelon when data differ by—

(1) Two mils or more in azimuth.

(2) Ten meters or more in radial error.

(3) Two meters or more in height.

*b.* If the battalion survey officer verifies that the battalion survey data is correct, he reports to his commander and to the survey officer of the next higher echelon any differences which may exist between the battalion survey data and the data provided by the next higher echelon.

*c*. If the next higher echelon converts its survey control to a different grid, the battalion must also convert to that grid.

## 14. Survey Methods

Field artillery battalion survey operations may be performed by using any or all of the artillery survey methods, provided the limitations of the selected methods are not exceeded. A comparison of the different methods is shown below.

*a. Traverse*. For most artillery survey operations, traverse (ch. 8) is the best method to use because of its simplicity, flexibility, and accuracy when performed over open terrain for comparatively short distances. In rough terrain, a tape traverse is time consuming and triangulation or distance-measuring equipment (DME) traverse should be used.

*b. Triangulation*. Triangulation (ch. 9) should be used in rough terrain where taping is difficult and would require an excessive expenditure of time. In gently rolling or flat, treeless terrain, traverse is faster than triangulation unless distances between stations exceed 1,500 to 2,000 meters. If the survey is to cover a large area or if there are considerable distances between stations, triangulation will save time and personnel. However, a more extensive reconnaissance is required for triangulation than for traverse.

*c. Intersection*. Locating the position of a point by intersection (ch. 9) is relatively simple and fast. However, this method depends on intervisibility between the ends of the base line and the unknown point. Intersection must be used to locate points beyond friendly frontlines. When practicable, these locations should be checked by intersection from more than one base.

*d. Resection*. The resection method of locating a point (ch. 9) requires very little fieldwork. Resection normally is used in artillery battalion survey to establish battery centers, observation posts, or other point locations in areas where the only existing control is on points which are inaccessible. Resection is used to improve map-spotted or assumed data. Any location determined by resection should be checked by a separate determination (preferably traverse or triangulation) at the first opportunity.

## 15. Use of Astronomic Observation

The problem of converting data to a common grid is greatly simplified if survey personnel use the correct grid azimuth to initiate survey operations. True azimuth can be obtained from astronomic observation or by use of the azimuth gyro and converted to grid azimuth. Battalion survey personnel should be trained to determine grid azimuth by observation of the sun and stars. They should also be trained in obtaining direction by simultaneous observations.

## 16. Division of Battalion and Battery Survey Operations

*a*. The survey operations of a field artillery battalion (separate or detached battery) consist of one or more of the following:

(1) Position area survey.

(2) Connection survey.

(3) Target area survey.

*b*. The survey operations performed by a field artillery battalion or a separate or detached field artillery battery depend mainly on three factors as follows:

(1) The type of unit (including assignment and mission).

(2) The availability of survey control.

(3) The amount of time available in which to perform initial survey operations.

## 17. Sequence of Battalion (Battery) Survey Operations

Battalion (battery) survey operations are performed in the sequence listed below:

*a. Planning (Including Reconnaissance)*. A general discussion of survey planning is contained in chapter 5. *To insure maximum effectiveness, battalion (battery) survey operations should be planned and initiated prior to the occupation of position.*

*b. Fieldwork.* Fieldwork consists of measuring angles and distances necessary to determine the survey data required to establish survey stations. The assignment of personnel to accomplish the required fieldwork is determined by the number of surveying parties available and the unit SOP.

*c. Computations.* Each survey computation must be performed by two computers working independently and, when possible, be checked with a slide rule by the chief of party. When possible, survey computations should be performed concurrently with the determination of field data. *This will insure that errors are detected at the earliest possible time and will facilitate the early use of a surveyed firing chart.*

*d. Dissemination of Data.* After the survey data have been determined, the battalion survey personnel furnish the computed data to the fire direction center for preparation of the firing chart. In the case of missile battalions, the data is used in the computer.

## 18. Survey Operations of Searchlight Batteries

When suitable maps are not available, survey operations are performed by personnel of searchlight batteries for the purpose of determining orienting data for the searchlights. The survey operations performed are those necessary to establish the grid coordinates and height of each searchlight. In addition, a grid azimuth for directional orientation of the searchlights must be established.

## 19. Survey of Alternate Positions

Survey operations for alternate positions should be performed as soon as survey operations are completed for primary positions. The requirements for alternate positions are identical with the requirements for primary positions.

## 20. Limited Time Survey

Battalion (battery) survey personnel must provide the best possible data for construction of the firing chart and the best means of orienting weapons in the time available. When time is a consideration, the survey officer must plan and accomplish the survey operations necessary to furnish the fire direction officer with an improved firing chart. The extent of the survey conducted and the methods employed will depend primarily on the time available. The procedures used for accomplishing the division of operations may be any combination of the following:

*a. Position Area Survey.*

(1) Map-spot the battery centers. Determine direction by compass, declinated aiming circle, astronomic observation, or azimuth gyro, as time and weather permit.

(2) Map-spot the center battery, and locate the flank batteries by open traverse. Determine a starting direction as in (1) above.

(3) Map-spot a battalion SCP and locate the batteries by open traverse. Determine starting direction as in (1) above.

*b. Connection Survey.*

(1) Establish control by firing.

(2) Use a map for the connection survey. Transmit direction by simultaneous observation (weather permitting) or by directional traverse.

*c. Target Area Survey.*

(1) *Target area base.*

(*a*) Map-spot 01 and traverse to locate 02.

(*b*) Map-spot a target area survey control point and traverse to locate 01 and 02.

(*c*) Map-spot a target area survey control point and intersect 01 and 02 from an auxiliary base.

(2) *Critical points.*

(*a*) Map-spot all critical points.

(*b*) Perform intersection from a target area base.

## Section II. POSITION AREA SURVEY

### 21. General

*a.* Survey control is required in the position area of each firing battery. The battery center is the point surveyed for cannon batteries, whereas the launcher position is the point surveyed for rockets and missiles. Position area survey is performed by battalion (separate or detached battery) survey personnel for the purpose of—

(1) Locating weapons positions and radars.

(2) Providing means for orienting weapons and radars.

*b.* The position area survey for field artillery cannon and missile units is usually performed to a minimum prescribed accuracy of fifth-order (1:1,000); however, when the TOE of the unit authorizes the aiming circle M2 as the instrument for survey, the position survey is performed to a minimum prescribed accuracy of 1:500.

### 22. Terms Used in Conjunction With Position Area Survey

The following terms are used in conjunction with position area surveys:

*a. Battery center*—A point on the ground at the approximate geometric center of the weapons position. The battery center is the chart location of the battery (FM 6–40). The location of the battery center is designated by the battery commander or battery executive. The survey officer may select a tentative battery center if the battalion (battery) SOP so states.

*b. Orienting line*—A line of known direction established near the firing battery, which serves as a basis for laying for direction (FM 6–40). (The azimuth of the orienting line (OL) is included in the data reported to the fire direction center.)

*c. Orienting station*—A point on the orienting line, established on the ground, at which the battery executive sets up an aiming circle to lay the pieces (FM 6–40). The location of the orienting station is designated by the battery commander or battery executive. The survey officer may select the location of the orienting station if the battalion (battery) SOP so states.

*d. Registration point*—A point in the target area the location of which is known on the ground and on the firing chart (FM 6–40).

*e. Direction of fire*—A base direction of fire for all weapons of the firing unit. It may be the computed azimuth from the battery center to the registration point or a selected azimuth of fire assigned to the unit by the battalion commander or other authority.

*f. Orienting angle*—The horizontal, clockwise angle from the direction of fire to the orienting line. The orienting angle determined by survey personnel is computed by subtracting the azimuth of the desired line of fire from the azimuth of the orienting line, adding 6,400 mils to the azimuth of the orienting line if necessary.

*g. Radar orienting point*—A point used to orient the radar. The radar operating point for field artillery radar sets is established in a direction as nearly in the center of sector of search of the radar as possible. The radar officer furnishes to the survey officer the approximate azimuth on which the radar orienting point should be established.

### 23. Method of Performing Position Area Survey

Any method or combination of methods listed in paragraph 14 may be used to perform the position area survey. The method most commonly used is traverse. The position area survey is initiated at a survey control point, the point that establishes the unit grid, or a station established by the connection survey. The survey is closed on the starting point or on a station established to an accuracy equal to or greater than that of the survey being performed.

### 24. Survey for Weapons Positions

*a.* In surveying a weapons position, an orienting station, from which all battery weapons should be visible, is established near the battery center. Normally, this point is used as one end of the orienting line, and the traverse leg used to establish the station is used as the orienting line. This makes the orienting line a leg of the closed traverse, thus permitting the detection of an error in the OL should the traverse not close in azimuth. If a traverse leg cannot be used as the orienting line, a prominent terrain object at least 300 meters away should be used as the end of the OL. The azimuth of this line is determined by measuring, at the orienting station, the angle from the last traverse station to the selected point. For all night operations, the orienting line must be prepared for orientation of the weapons by placing a stake equipped with a night lighting device on the orienting line approximately 100 meters from the orienting station. When an intermediate point cannot be established on the orienting line, an alternate orienting line is established on which the night orienting point can be set up.

*b*. The coordinates and height of the battery center are determined by establishing a traverse station over the battery center or by establishing an offset leg (an open traverse leg) from the orienting station to the battery center.

### 25. Survey for Radar

One countermortar radar is organic to each divisional direct support artillery battalion. The coordinates and height of the radar position and a line of known direction are required to properly orient the system. It may be necessary to determine the same data for the surveillance radar of division artillery should it be located near the battalion position area.

*a*. Data for the radars are determined in the same manner as data for weapons positions. An orienting azimuth from the radar positioning stake to an orienting point must be determined.

*b*. The height of the radar antenna also must be computed. Height is determined by measuring the distance from the ground to the parabola, to the nearest 0.1 meter, by means of a steel tape. The distance measured is added to the computed ground height.

## Section III. CONNECTION SURVEY

### 26. General

*a*. Connection survey is that part of the survey operation performed by battalion (separate battery) survey personnel for the purpose of placing the target area survey and the position area survey on a common grid.

*b*. Connection surveys are performed to fifth-order accuracy.

### 27. Methods of Performing Connection Survey

*a*. A closed traverse normally is used to perform the connection survey, although triangulation may be used when the terrain is unsuitable for traverse. The connection survey is used to establish a target area survey control point or one or more of the target area base observation posts from which target area base survey operations are initiated. The connection survey is usually initiated at a station on the position area survey. The station may be a Bn SCP or the point which establishes the battalion grid. When the connection survey is initiated at a Bn SCP it may close on that SCP or on any other SCP established to an accuracy of 1:1,000 or greater on the same grid as the Bn SCP. When the connection survey is initiated at the point that establishes the battalion grid (i.e., when data for the starting point is assumed), it must close on the starting point. This point does not become the Bn SCP unless survey control for the point is established by the next higher echelon of survey.

*b*. A secondary requirement for connection survey may include providing control for the mortars within the supported brigade or for radars and other target acquisition devices located within the area of operation. Control is extended to these installations as time permits. The requirements of the artillery battalion takes priority in these instances.

*c*. Since missile units are normally employed in a general support or reinforcing role, they normally receive target data from higher headquarters or the supported unit. Therefore, these units do not perform target area or connection survey.

## 28. General

Target area survey is that part of the survey operation performed by battalion (detached battery) survey personnel for the purpose of establishing the target area base and locating critical points and targets in the target area; i.e., registration point(s) and restitution points.

## 29. Terms Used in Conjunction With Target Area Survey

*a. Target Area Base.* A target area base consists of two or more observation posts which are used to locate the critical points in the target area and/or targets of opportunity and to conduct center-of-impact and high-burst registrations. When there are more than two observation posts, any two of them can be used to form an intersection base.

*b. Azimuth Mark for Target Area Observation Post.* An azimuth mark is a reference point used to orient the instrument at each observation post. The azimuth to the azimuth mark may be determined by using the back-azimuth of a traverse or intersection leg used to locate the observation post. The adjacent observation post (when OP's are intervisible) may also be used as an azimuth mark. An auxiliary or intermediate orienting point should be established for night operations.

## 30. Selection of Observation Posts

*a.* Initially, two or more observation posts are established at points from which the critical points in the target area are visible. If possible, the distance between any two observation posts should be sufficient to insure a minimum angle of intersection of 300 mils at any of the critical points. These minimum angles at the critical points in the target area are necessary to insure results that approach the accuracies prescribed for target area survey. If the observation posts of the target area base cannot be located sufficiently far apart to provide a minimum angle or intersection of 300 mils, they should be located as far apart as possible. *In any case, the distance between observation posts that are used as the ends of an intersection base must be sufficient to provide a minimum angle of intersection of 150 mils at any critical point in the target area.* The consistent accuracy that can be obtained from the location of points with angles of this minimum size is approximately 1:200.

*b.* The location of each critical point should be checked from at least two intersection bases. As soon as possible, additional observation posts should be selected to provide this check. Besides providing the check, the additional observation posts should provide observation into the unit's zone of action, especially into those areas which are not visible from the observation posts originally selected.

## 31. Methods of Performing Target Area Base Survey

*a.* The method of survey normally used by the survey party in the field artillery battalion to perform the target area base survey is a closed traverse. If the enemy situation is such that traversing to an OP would disclose its position, and if the terrain allows, triangulation is used. On some occasions, it may be necessary to locate the OP by intersection or offset from a traverse station in the vicinity of the OP. The OP's are located to fifth-order accuracy.

*b.* In issuing the survey order, the survey officer designates which of the survey parties is to perform the target area base survey. The specific location of each OP may also be designated or an approximate location may be given and the specific location left to the discretion of the chief surveyor or chief of party. The location of a target area survey control point is given. If one OP is located as part of the connection survey, it may be designated as the target area survey control point.

*c.* The observation posts are designated 01, 02, etc. 01 is considered the control OP and is plotted on the firing chart. 01 may be on the right or left. 01 is always that OP requiring the least amount of fieldwork to establish its location since less directional accuracy is lost through angular measurements when the number of main scheme angles is held to a minimum. Examples of target area base surveys are shown in figure 1.

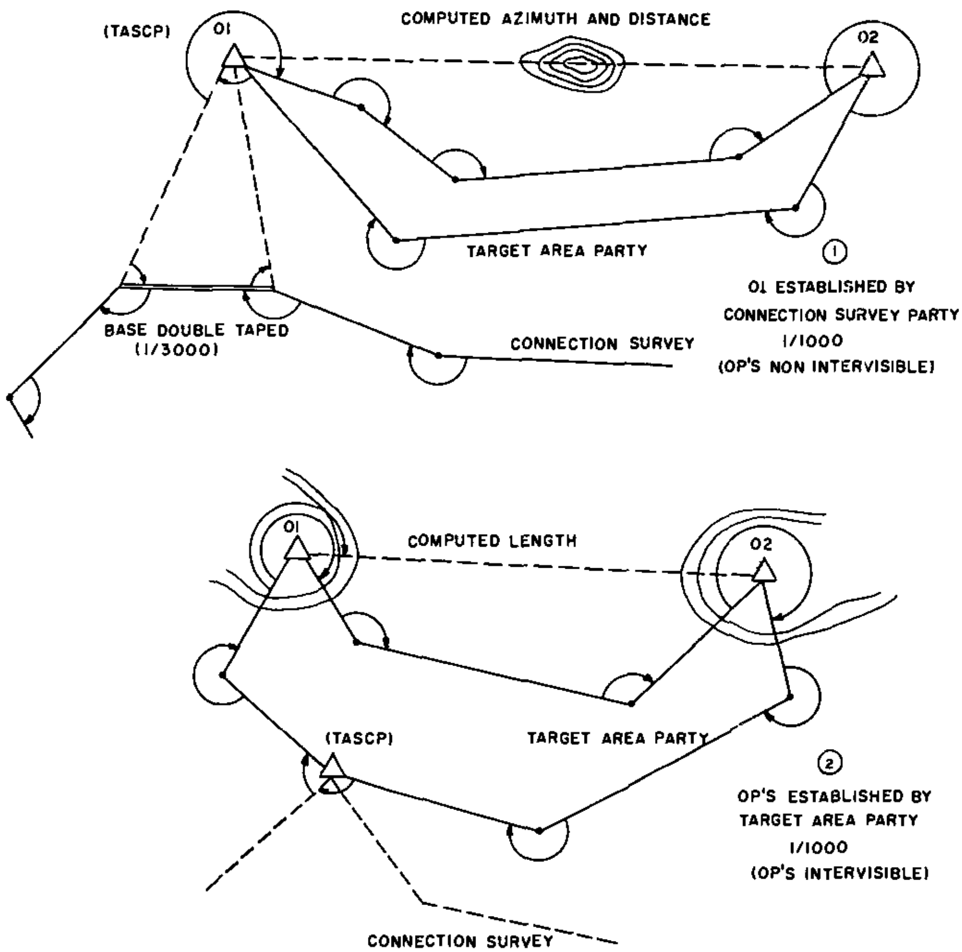
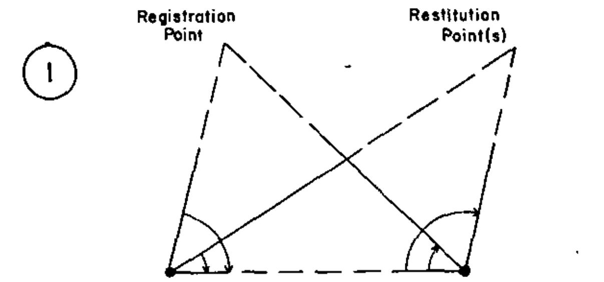



*Figure 1. Target area base survey.*

## 32. Method of Performing Target Area Survey

*a.* Intersection must be used to perform the target area survey. The length of each intersection base of the target area base is obtained by computation from the coordinates of the two observation posts that establish the base. (The length of the base may be determined by double-taping to a comparative accuracy of 1:3,000 *when the base is located in an area not under direct observation of the enemy.*) If the observation posts are intervisible, the azimuth of the base is determined by measuring the horizontal angle at an observation post from the rear station to the observation post at the other end of the base. If the observation posts are not intervisible, the azimuth of the base is determined by computation, using the coordinates of the ends of the base.

*b.* If the observation posts are intervisible, the interior horizontal angles are measured (1, fig. 2). If the observation posts are not intervisible, the angles at the ends of the base must be determined by comparing the azimuth of the base with the azimuth from each observation post to the point being located (2, fig. 2). The azimuth of the line from each observation post to the critical point is determined by measuring the horizontal angle, at the observation post, from the established azimuth mark (orienting station for night operations) to the point in the target area. When the critical point does not present a clearly defined vertical line and cannot be accurately bisected, the horizontal angles are measured by using a special technique of pointing. Pointings are made by placing the vertical line in the reticle on the left edge of the object in measuring the first value of the angle and by placing the vertical



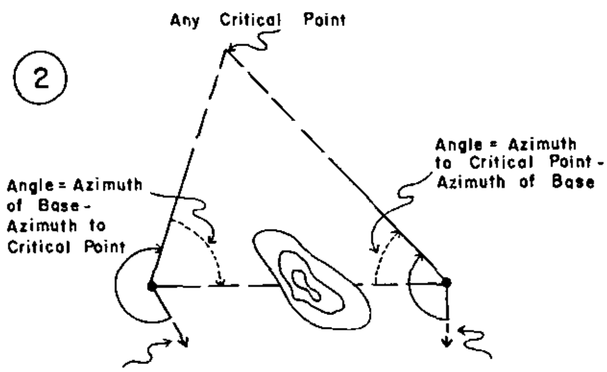




*Figure 2. Target area survey.*

line in the reticle on the right edge of the object in measuring the second value of the angle, accumulating these angles on the aiming circle. The angles are meaned. The mean angle obtained with this method must be verified by determining at least one more mean angle by using the same technique. The accumulated value of the first set (one pointing to each edge of the object) should agree with the accumulated value of the second set within 1 mil. The means of both sets are then meaned to provide an angle to the point to the nearest 0.1 mil.

*c.* Vertical angles are measured to the lowest visible point on the object.

*d.* The distance from either end of the intersection base to each critical point is computed by using the base length determined in *a* above and the angles determined by direct measurement (1, fig. 2) or by comparison of azimuths (2, fig. 2). The coordinates and height of each point are determined in the same manner in which they are determined by triangulation (chap 9).

*e.* The party performing the target area survey furnishes the location of the registration point(s) to the party performing the position area survey for computation of the orienting angle(s).

*f.* The locations of critical points determined from the target area base should be checked by establishing a second intersection base. A second intersection base can be established by using a third observation post and either of the two initial observation posts.

## 33. Center-of-Impact and High-Burst Registrations

In either a center-of-impact (CI) or high-burst (HB) registration, a group of rounds is fired in order to determine corrections to firing data. The location of the center of the group of rounds must be determined and then plotted on the firing chart. One method commonly used to determine the location of the burst center is by a computed intersection from the 01–02 target area base. This method requires that the bursts be observed by both 01 and 02; therefore, primary consideration must be given to the topography of the impact area and the location of each observation post. For a high-burst registration, which is conducted with time fuze to obtain airbursts, these considerations are normally of lesser importance than for a center-of-impact registration. For a center-of-impact registration, for which impact fuze is employed, the burst area should be free of trees, buildings, sharp ravines, etc. A gentle forward slope, free of all vegetation, or the center of a lake is ideal. When a center-of-impact or high-burst registration is conducted, the location of each observer and the desired point of burst are known at the fire direction center. The fire direction center determines and furnishes to each observer the azimuth and vertical angle to the expected point of burst. The message to the observers from the fire direction center includes instructions to the observer at 01 to measure the vertical angle to each burst. A typical message to the observers from the fire direction center is as follows: "*Observe high burst (or center of impact). 01 azimuth 1049, vertical angle + 15, measure the vertical angle.*

*02 azimuth 768, vertical angle + 12. Report when ready to observe."* Each observer orients his instrument on the azimuth and vertical angle given for his OP and reports to the FDC when ready to observe. One round at a time is fired, and *"On the way"* is given to the observers for each round. The first round fired is normally an orienting round, and each observer orients the center of the reticle of his instrument on the burst and records the scale readings of his instrument corresponding to the new position of the telescope. After the observer orients his instrument on the orienting round, he normally should not have to change the orientation during the rest of the registration. One round at a time is fired until six usable rounds have been obtained (excluding erratic rounds and rounds observed by only one observer). After the instrument has been oriented on the orienting round, the deviation observed for each burst is combined with the reference reading on the instrument scales to derive the azimuth to the burst. The same general procedure is used to measure the vertical angle. Both observers report azimuth readings to the fire direction center after each round, but only the observer at 01 reports the vertical angle. At the fire direction center, the instrument readings from 01 and 02 for the six usable rounds are used to determine the mean point of burst for the registration.

## 34. Computation of Center of Impact and High Burst

The target area base may be used as a tool in performing a center-of-impact or high-burst registration. Normally the computations associated with the instrument readings to determine the location of the center of impact or high burst are performed by the fire direction personnel. A knowledge of the manner in which these computations are performed is of value to the survey personnel operating the target area base. The computations are normally made on DA Form 6–55.

*Example:*

| | | |
|---|---|---|
| *Given:* | Coordinates of 01: | (561599.8–3839123.3) |
| | Azimuth 01 to 02: | 3,960 mils |
| | Distance 01 to 02: | 843 meters |
| | Height 01: | 453 meters |

*Instrument readings of usable rounds*

| *Round* | *Azimuth 01 (mils)* | *Vertical ∢ 01 (mils)* | *Azimuth 02 (mils)* |
|---|---|---|---|
| 1 | 5,710 | +24 | 5,959 |
| 2 | 5,710 | +28 | 5,950 |
| 3 | 5,708 | +29 | 5,953 |
| 4 | 5,705 | +25 | 5,951 |
| 5 | 5,715 | +23 | 5,952 |
| 6 | 5,713 | +26 | 5,955 |

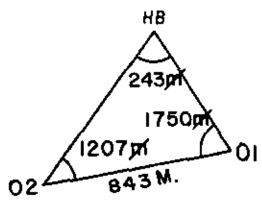
*Requirement:* Solve for the azimuth and distance from 01 to the center of the high burst and the height of the high burst, using DA Form 6–55 (fig. 3).

**HIGH BURST (*CENTER OF IMPACT*) REGISTRATION**
(FM 6-40)

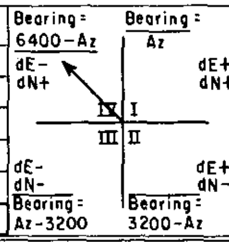
**COMPUTATION OF HB (CI) LOCATION**

| Data Fired | Chg | Df | FS | QE |
|---|---|---|---|---|
| | | | | |

| Observer Readings | | | | Interior Angles | | | |
|---|---|---|---|---|---|---|---|
| Rd Nr | O1 Az | VA | O2 Az | O1 on Left | | O1 on Right | |
| 1 | 5710 | 24 | 5959 | Az O1→O2 | | Az O1→HB ~~(CI)~~ | 5710 |
| 2 | 5710 | 28 | 5950 | +6400 if necessary | | +6400 if necessary | — |
| 3 | 5708 | 29 | 5953 | Total | | Total | 5710 |
| 4 | 5705 | 25 | 5951 | −Az O1→HB (CI) | | −Az O1→O2 | 3960 |
| 5 | 5715 | 23 | 5952 | ∡ at O1 | | ∡ at O1 | 1750 |
| 6 | 5713 | 26 | 5955 | Az O2→HB (CI) | | Az O2→O1 | 760 |
| 7 | | | | +6400 if necessary | | +6400 if necessary | 6400 |
| 8 | | | | Total | | Total | 7160 |
| 9 | | | | −Az O2→O1 | | −Az O2→HB (CI) | 5953 |
| 10 | | | | ∡ at O2 | | ∡ at O2 | 1207 |
| | 34261 | 155 | 35720 | Total | | | |
| | 5710 | 26 | 5953 | Average | | | |




| Apex Angle | |
|---|---|
| ∡ at O1 | 1750 |
| +∡ at O2 | 1207 |
| Sum | 3057 |
| | 3200 |
| −Sum | 3057 |
| Apex Angle | 243 |




| Az O1→HB→Bearing |
|---|
| 6400 |
| 5710 |
| Bearing |
| N690W |

| Distance O1 HB (CI) | | | | |
|---|---|---|---|---|
| Log base O1→O2 | 843M. | 2 | 925 | 828 |
| +Log sin ∡ at O2 | 1207m̸ | 9 | 966 | 840 |
| Sum | | 2 | 892 | 668 |
| −Log sin Apex Angle | 243m̸ | 9 | 373 | 479 |
| diff=Log dist O1→HB(CI) | | 3 | 519 | 189 |
| Dist O1→HB ~~(CI)~~* | | 3305.1 M | | |

Log conversion factor, meters to yards add 0.038863

*Determine the distance O1—HB (CI) to check computations of dE, dN & dH by polar plotting from O1 on average azimuth and computed dist

**Log of dE, dN, and dH**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Log dist O1→HB (CI) | 3 | 519 | 189 | Log dist O1→HB (CI) | 3 | 519 | 189 | Log dist O1→HB (CI) | 3 | 519 | 189 |
| Log sin Bearing | 9 | 797 | 111 | Log cos Bearing | 9 | 891 | 650 | Log Tan Vert ∡ | 8 | 407 | 068 |
| Sum= Log dE | 3 | 316 | 300 | Sum= Log DN | 3 | 410 | 839 | Sum= Log dH | 1 | 926 | 257 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Coordinates of O1 | E | 561 599.8 | N | 3 839 123.3 | H | 453.0 |
| | ± dE | 2 071.6 | ± dN | 2 575.4 | ± dH | 84.4 |
| Location of HB (CI) | E | 559 528.2 | N | 3 841 698.7 | H | 537.4 |

**COMPUTATION OF GFT SETTING**

| | | | | | |
|---|---|---|---|---|---|
| Alt HB (CI) | | QE fired | | Chart data to HB (CI) location | Df corr |
| −Alt Btry | | −Site VI/HB(CI)Rg | | Deflection ______ m̸ Range ______ M; GFT " ______ " Charge ______ Lot ______ | |
| VI | | Adj Elev | | Range ______ Elevation ______ Time ______ (HB or CI Rg) (Ti fired) | |

DA FORM 1 OCT 60 6-55

* U.S. GOVERNMENT PRINTING OFFICE : 1960 O—573493

*Figure 3. High burst registration computation (DA Form 6-55).*

# CHAPTER 3

# HIGHER ECHELON SURVEYS

## Section I. DIVISION ARTILLERY SURVEY OPERATIONS

### 35. General

*a.* Survey operations are performed by survey personnel of division artillery headquarters battery for the purpose of placing the field artillery units organic, assigned, or attached to the division on a common grid.

*b.* Division artillery surveys are executed to a prescribed accuracy of fourth-order. Specifications and techniques for fourth-order survey are given in appendix II.

### 36. Division Artillery Survey Officer

*a.* A survey officer is assigned to the division artillery staff. The division artillery survey officer plans and supervises the division artillery survey operations. He advises the commander and appropriate staff officers on matters pertaining to survey. He coordinates the survey operations of the field artillery battalions (separate batteries) within the division.

*b.* The division artillery survey officer should maintain close liaison with the corps artillery survey officer to obtain data for survey control points which have been established in the division area by the target acquisition battalion. The use of these points can save time and can eliminate unnecessary duplication of survey operations. He can also obtain data for points established in the vicinity of the target area; the data for these points can be used by the battalion survey parties in performing target area surveys.

### 37. Division Artillery Survey Information Center

*a.* A file of survey information and a survey information map are maintained in a survey information center (SIC) at the division artillery headquarters. The survey information center is normally located in the operation center at the division artillery command post.

*b.* The survey information map shows the locations of survey control points and trig points and the schemes of all surveys performed by the division artillery survey section. The survey information file consists of the trig lists prepared and issued by the Corps of Engineers, the trig lists prepared by the field artillery target acquisition battalion, and data for each control point established by division artillery survey operations. The data for each control point established by division artillery are recorded on DA Form 6–5 (Record—Survey Control Point) (figs. 4 and 5).

### 38. Division Artillery Survey Control

*a.* Division artillery battalions, batteries, and other division installations that require survey control should be located with respect to a common grid. This grid should be the corps grid whenever control points on the corps grid are available. Control points on the corps grid are normally available in the form of trig points and survey control points for which data are known with respect to the universal transverse mercator (UTM) grid or universal polar stereographic (UPS) grid for the area of operations.

*b.* When neither survey control points nor trig points are available in the division area, the division artillery survey officer establishes a point and assumes data for it. This point establishes the division grid which is used as the basis for division artillery survey operations. When the assumed data for the point differ from the data subsequently established by the field artillery target acquisition battalion of corps artillery, the division artillery data are converted to the corps grid (ch. 15). Although during the initial stages of an operation, it is not necessary for division artillery to convert assumed azimuth to the corps azimuth if it differs by 0.3 mil (1 minute) or less, it should be converted as soon as practicable. In any case, coordinates and height should be converted to the corps grid.

### 39. Division Artillery Survey Operations

*a.* Division artillery survey operations should provide the best possible data at the earliest practicable time. Any of the artillery survey methods may be used to perform the surveys. In areas where survey control points are not available in the vicinity of the battalions, common direction can be provided by astronomic or gyroscopic observations or obtained by simultaneous observations.

*b.* In addition to providing survey control points for battalions and/or batteries, the division artillery survey officer may designate points for which battalion survey parties should determine survey data in order to check the accuracy of the surveys being performed by the battalions.

*c.* Normally, division artillery survey operations are performed by the division artillery survey section. When the time available to perform division artillery survey is limited, the division artillery commander may direct battalions of the artillery with the division to assist in performing the surveys necessary to establish the division artillery grid after they have completed their battalion survey operations. *When this is necessary, the division artillery survey section should, at the first opportunity, conduct another survey of those installations surveyed by the battalions.*

*d.* When a target acquisition battery is attached to a division artillery, the survey parties of the battery may perform part of the division artillery survey operations. The division artillery survey officer, in conjunction with the target acquisition battery commander, plans and supervises the coordinated survey operations.

## Section II. CORPS ARTILLERY SURVEY

### 40. General

*a.* Corps artillery survey operations are performed by the field artillery target acquisition battalion (FATAB) assigned to each corps artillery. The battalion commander of the field artillery target acquisition battalion is the corps artillery survey officer. The target acquisition battalion survey officer is responsible to the battalion commander for planning and supervising the battalion survey operations.

*b.* Provisions exist for the attachment of officers of the U. S. Coast and Geodetic Survey to the FATAB in time of war. These officers will fill positions as directed.

*c.* Survey operations are performed by survey personnel of the field artillery target acquisition battalion for the purpose of placing the field artillery with the corps (and other units requiring survey control) on a common grid and of locating the target acquisition battalion installations, which include flash, sound, and radar installations. Also included in the FATAB survey operations are the collection, evaluation, and dissemination of survey information for all surveys executed in the corps area to a prescribed accuracy of fourth-order or greater. Surveys performed by the target acquisition battalion are executed to a prescribed accuracy of fourth-order.

### 41. Survey Information Center

*a.* A survey information center is established at corps artillery and maintained by the survey personnel of headquarters battery of the target acquisition battalion. It is usually located in the vicinity of the corps artillery fire direction center. The SIC is an agency for collecting, evaluating, and disseminating survey data. The dissemination is accomplished by preparing and distributing trig lists and by furnishing survey information to personnel of other units upon request. Unless the battalion commander directs otherwise, *all survey information is disseminated in writing only through the survey information center.*

SURVEY CONTROL POINT

NAME OR DESIGNATION (SCP) BECK

554 436 44 EASTING | 3 835 704 45 NORTHING | 359 6 HEIGHT (FT / M / YD)

LOCATED BY: BTRY B, 1ST TAB 25 ARTY

NOTEBOOK REFERENCE: BOOK NR 4

AREA: FORT SILL

DATE DONE: 1 DEC 1960 | DATE FILED: 1 DEC 1960

RECORDS FILED AT: 1ST INF DIV ARTY, SIC

HOW LOCATED — HORIZONTAL: TRIG LIST; X TRAVERSE; TRIANGULATION; MAP; OTHER — VERTICAL: TRIG LIST; ALTIMETRIC; X TRIGONOMETRIC; MAP; OTHER

ACCURACY: 1ST-ORDER; 2D-ORDER; 3D-ORDER; X 1/3000; OTHER

DESCRIPTION (General and specific locations, type of mark, etc.): STATION IS 1-INCH HOLLOW PIPE IN CENTER OF 8-INCH SQUARE CONCRETE BLOCK; 5 METERS WEST AND 1½ METERS SOUTH OF SOUTHWEST CORNER OF BLDG T3077; ON FT SILL MILITARY RESERVATION.

AZIMUTH MARK

NAME OR DESIGNATION (AZ MK): WATER TOWER

EASTING | NORTHING | HEIGHT (FT / M / YD)

DISTANCE FROM SCP (Ft, M, etc.): MEASURED; X ESTIMATED — 1200 METERS

AZIMUTH FROM SCP: 42 84 73 m

HOW DETERMINED: TRIG LIST; ANGLE TURNED; MAP; TRAVERSE; X ASTRONOMIC; OTHER

OTHER AZ MKS VISIBLE FROM SCP: 2 NONE; 3; 4

DESCRIPTION (specific location, type of mark, etc.): WATER TOWER IS LARGE STEEL WATER TOWER IN 2900 AREA ON FT SILL MILITARY RESERVATION. EXACT STATION IS RED LIGHT BULB ON TOP OF TOWER.

(Station and Azimuth Mark Descriptions continued on Reverse Side)

DA FORM 1 OCT 55 6-5 — REPLACES DA FORM 6-5, 1 OCT 52, WHICH WILL BE USED UNTIL EXHAUSTED. — RECORD - SURVEY CONTROL POINT

*Figure 4. Entries made on the front of DA Form 6–5.*

*b.* Files of all fourth-order or higher survey control existing in the corps area and files of tie-in points established in adjacent corps areas by the target acquisition battalions or division artilleries are maintained in the survey information center. These files consist of trig lists published by higher headquarters (including trig lists prepared by the Corps of Engineers), trig lists published by field artillery target acquisition battalions operating in the adjacent corps areas, and data for each survey control point established by the target acquisition battalion survey parties and by the parties of the division artilleries with the corps. The data for each survey control point established by the target acquisition battalion and by division artillery headquarters are recorded on DA Form 6–5 (figs. 4 and 5).

*c.* An operations map is maintained in the survey information center. The operations map shows the locations of all existing trig points and survey control points and the schemes of completed surveys. Overlays to the map show the survey operations that are currently being performed by the target acquisition battalion and division artilleries with the corps. The overlays also show the tactical situation, the location of each installation of the target acquisition battalion, present and proposed artillery positions, and proposed survey plans.

*d.* Time accurate to 0.2 second is maintained for the use of FATAB survey parties and subordinate units when making astronomic observations.

*e.* In addition to performing the functions discussed in *a* through *d* above, survey information center personnel assist in the survey operations of the target acquisition battalion by computing and checking data. Computations

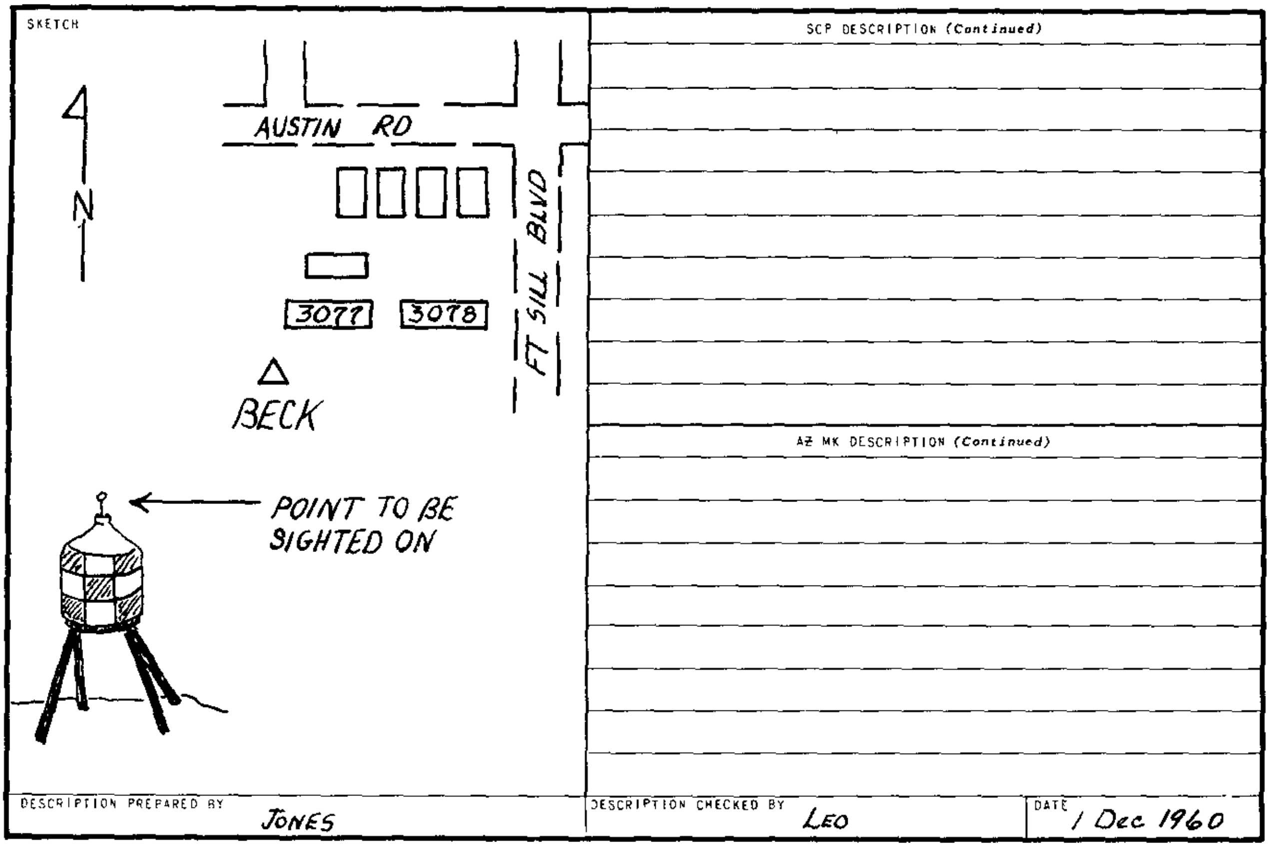



*Figure 5. Entries made on the back of DA Form 6–5.*

and checks performed by the survey information center personnel include the following:

(1) Checks of field records and computations of field parties.

(2) Adjustment of traverses.

(3) Conversion of survey data to the corps grid when survey operations have been performed with assumed data.

(4) Transformation of coordinates and grid azimuths.

(5) Conversion of coordinates (geographic to grid and/or grid to geographic).

## 42. Field Artillery Target Acquisition Battalion Survey Personnel

*a.* The field artillery target acquisition battalion commander is the corps artillery survey officer. Under the direction of the corps artillery commander and assisted by the battalion survey officer, the corps artillery survey officer—

(1) Plans the corps artillery survey.

(2) Coordinates the survey of the target acquisition battalion with all other artillery units in the corps area.

(3) Maintains liaison with, and obtains control data from, the topographic engineer unit operating with the corps.

(4) Establishes the survey information center at corps artillery.

*b.* The battalion survey officer is assigned to the battalion staff. The battalion survey officer plans and supervises the battalion survey operations, advises the battalion commander and the staff on matters pertaining to survey, and performs the coordination of the survey operations of *all* field artillery units operating in the corps area. An assistant battalion survey officer, the survey platoon commander in headquarters battery, performs duties as directed by the battalion survey officer.

*c.* A warrant officer, assigned to headquarters battery, supervises the operations of the survey information center.

*d.* A survey platoon is assigned to each battery of the target acquisition battalion. The platoon commander is the survey officer of the battery. He plans and supervises the survey operations of the survey platoon and advises the battery commander on matters pertaining to survey.

### 43. Coordination and Supervision of Battalion Surveys by the Battalion Survey Officer

The target acquisition battalion survey officer normally is authorized by the battalion commander to issue instructions on matters concerning survey operations directly to the batteries. The relations between the battalion survey officer and the battery survey officers in issuing and receiving instructions are similar to the relations between the battalion fire direction officer in a howitzer or gun battalion and the battery executive officers. The battery survey officers must keep their battery commanders informed of the survey operations that they have been instructed to perform. They must also keep their battery commanders informed of the areas in which the battery survey platoon will be operating and the progress of the survey operations.

### 44. Field Artillery Target Acquisition Battalion Survey Operations

*a.* Target acquisition battalion survey operations are conducted in two phases—an *initial phase* and an *expansion phase.*

*b.* The survey operations conducted during the initial phase consist of those surveys necessary to establish a survey control point for each division artillery and each corps artillery battalion (and other points as directed by the battalion commander) and those necessary to establish survey control for the installations organic to the target acquisition battalion that require survey control.

*c.* The survey operations conducted during the expansion phase consist of the surveys necessary to place survey control points within 1,500 to 2,000 meters of any possible artillery position in the corps area.

*d.* The battalion survey officer designates to each platoon commander the areas requiring survey control points. These survey control points are *established* for later extension of control and for checking surveys.

*e.* Survey operations of the target acquisition battalion are continuous. The amount of survey performed by the target acquisition battalion in any area of operations depends on the length of time that the corps remains in the area. In rapidly moving situations, the target acquisition battalion may be able to complete only the initial phase of survey operations. If the corps remains in one area for an extended period of time, the target acquisition battalion conducts extensive survey operations.

### 45. Use of Assumed Data

When possible, survey platoons initiate their survey operations at survey control points (or trig points). If no survey control points exist in the area, the battalion survey officer designates a point and furnishes assumed data for that point. The assumed data should approximate the correct grid data as closely as possible. The surveys of all of the platoons are then tied to this point, thus establishing a common grid and azimuth. Assumed data are converted to known data as soon as practicable.

### 46. Azimuths

Azimuths at all points of the battalion survey should be correct grid azimuths. Correct grid azimuth can normally be established by astronomic observation or by use of the azimuth gyro. When two intervisible survey control points (based on correct grid data) or trig points exist, correct grid azimuth can be obtained from these points. If the correct grid azimuth between the points is not known, it can be computed by using the grid coordinates of the points.

### 47. Survey Control Points

Survey parties of the battalion establish survey control points approximately every 1,500 to 2,000 meters along the routes of their surveys. A station is established for each division artillery, for each corps artillery battalion, and for each point from which target acquisition battery installations are located. A station is also established at each point designated for later extension of control and for checking surveys. Each of these survey control points is marked by a hub and a reference stake (fig. 45). An azimuth for each survey control point is established either to an azimuth marker or to an adjacent survey control point. A description of each survey control point is prepared on DA Form 6–5 and forwarded to the survey information center for filing.

## 48. Planning Battery Survey Operations

The points for which survey control must be established by the survey platoon of each battery of the target acquisition battalion fall into two general categories—those for installations of the target acquisition battalion and those for installations of other units. The commander of the survey platoon plans the initial phase operations of the platoon by first considering the operations necessary to locate the target acquisition battalion installations. He then modifies this plan, as necessary, to provide survey control for the installations of other units. If priorities have been established by the battalion survey officer, the platoon commander must incorporate them in his survey plan.

## 49. Target Acquisition Survey Platoon Operations During the Initial Phase

*a.* The survey operations performed by a target acquisition survey platoon during the initial phase are those necessary to locate the target acquisition battery installations that require survey control and to provide a survey control point for the division artillery and for each corps artillery battalion in the platoon's area of responsibility.

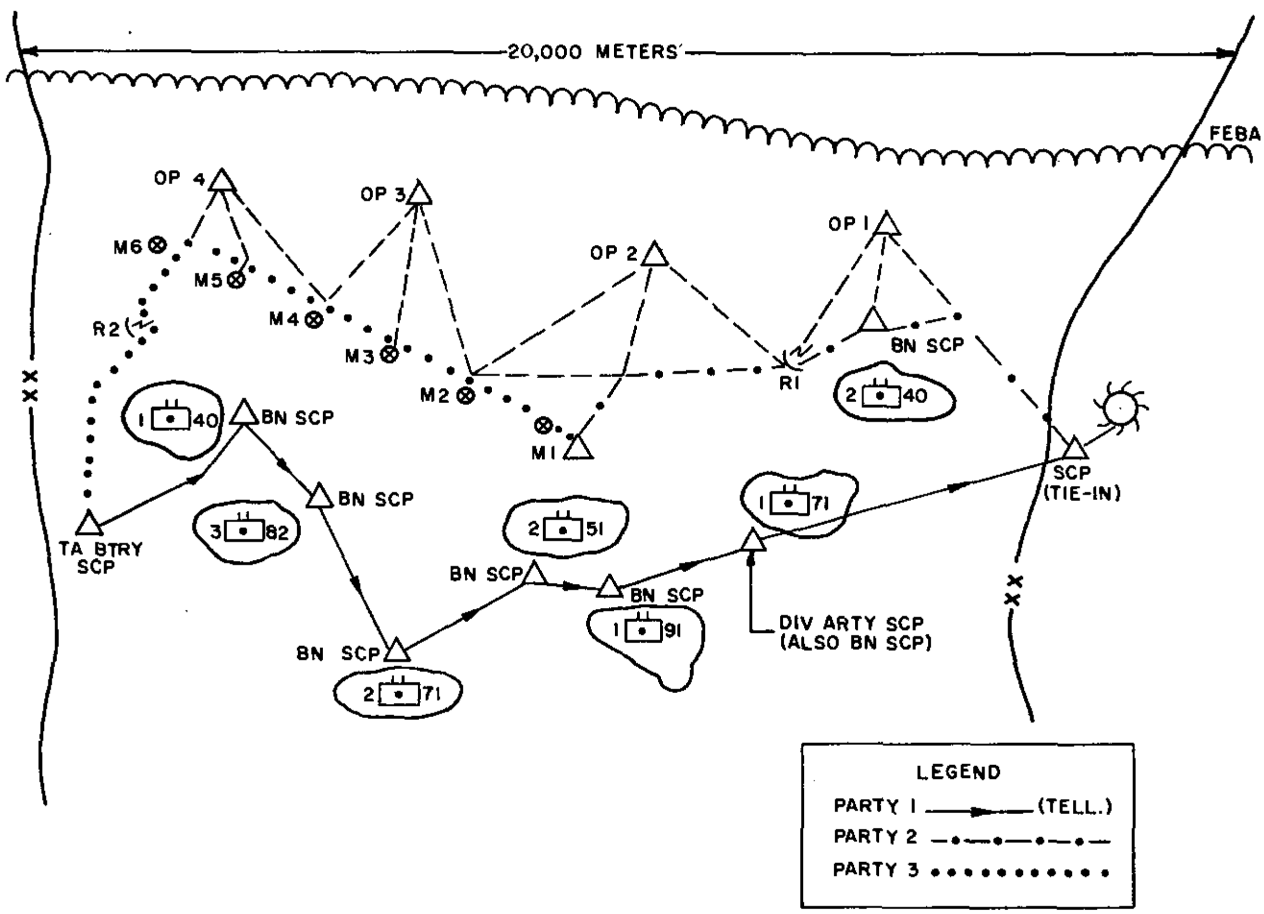



*Figure 6. Target acquisition platoon survey during the initial phase.*

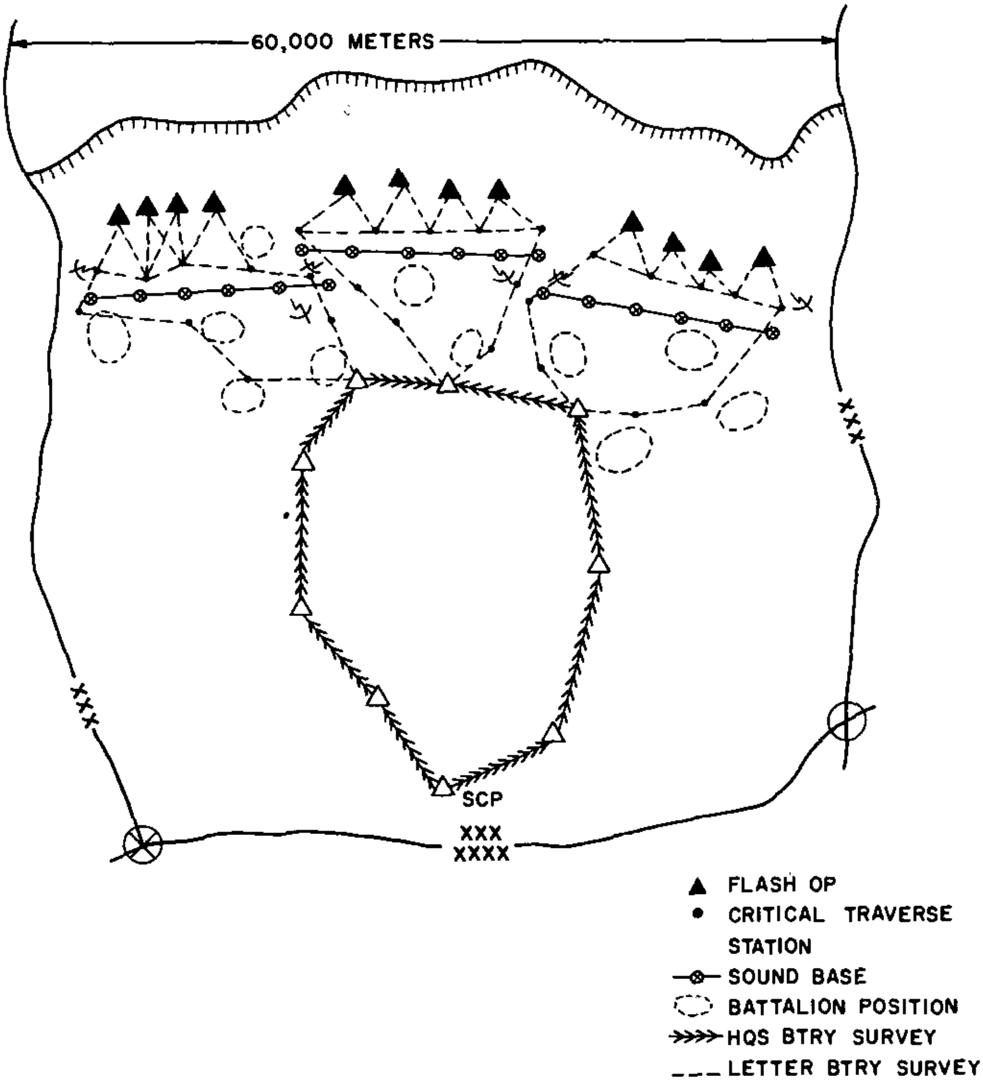



*Figure 7. Target acquisition battalion survey operations during the initial phase.*

*b.* All or part of the survey platoon operations are frequently started with assumed coordinates and height. For example, if survey control points do not exist in the vicinity of the selected sound base microphones, the sound base survey (and the establishment of any survey control points along the line of the sound base) is frequently performed by two parties starting at a point near the center of the sound base with assumed data, while a third party extends survey control to the starting point.

*c.* Figure 6 shows an example of the survey operations conducted by a survey platoon during the initial phase. Figure 7 shows an example of the survey operations conducted by a target acquisition battalion during the initial phase. The critical traverse stations shown in black are those at which a traverse is initiated or closed.

*d.* The initial phase operations include those actions necessary to close all traverses, to check all intersected and resected points, to establish a declination station in the division area, and to determine the locations of survey control points that were established by the target acquisition battery survey platoons operating in the adjacent division areas. The initial phase of the battalion survey operations is considered complete when these operations have been performed by the survey platoons of each of the target acquisition batteries.

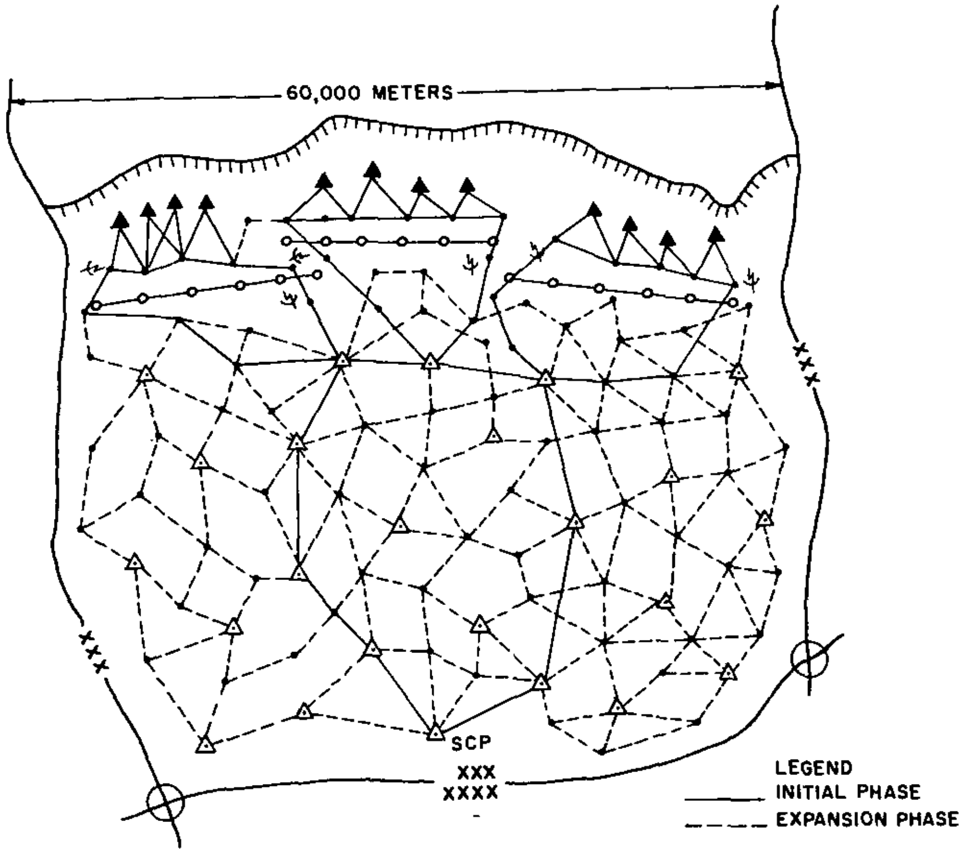



*Figure 8. Target acquisition battalion survey operations during the expansion phase.*

## 50. Survey Operations During the Expansion Phase

*a.* Survey operations of the target acquisition battalion during the expansion phase consist of establishing, usually by triangulation or DME traverse, a basic net throughout the corps area. From stations of the basic net, control is extended to provide survey control throughout the corps area. The ultimate goal is a survey control point within 1,500 to 2,000 meters of every possible artillery position. This goal is accomplished to the extent permitted by the time available.

*b.* During the expansion phase, the survey platoons of the battalion are assigned tasks by the battalion survey officer as necessary to accomplish the required survey operations. The survey platoon of each battery should be assigned tasks in areas as near as possible to its battery area to facilitate operations.

*c.* Figure 8 shows an example of the survey operations of a target acquisition battalion during the expansion phase.

## 51. Extension of Survey Control From Rear Areas

When the only existing survey control is a considerable distance to the rear of the corps area, control should, if possible, be extended to the corps area by engineer topographic units. When this is not possible, the target acquisition battalion may be required to extend the control. This normally is accomplished by the use of DME traverse schemes. This extension of control may be initiated either during the initial phase or during the expansion phase, depending on the situation. When it is initiated during the initial phase, it is usually accomplished by the headquarters battery survey platoon. The battery survey platoons may be required to furnish one or more survey parties to assist in these operations.

## 52. Survey Control for Sound Ranging Microphones

*a.* The operations necessary to establish survey control for sound ranging microphones depend on the type of sound base selected by the sound ranging personnel. When the microphones are employed in an irregular base, the microphone positions are marked, either with a stake or with a microphone, by sound ranging personnel. The location of each irregular-base microphone is determined in the manner used to locate any other survey station. When the microphones are employed in a regular base, the coordinates of each microphone are predetermined on DA Form 6–2, using the distance between microphones and the azimuth of the base, as furnished by sound ranging personnel (FM 6–122). Then, points are established on the ground at the location of the computed coordinates by following the procedure in (1) through (6) below.

(1) A traverse is performed roughly parallel to the line of the sound base, following the best traverse route. A traverse station is established at a point from which the microphone position is visible. A traverse station is established for each microphone.

(2) The azimuth and distance from the traverse station to the microphone position are computed on DA Form 6–1 by using the coordinates of the traverse station and the predetermined coordinates of the microphone. The microphones must be located relative to each other within a tolerance of 0.5 meter.

(3) The direction of the microphone position is established by setting off on the theodolite the horizontal angle, at the traverse station, from the rear traverse station to the microphone position. This angle is determined by subtracting the azimuth to the rear traverse station from the azimuth to the microphone position. The value that must be set on the horizontal circle of the theodolite is equal to the sum of the initial circle setting (the horizontal circle reading when the instrument is pointed at the rear traverse station) and the computed horizontal angle. As an example, assume that the initial circle setting is 0000.151 mil and that the computed horizontal angle is 3,089.422 mils. The value that must be set on the horizontal circle is 3,089.573 mils (0000.151 mil + 3,089.422 mils).

(4) A rodman, guided by the instrument operator sighting through the telescope of his instrument, emplaces a range pole on the line of sight at a distance approximately equal to the computed distance to the microphone position. The rodman paces the computed distance to the microphone position; this serves as a check for large errors in taping ((5) below).

(5) A taping team then tapes the computed distance from the traverse station to the microphone position and places a hub at the microphone position. To prevent errors, the front tapeman should give all taping pins to the rear tapeman except those actually required to make the distance measurement. If it is necessary to break tape, the normal pin procedure should be followed (para 87). When the front tapeman has placed his last pin in the ground, he should pull the tape forward a partial tape length until the rear tapeman can hold the proper graduation over the last taping pin (para 89). The front tapeman should then place the hub in the ground, at the point directly under the zero graduation on the tape. The tapemen should then check their work by taping the distance from the hub back to the traverse station.

(6) As an example of the method of establishing the distance from the traverse station to the microphone position, assume this distance to be 130.67 meters. This distance consists of four full tape lengths and a partial

tape length of 10.67 meters. The front tapeman gives seven taping pins to the rear tapeman and retains four pins before starting the distance measurement. When the front tapeman has placed his fourth pin in the ground, he pulls the tape forward a partial tape length so that the rear tapeman can hold the 10.67-meter graduation directly over the last taping pin. The front tapeman then places the hub in the ground under the zero graduation on the tape.

*b.* The location of the microphone position hub can be checked by using the hub as a traverse station. It can also be checked by measuring the direction to the hub from a traverse station other than the one used to establish the microphone position and comparing the measured direction with the computed direction with the computed direction to the hub.

*c.* If sound ranging microphones are established from a traverse based on assumed data for the starting station, the coordinates of the microphone positions must be converted to the common grid when the correct grid data for the starting point become available. *No change in the ground location of the microphones is required.*

## 53. Survey Control for Flash Ranging Observation Posts

Flash ranging observation posts are located in the same manner as observation posts for field artillery battalions.

# CHAPTER 4

# OTHER ARTILLERY UNIT SURVEYS

## Section I. FIELD ARTILLERY GROUP SURVEYS

### 54. Field Artillery Group

*a.* The field artillery group headquarters battery has no capability for performing survey operations. The battalions of the group are normally furnished survey control by the artillery headquarters with which the group is working. When survey has not been furnished by such headquarters, the group commander may designate one battalion to establish a group survey control point. When heavy battalions of a group are required to perform target area surveys, the group commander usually designates one battalion to perform the target area surveys for the entire group.

*b.* The group assistant intelligence officer (assistant S2) is also the group survey officer. During training, the group survey officer supervises the training of the survey personnel of the battalions of the group. The group survey officer coordinates the survey operations of the battalions of the group. He verifies that survey control points are provided by the next higher survey echelon. He verifies, by frequent inspections, that the survey sections of the group battalions perform survey operations properly. Two enlisted survey specialists are assigned to group headquarters battery for the purpose of assisting the group survey officer in carrying out his responsibilities.

### 55. Field Artillery Battalion Group

In addition to normal survey responsibilities, the commander of a battalion group has survey responsibilities similar to those of a group commander. If survey control has not been furnished to the battalion group by the artillery headquarters with which it is working, the commander of the battalion group directs the survey officer of his battalion to establish a battalion group survey control point.

### 56. Field Artillery Missile Command, Air Transportable

*a.* The survey requirement of the missile command, air transportable, consists of the location and orientation of the weapons and target locating installations of the command. The firing element of the missile command is one Honest John (Little John) battalion. The survey officer of the Honest John (Little John) battalion serves as the survey officer for the missile command. There are no survey personnel authorized in the headquarters company, missile command, air transportable.

*b.* The missile command, air transportable, receives engineer survey support from the topographic engineer survey section of the organic engineer combat company. The engineer survey personnel establish survey control points as required by the Honest John (Little John) battalion.

*c.* The Honest John (Little John) battalion is authorized two 8-man survey parties to extend control to each of the four launchers. The survey parties locate the launchers to fifth-order accuracy and provide direction for orientation of the launchers and wind measuring sets (windsets).

## Section II. AIR DEFENSE ARTILLERY SURVEYS

### 57. General

*a.* Four major factors determine the type and the extent of survey operations which must be performed by or in support of air defense artillery (ADA units). These factors are the—

(1) Type of mission assigned to the unit.

(2) Availability of maps.

(3) Restrictions placed on air defense fire.

(4) Fire distribution system being used.

*b.* When air defense artillery units are assigned air defense missions, they must be capable of transmitting, from one unit to another, information concerning the location of aircraft. To transmit this information, the units must be located with respect to a common grid. When suitable maps are available, units can be located with respect to a common grid by map inspection for both position and direction. When suitable maps are not available, units must be located with respect to a common grid by extending control to each unit from control points located on the grid.

*c.* When air defense artillery units are assigned air defense missions and are restricted from firing in certain areas, they must be located with respect to the grid on which the limits of the restricted areas are designated. Units must be located on the grid by extending control to each fire unit from control points located on the grid.

*d.* When air defense artillery units are assigned field artillery type missions, their survey requirements are the same as those for field artillery units.

*e.* Air defense artillery battalions normally do not have the capability of performing survey. Control must be extended by an agency having suitable survey equipment and trained survey personnel. Arrangements should be made for the nearest engineer or artillery unit capable of providing the control to perform the necessary survey operations. When employed in a corps area, coordination for extending survey control to air defense artillery units should be made through the corps artillery survey officer.

## 58. Surveys for Air Defense Artillery Automatic Weapons Battalions Not Equipped With Electronic Fire Control

*a.* Unless there are restricted areas, survey control is not required for air defense artillery automatic weapons (ADA AW) battalions not equipped with electronic fire control systems. However, the relative locations of weapons and early warning observation posts must be known so that an early warning system can be established. When suitable maps are available, the relative locations of the weapons and observations posts are determined by map inspection. When suitable maps are not available, the relative locations can be established by limited rough survey as explained in FM 21-26.

*b.* When there are restricted areas, survey control is established to determine the relative horizontal and vertical locations of each weapon and to provide an orienting line for each weapon. Control is extended to each weapon from survey control points established within 1,000 meters of the position. Extension of control to the weapons must be performed to a prescribed accuracy of 1:500.

*c.* When ADA AW battalions are required to accomplish the surveys discussed in *b* above, the necessary survey support must be made available from the sources outside the battalion.

## 59. Acquisition Radars

*a.* The location of each air defense artillery acquisition radar position must be established on the UTM (or UPS) grid for the zone. When suitable maps are available, the position can be located by scaling from a map, and direction can be determined with a declinated aiming circle.

*b.* When suitable maps are not available, the horizontal and vertical locations of each acquisition radar are determined and a line of known direction established by extending control from a control point on the UTM (or UPS) grid for the zone by survey operations executed to fifth-order accuracy.

## 60. Air Defense Artillery Battalions

*a. Nike-Hercules.* The location of each target tracking radar of air defense artillery battalions, Nike-Hercules, must be established on the UTM (or UPS) grid for the zone. The altitude above mean sea level and a line of known direction for each target tracking radar must also be established. Location and altitude above mean sea level must be established to an accuracy of artillery fifth-order survey, and the line of direction to plus or minus one minute of arc (0.3 mil). Survey operations may be performed by engineer or artillery units possessing the necessary capability. Temporary survey control may be established by scaling from a map, when suitable maps are available, and by using a declinated aiming circle. However, the accuracy thus obtained is adequate only for the surface-to-air mission and is acceptable only as a matter of expediency. Extension of survey from the target tracking radars to other battery radars and to the launching sections is performed by battery personnel using organic equipment. The accuracy required for this survey extension to other battery radars is prescribed in equipment technical manuals; the accuracy required to launching sections is 1:500.

*b.Hawk.* Directional control for Hawk battalions may be established by scaling from a map, when suitable maps are available, and by using a declinated aiming circle.

## 61. Air Defense Artillery Fire Distribution Systems

The location of each fire distribution system must be established on the UTM (or UPS) grid for the zone. Survey operations may be performed by engineer or artillery units possessing the necessary capability. An accuracy of artillery fifth-order survey is required.

# CHAPTER 5

# SURVEY PLANNING

## Section I. GENERAL

### 62. Survey Missions

*a.* The general mission of artillery survey personnel is to provide accurate and timely survey information and control to artillery units and installations. Successful accomplishment of this mission requires careful preparation and the formulation of a survey plan which is as complete as possible.

*b.* The specific mission of artillery survey personnel for any survey operation is contained in orders and instructions issued by the organization commander. These orders and instructions are contained in the unit SOP, operations orders, and training directives.

*c.* After the commander has issued orders and/or instructions which require the execution of survey operations, the survey officer must plan the operations and issue necessary instructions to survey personnel to execute the assigned mission.

### 63. Factors Affecting Survey Planning

The artillery survey officer must consider many factors in formulating the plan by which the survey mission is to be accomplished. The factors which affect survey planning cannot be considered independently because each is related to the others.

*a. Tactical Situation.* The survey planner must consider both the enemy and friendly situations as they affect survey operations. He must consider the enemy's capability to interfere with or restrict survey operations. He must consider the locations of friendly elements and their missions. He must consider any restrictions that the situation places on travel and/or communication.

*b. Mission.* The overall mission of the unit as well as the survey mission will affect survey planning. The survey officer, in his planning, must be aware of the general situation as well as the details.

*c. Installations That Require Survey Control.* The number and locations of installations that receive survey control will be determined by the time and personnel available. The survey operations necessary to locate a small number of widely scattered installations will often require more time and/or personnel than would be required for a large number of closely grouped installations. In the survey plan, tasks should be allocated so that the various parties executing the survey will complete their tasks at approximately the same time. This might require, for example, the use of two parties to establish control for one installation located at a considerable distance from the starting point while one party establishes control for three installations located relatively close to the starting point.

*d. Amount of Survey Control Available.* More extensive survey operations are required in areas where limited survey control exists than are required in areas where survey control is dense.

*e. Number and Status of Training of Personnel.* Sufficient trained personnel must be available to perform the required survey in the allotted time. The survey plan must be based on the use of methods which are completely familiar to all personnel.

*f. Time.* The time allotted for survey will influence not only the choice of methods to be used but also the amount and type of control which can be extended.

*g. Terrain.* The survey officer should be so familiar with the effects of various types of terrain on survey operations that he can promptly and properly assess the time and personnel required for a particular operation.

*h. Weather.* Bad weather may eliminate or greatly reduce the capability of survey parties. Fog, rain, snow, or dust can reduce visibility to the extent that observations through an instrument are impossible. Heavy rain or snow can make fieldwork impossible. Extreme heat or cold can reduce the efficiency of a party to the extent that the time necessary to finish a phase must be considerably increased. Trilateration can often be conducted when weather conditions prevent the use of other methods of survey.

*i. Availability of Special Survey Equipment.* Consideration must be given to the availability and operational readiness of such special equipment as the Tellurometer, the DME, and the azimuth gyro. The presence or lack of such equipment can greatly affect the time and work required for a survey operation. In addition, the proper use of special techniques, such as simultaneous observation, can materially affect the accomplishment of the survey mission.

*j. Priority.* Priorities established by the commander or indicated by the tactical situation must be considered in developing the survey plan.

### 64. Essentials of a Good Survey Plan

In formulating the survey plan, the survey officer should remember and strive to meet certain essentials. The survey plan must—

*a. Be Simple.* The plan must be understood by all personnel.

*b. Be Timely.* The plan must be capable of execution in the time allotted.

*c. Be Flexible.* The plan must be capable of being changed if the situation warrants a change.

*d. Be Adaptable.* The plan must be adaptable to the terrain, situation, personnel available, etc.

*e. Provide for Checks.* Whenever possible, the plan must provide for checks; i.e., closed surveys, alternate bases, and checks made by each member of the party.

*f. Provide Required Control.* The plan must provide survey control with the required accuracy to all installations which require survey.

## Section II. STEPS IN SURVEY PLANNING

### 65. General

The steps in survey planning are gathering information, making a map reconnaissance and a ground reconnaissance, and formulating a survey plan. These steps are discussed in paragraphs 66 through 69.

### 66. Gathering Information

The survey officer must gather all possible information which might influence his plan. The factors affecting survey planning outlined in paragraph 64 will indicate what information is needed. The information can be obtained from the commander's briefing, from members of the staff, from other survey sources, from personal observation and from his own knowledge of, and experience with, his men and equipment.

### 67. Map Reconnaissance

A map reconnaissance is performed by using any suitable map or map substitute. The first step in making a map reconnaissance is to plot the installations requiring control on the map. The survey officer then evaluates the factors affecting the survey plan and—

*a.* Makes a tentative choice of survey methods, based on the terrain shown on the map.

*b.* Determines whether the survey mission can be accomplished in the allotted time with the personnel available. If the mission cannot be accomplished in the allotted time, he makes appropriate recommendations to his commander. For example, he can recommend that additional survey personnel be made available, that the time allotted for survey be increased, and/

or that certain installations be given a low priority.

*c.* Makes a tentative survey plan, noting the critical areas which will require detailed ground reconnaissance.

*d.* Issues the necessary warning order to the survey personnel.

### 68. Ground Reconaissance

The survey officer makes as complete a reconnaissance of the ground as time permits. He makes a detailed reconnaissance of those critical areas noted during the map reconnaissance. A general ground reconnaissance can be performed by motor vehicle, aircraft, or other means, but a detailed ground reconnaissance should be performed on foot if time permits. If no suitable map or map substitute is available, the survey officer must take the action indicated in paragraph 67 after performing the general ground reconnaissance but before performing a detailed ground reconnaissance.

### 69. Formulation of the Survey Plan

On completion of the ground reconnaissance and after considering all of the factors and information at his disposal, the survey officer modifies his tentative plan.

## Section III. THE SURVEY ORDER

### 70. General

The survey plan becomes a survey order when specific instructions are given to each survey party. The survey order contains those instructions which are not covered by the standing operating procedure and which are not general information but are necessary for the efficient accomplishment of the survey mission.

### 71. Sequence in Which Survey Order Is Issued

The survey order may be issued by radio, wire, or both. The survey order is issued in the five-paragraph sequence of an operation order, as follows:

1. SITUATION (as it affects the survey operations)
   - *a.* Enemy forces.
   - *b.* Friendly forces.
   - *c.* Attachments and detachments.
2. MISSION (survey)
3. EXECUTION
   - *a.* Concept of survey operations.
   - *b.* Detailed instructions to each party.
   - *c.* Instructions for more than one party.
4. ADMINISTRATION AND LOGISTICS
5. COMMAND AND SIGNAL (location of survey officer)

### 72. Changes to the Survey Order

The survey officer closely supervises the work of the survey parties to insure that the order is properly executed and to detect any situation that may necessitate changes in the survey plan. If it becomes necessary to change the plan of survey, he issues appropriate instructions to the party chief(s) concerned.

### 73. Execution of the Survey Order

Each chief of survey party plans the detailed operations of his party. His planning is similar to that of the survey officer. The mission of his party is contained in the instructions issued by the survey officer. The survey plan prepared and issued by the chief of party contains those items from the survey officer's order which his personnel must know to accomplish the survey mission and any additional instructions which may be necessary. The chief of party supervises the operations of his party and issues additional instructions as necessary throughout the conduct of the survey. Whenever it becomes impracticable to comply with the instructions received from the survey officer, the chief of party reports this fact to the survey officer or chief surveyor if either is immediately available. If neither is immediately available, the chief of party changes his survey plan as necessary to accomplish that portion of the unit's survey mission for which he is responsible. As the first opportunity, he reports the action which he has taken to the survey officer.

## Section IV. STANDING OPERATING PROCEDURE

### 74. General

*a.* A standing operating procedure (SOP) is a set of instructions setting forth the procedures to be followed for those phases of operation which the commander desires to make routine. The SOP sets down the regular procedures that are to be followed in the absence of specific instructions.

*b.* The SOP of a battalion (separate battery) or higher artillery headquarters should contain a section on survey. The SOP for each echelon must conform to the SOP of the next higher echelon. Therefore the survey portion of the SOP at each artillery echelon should contain only those survey procedures which the commander desires to make standard throughout his command. Survey items which the commander desires to make standard only for the survey unit or section of his headquarters should be contained in the SOP for that particular unit or section.

### 75. Purposes of Survey Section SOP

The purposes of the survey section SOP are to—

*a. Simplify the Transmission of the Survey Order.* Instructions included in an SOP need not be restated in the survey order. For example, if the battalion SOP prescribes the size of distance angles for triangulation, this information need not be included in the survey order. However, inclusion of this information in the SOP would not preclude the survey officer from restating it in the survey order for emphasis.

*b. Simplify and Perfect the Training of Survey Personnel.* Establishment of standard procedures for survey operations in a unit insures uniform training and minimizes the need for special instruction.

*c. Promote Understanding and Teamwork.* In those units which have more than one survey party, the establishment of standard procedures insures uniform performance of survey operations and minimizes the time and effort required for coordination.

*d. Facilitate and Expedite Survey Operations and To Minimize Confusion and Errors.* When personnel become familiar with, and employ, standard signals, techniques, and procedures, they will accomplish their tasks in a minimum amount of time. Furthermore, the use of standard procedures reduces confusion and eliminates many errors, which, in turn, speeds up survey operations.

# PART TWO

# POSITION DETERMINATION

## CHAPTER 6

## DISTANCE DETERMINATION

### Section I. HORIZONTAL TAPING

#### 76. Tapes and Accessories

*a.* Field artillery survey personnel are equipped with 30-meter steel tapes for making linear measurements (taping). These tapes are graduated on one side only, in meters, decimeters (0.1 meter), and centimeters (0.01 meter), with the first decimeter graduated in millimeters (0.001 meter). There is a blank space at each end of the tape. A reel and two leather thongs are furnished with each tape.

*b.* In addition to a tape, each taping team should be equipped with 2 plumb bobs, 1 pin and plumb bob holder, 1 clamping handle, 1 set of 11 taping pins, 1 hand level, 1 tension handle, 2 leather thongs, 2 notebooks, and 2 pencils (fig. 9).

#### 77. Care of Steel Tapes

*a.* Steel tapes are accurate surveying instruments and must be handled with care. Although steel tapes are of durable construction, they can be easily damaged through improper care and use.

*b.* When a steel tape is being used, it should be completely removed from its reel and kept straight to prevent its being kinked or broken. The tape should never be pulled around an object that will cause a sharp turn in the tape. Care should be taken to avoid jerking or stepping on the tape or allowing vehicles to run over it. A loop in the tape may cause the tape to kink or break when tension is applied. Before applying tension, the tapemen should insure that there are no loops in the tape.

*c.* The tape should be wiped clean and dry and oiled lightly after each use. The tape is oiled by running it through an oily rag as it is being reeled in. The tape should be loosely wound on its reel when not in use. In winding the tape on the reel, the tapeman should insert the end of the tape with the 30-meter graduations into the reel and wind the tape so that the numbers are facing the axle of the reel.

#### 78. Repair of Broken Tape

*a.* A broken tape can be repaired by fitting a sheet metal sleeve, coated on the inside with solder and flux, over the broken ends of the tape. The sleeve is hammered down tightly, and heat is applied to the sleeve to cause the solder to securely bind the broken ends of the tape within the sleeve. An ordinary match may be used to heat the solder.

*b.* The repaired section of the tape must be checked with another section of the tape to insure that the ends of the tape were joined and that the tape still gives a true measurement.

#### 79. Horizontal Taping, General

*a.* The method of taping used in artillery surveys is known as *horizontal taping*. In this method, all measurements are made with the tape held horizontally. The point *from which* the distance is to be measured is the *rear station*. The point *to which* the distance is to be measured is the *forward station*. The distance between stations is usually several times greater than a full tape length. The taping team, starting at the rear station, determines the distance by measuring successive full tape lengths until the distance remaining is less than a full tape length. This length is then measured. The distance between stations is de-

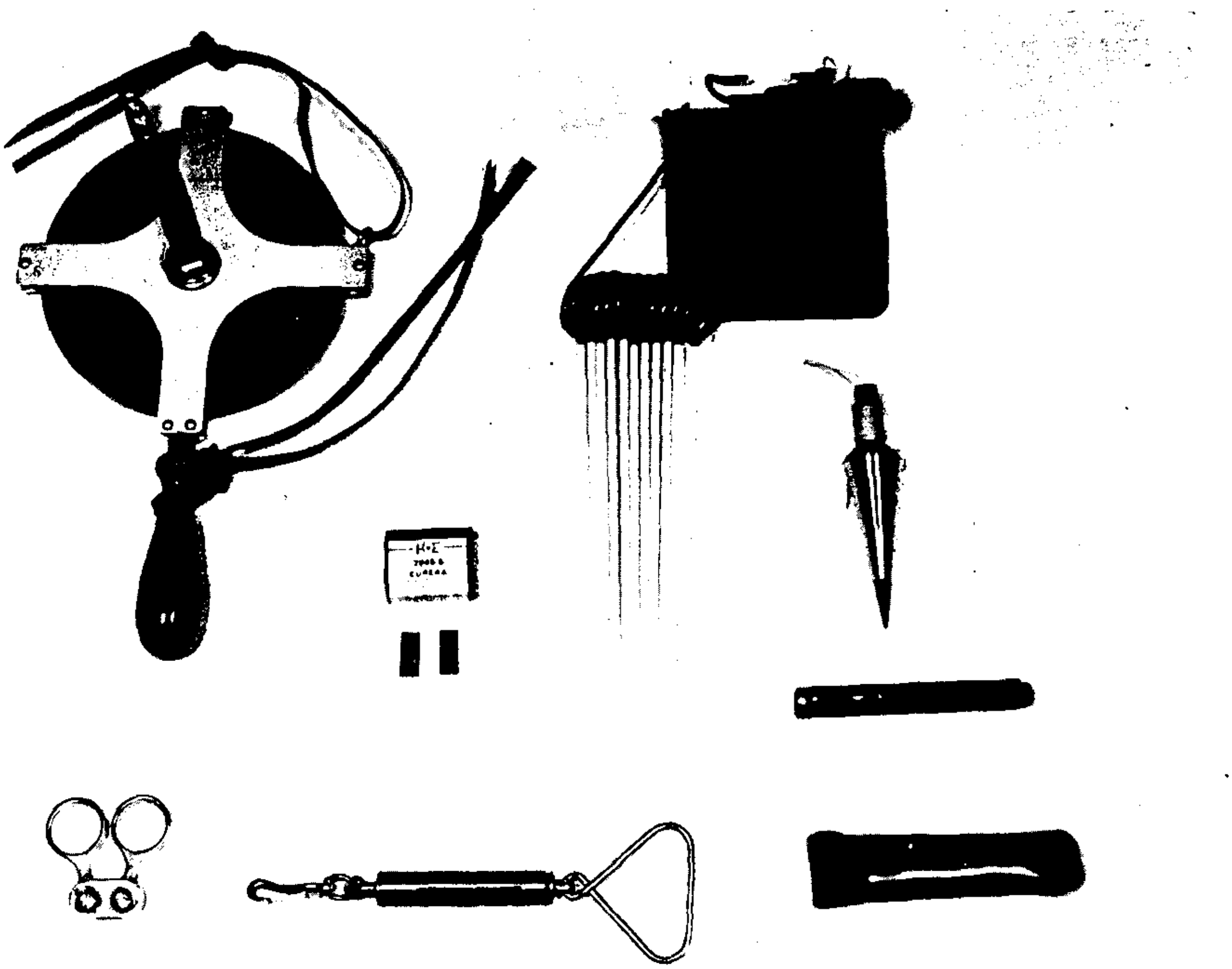


*Figure 9. Taping equipment.*

termined by multiplying the number of tape lengths by the length of the tape and adding the partial tape length.

*b.* A taping team consists of two men—a front tapeman and a rear tapeman. The rear tapeman commands the taping team. The rear tapeman determines and reports the distance measurement; *the front tapeman independently checks the distance measurement.* Additional personnel are required for taping at night (para 92).

## 80. Measuring First Full Tape Length

The first full tape length is measured using the following procedures:

*a.* The front tapeman gives 1 taping pin to the rear tapeman, keeping 10 pins in his possession. The pin given to the rear tapeman represents the first full tape length. The front tapeman moves toward the forward station with the zero end of the tape.

*b.* As the end of the tape reaches the rear station, the front tapeman stops, either on his count of paces or on the command TAPE given by the rear tapeman. The rear tapeman sights toward the forward station and signals the direction that the front tapeman should move to aline the tape, first with the forward station and then in an estimated horizontal plane. The tape must be alined within 0.5 meter of the line of sight from one station to the succeeding station and within 0.5 meter of the horizontal plane.

*c.* Each tapeman places a leather thong on his wrist and the plumb bob cord on the proper graduation on the end of the tape. The rear tapeman alines his plumb bob roughly over the rear station and commands PULL, and the tapemen exert a pull of 25 pounds on the tape.

*d.* After the tapemen have properly alined and applied tension to the tape, the rear tapeman places his plumb bob exactly over the rear station and commands STICK. At this command, the front tapeman drops his plumb bob and then marks the point of impact with a taping pin. When the pin has been placed firmly in the ground, the front tapeman reports STUCK, which instructs the rear tapeman to move forward to measure the next tape length.

*e.* When a team is taping on gently sloping ground void of brush and tall grass, the plumb bob need *not* be used at the uphill end of the tape. The end of the tape may be held immediately adjacent to the taping pin.

### 81. Measuring Succeeding Full Tape Lengths

Succeeding full tape lengths are measured as discussed in paragraph 80, except as follows:

*a.* The front tapeman should obtain his approximate horizontal alinement by sighting back along the tape toward the rear station, moving right or left until the tape is approximately on line. Final alinement usually is made as directed by the rear tapeman. However, if the rear tapeman cannot see the forward station, final alinement is made either by the front tapeman sighting back on the rear station or by the rear tapeman through the use of previously selected reference points in alinement with the forward station. The instrument operator, if available, may assist in this alinement.

*b.* The rear tapeman should place his plumb bob exactly over the point at which the taping pin enters the ground.

*c.* The rear tapeman pulls the taping pin from the ground before moving forward to the next pin position. *If a taping pin is lost during the measurement of the distance, the tapeman must tape the entire distance again, rather than complete the taping from a recovered pin hole.*

### 82. Moving Forward

*a.* The front tapeman should select a landmark (rock, bush, etc.) in line with the forward station. In moving forward, the front tapeman should keep his eyes on the line to the forward station and should not look back. He should determine the number of paces to the tape length so that he can stop without being signaled when he has moved forward a tape length.

*b.* By moving forward at a point 2 or 3 meters in front of the rear end of the tape, the rear tapeman can usually locate the taping pin by the time the front tapeman has stopped.

*c.* When there is an instrument used at either the forward or the rear station, the tapemen must remain clear of the line of sight.

### 83. Tape Alinement

The tapemen must carefully aline the tape. The maximum allowable error in both horizontal and vertical alinement is one-half meter for a full 30-meter tape length. The tapemen aline the tape with the stations which establish the line by sighting along the tape toward the stations at each end of the line (fig. 10). The tapemen then level the tape horizontally by holding it parallel to an estimated horizontal plane. If difficulty is encountered in keeping the tape level in rough terrain, then the hand level should be used. To use the hand level to establish a horizontal plane, the downslope tapeman—

*a.* Sights through the level at the upslope tapeman.

*b.* Raises or lowers the objective end of the hand level until the image of the level bubble is centered on the center horizontal crossline.

*c.* Determines the point on the upslope tapeman which is level with his eye. This establishes the horizontal plane.

*d.* Instructs the upslope tapeman how to hold his end of the tape so that the tape will be parallel to the established horizontal plane. *The downslope tapeman must hold the tape no higher than his armpits.*

*Note.* The tapeman should check the accuracy of the bubble of the hand level when it is first used each day This is accomplished by having the upslope tapeman

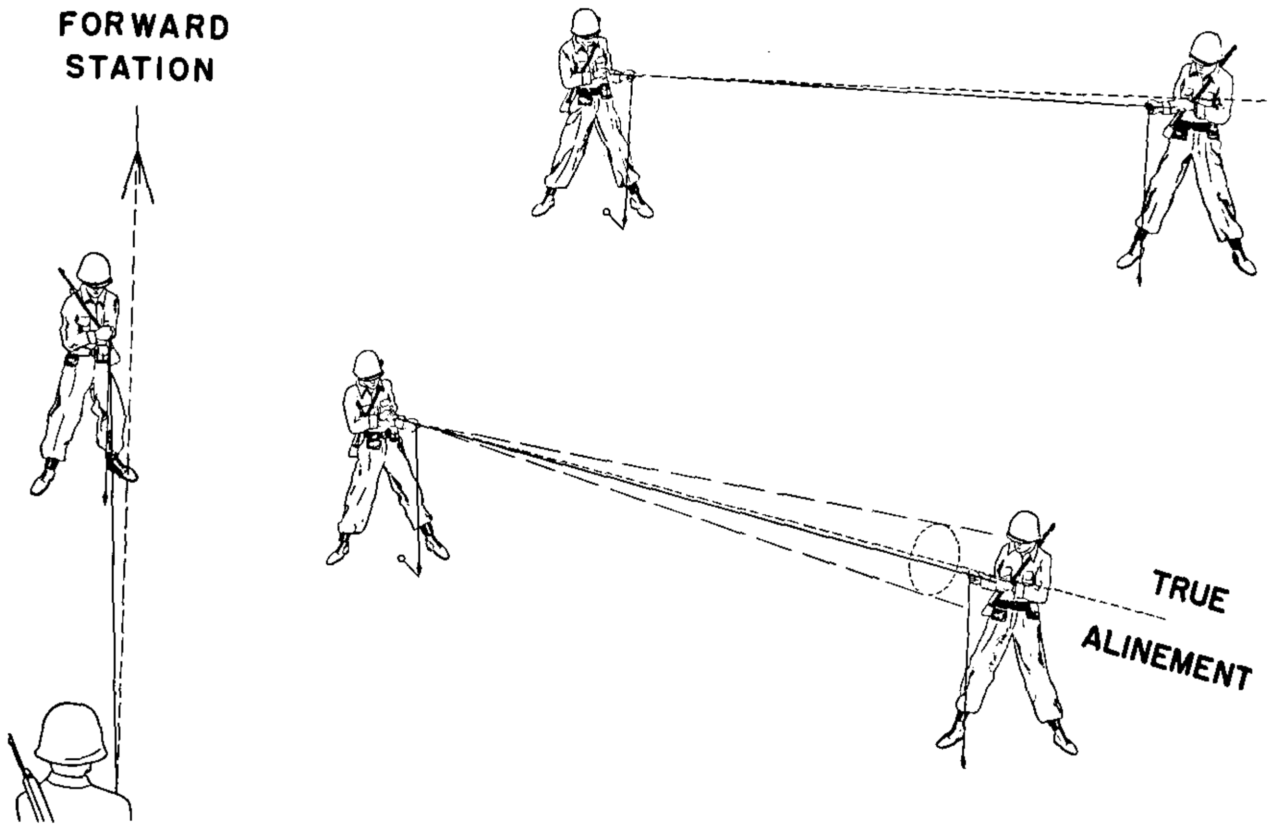



*Figure 10. Tape alinement.*

use the hand level to sight on the downslope tapeman to verify the established horizontal plane.

## 84. Applying Tension to Tape

The tapeman must apply 25 pounds tension (pull) to each full or partial tape length.

*a.* The tapeman should apply tension to the tape by using the leg muscles and the large muscles of the back. To do this, the tapeman faces across the tape with his shoulders parallel to the length of the tape, passes the hand of the arm which is away from the other tapeman through a loop in the thong, and places the elbow of that arm tight against some part of his body (fig. 11). When the tapeman is standing, he applies tension by bending the knee which is away from the other tapeman, causing the weight of the body to push against the arm holding the tape. When the tapeman is kneeling, he applies tension by pushing the knee which is away from the other tapeman against the arm holding the tape.

*b.* The clamping handle is used to hold the tape at any point other than a tape end. *In order to avoid kinking the tape, the tapeman should hold the clamping handle with the index and middle fingers.* Normally, the handle will clamp as tension is applied to the tape. If additional pressure is required, it is applied to the outside of the finger grips by using the thumb and ring finger.

*c.* The tension handle (a scale which measures tension in pounds) should be used by the front tapeman until both tapemen become accustomed to the "feel" of 25 pounds tension.

## 85. Use of Plumb Bobs

The tapemen use plumb bobs to project points on the tape to the ground. Each tapeman holds the plumb bob cord on the proper tape graduation with the thumb of one hand on the cord and the forefinger of that hand beneath the tape (fig. 11). After alining the tape and

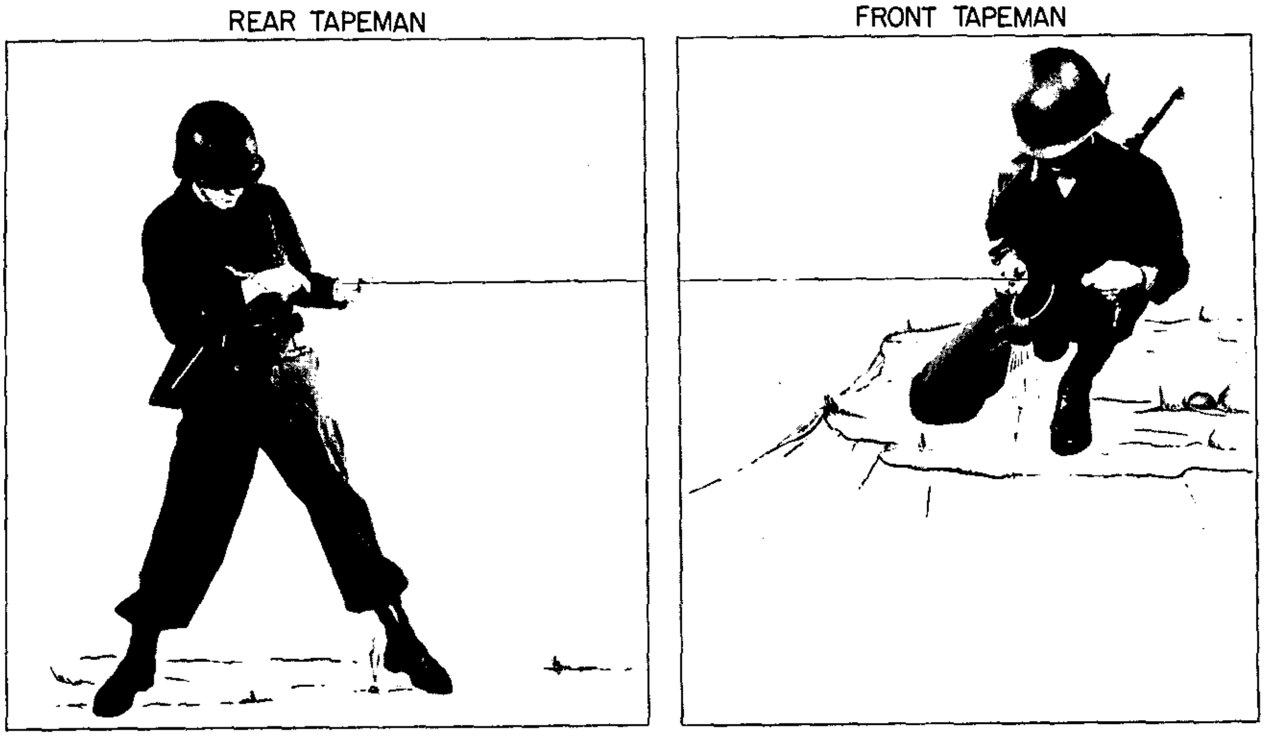



*Figure 11. Applying tension to a tape.*

applying tension to it, each tapeman lowers the plumb bob by letting the cord slip across the tape until the tip of the plumb bob is approximately one-fourth inch above the desired point. Swinging of the plumb bob is eliminated by gently lowering the tape until the plumb bob tip touches the ground and then slowly raising it.

*a.* The rear tapeman uses his plumb bob to position his end of the tape directly over the point from which each tape length is measured.

*b.* The front tapeman establishes the point on the ground to which each length is measured by dropping his plumb bob. After establishing the point with the plumb bob, the front tapeman marks the point with a taping pin. The rear tapeman can locate each pin more readily if the front tapeman clears the ground of grass, leaves, etc. or kicks a groove in the ground.

## 86. Use of Taping Pins

The tapemen must use the taping pins to mark points on the ground for each full or partial tape length. The front tapeman marks the point struck by the tip of the plumb bob by sticking the pin into the ground at exactly that point. The shaft of the pin should be placed at an angle of about 45° with the ground and perpendicular to the length of the tape. *When moving forward, the tapemen should not pull the tape through the loop of the taping pin.* When taping over a hard surface, it may be necessary to mark the point struck by the plumb bob in an identifiable fashion (point of taping pin or pencil). The point of the pin should be laid at the point struck by the plumb bob, perpendicular to the line of direction of the tape.

## 87. Breaking Tape

When the tape cannot be alined within one-half meter of a horizontal plane because of the slope of the ground, the tapemen use a special procedure known as breaking tape (fig. 12). The procedure for breaking tape is as follows:

*a.* The front tapeman pulls the tape forward a full tape length, drops it approximately on line, and then comes back along the tape until he reaches a point at which the tape, when held

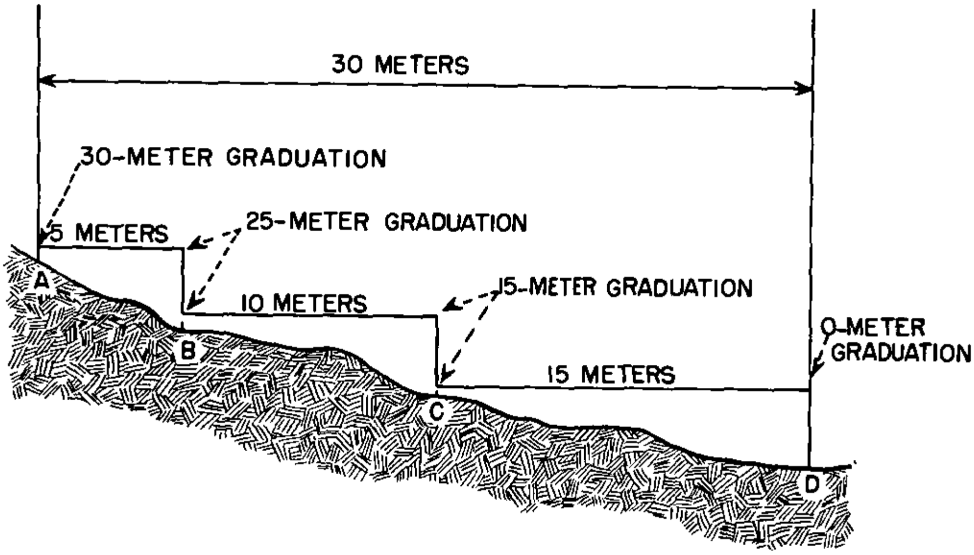



*Figure 12. Breaking tape.*

level, would be no higher than the armpits of the downslope tapeman. At this point, the front tapeman selects any convenient full meter graduation. The tapemen then measure the partial tape length, applying the full 25-pound tension to the tape. Clamping handles are used at any holding point between ends of the tape.

*b.* After he has placed the taping pin, the front tapeman waits until the rear tapeman comes forward. The front tapeman tells the rear tapeman which full meter graduation was used, e.g., HOLDING 25. The rear tapeman repeats HOLDING 25. The front tapeman receives a pin from the rear tapeman and moves forward, repeating this procedure until the zero mark on the tape is reached.

*c. When holding a point on the tape other than the zero graduation, the front tapeman must receive a pin from the rear tapeman before moving forward.*

## 88. Measuring Distances in Excess of 10 Tape Lengths

To measure a distance longer than 10 full tape lengths, the tapemen use the procedures discussed in paragraphs 80 through 87 except as follows:

*a.* When the front tapeman has set his last pin in the ground, he has established a point which is 10 full tape lengths from the rear station. The front tapeman waits at the last pin position until the rear tapeman comes forward.

*b. Both tapemen count the pins to verify that none have been lost.* (One pin is in the ground; 10 pins should be in the possession of the rear tapeman.)

*c.* The rear tapeman gives the front tapeman the 10 pins.

*d.* Both tapemen record 10 tape lengths and then continue taping.

## 89. Measuring Partial Tape Lengths

To measure the partial tape length between the forward station and the taping pin representing the last full tape length, the tapemen use the following procedure:

*a.* The front tapeman moves to the forward station and places the plumb bob cord on the zero graduation of the tape. The rear tapeman moves forward along the tape to the taping pin.

*b.* If slack is needed, the front tapeman commands SLACK and the rear tapeman allows the tape to move forward. When the front tapeman is ready, he commands PULL and the tapemen exert a pull of 25 pounds on the tape. To exert this pull, the rear tapeman uses a clamping handle to hold the tape. As tension is applied to the tape, the rear tapeman slides his plumb bob cord along the tape until the plumb bob is exactly over the pin.

*c.* When the zero graduation is exactly over the forward station, the front tapeman commands READ. The rear tapeman reads the graduation marked by his plumb bob cord and announces the measurement of the partial tape length to the nearest 0.01 meter.

*d.* The front tapeman repeats the reading aloud, and both tapemen record the measurement.

## 90. Taping at an Occupied Station

When a taping team is making a measurement at a station occupied by an instrument, the tapeman at the station must be careful not to disturb the instrument. If a plumb bob is used with the instrument, the tapeman can make his measurement at the plumb bob cord of the instrument.

## 91. Use of Two Taping Teams

When two taping teams are used to measure the distance between two stations, one taping team uses a pin to establish a starting station a half tape length (15 meters) from the rear station. In this case, the front tapeman does not give a pin to the rear tapeman. The taping pin marking the half tape length represents one full tape length plus 15 meters. *After the starting station is established a half tape length from the rear station, the taping procedures are the same as those discussed in paragraphs 80 through 90, except that each tapeman adds 15 meters to the distance measurement. This procedure precludes both teams placing their taping pins in the same hole.*

## 92. Taping at Night

Daytime taping methods may be used at night with certain modifications. A piece of white cloth should be tied to each end of the tape to assist the tapemen in following and locating the tape. Three men should be added to each taping team. One man accompanies each tapeman as a light holder; the third man marks the taping pin. When the rear tapeman comes to the taping pin, the third man walks the length of the tape, freeing it from any obstructions. This procedure is repeated for each full or partial tape length. The light holders must observe security precautions when using their lights.

## 93. Determining Taped Distance

The tapemen determine and check the distance measurement (fig. 13), using the following procedures:

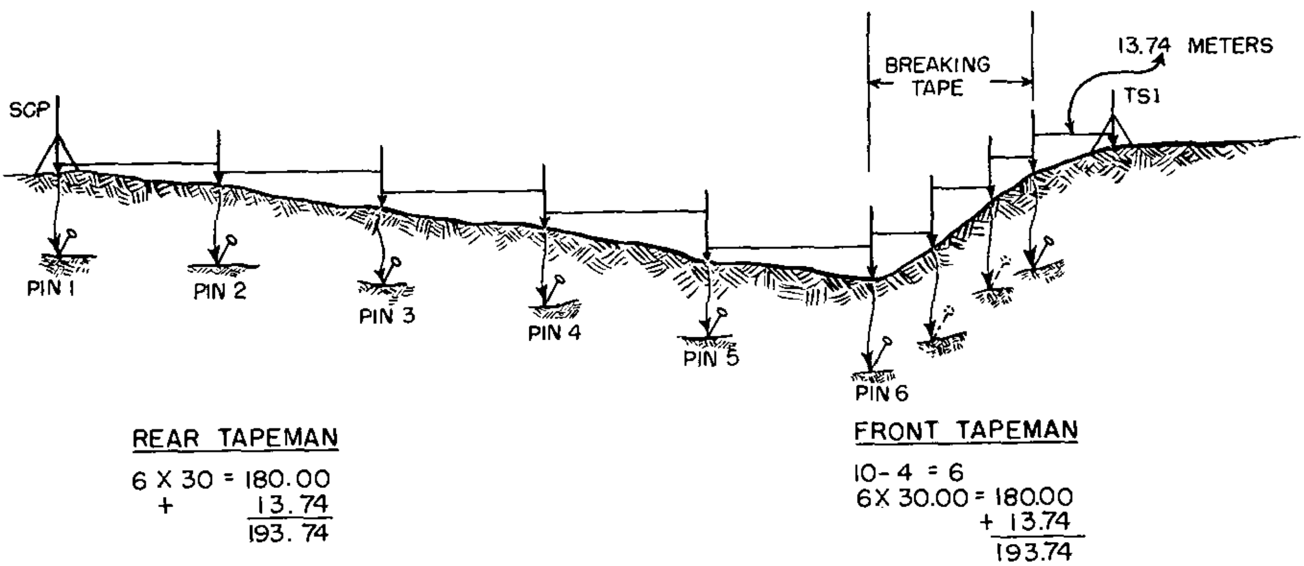



*Figure 13. Determining taped distance.*

*a*. Each tapeman counts the number of pins in his possession. (*The pin in the ground at the last full tape length is not counted.*)

*b*. The rear tapeman determines the distance measurement by multiplying the length of the tape (30 meters) by the number of full tape lengths measured and adding the partial length read from the tape. (The number of full tape lengths measured is equal to 10 for each exchange of pins *plus the number of taping pins in his possession.*)

*c*. The front tapeman independently checks the distance measurement by multiplying the length of the tape by the number of full tape lengths measured and adding the partial tape length. (The number of full tape lengths measured is equal to 10 for each exchange of pins *plus the difference between 10 and the number of pins in his possession.*)

*d*. The rear tapeman reports the distance measurement to the recorder for entry in the field notebook.

## 94. Comparative Accuracy for Double-Taped Distances

*a*. When the distance between two stations has been determined by double-taping, the two measurements are compared and the *comparative accuracy* for the two measurements is determined. Comparative accuracy is expressed as a ratio between the difference in the measurements and the mean of the measurements. The ratio is expressed with a numerator of 1; e.g., 1/1,000 or 1:1,000. The denominator is determined by dividing the mean of the measurements by the difference in the measurements. After computing the comparative accuracy, the denominator of the fraction is always reduced to the next lower hundred.

*b*. The following example illustrates the computation of a comparative accuracy for a distance measurement:

| | | |
|---|---|---|
| Distance measurement by taping team 1 | = | 375.84 meters |
| Distance measurement by taping team 2 | = | 357.76 meters |
| Difference between measurements | = | 0.08 meter |
| Mean of the measurements | = | 357.80 meters |

$$\text{Comparative accuracy} = \frac{\text{difference}}{\text{mean}} = \frac{0.08}{357.80} = \frac{0.08 \div 0.08}{357.80 \div 0.08} =$$

$$\frac{1}{357.80 \div 0.08} = \frac{1}{4472} \text{ or } \frac{1}{4400}.$$

*c*. When the double-taped distance does not meet the required comparative accuracy, the distance must be taped a third time. The third measurement is then compared with each of the first two measurements to determine if a satisfactory comparative accuracy can be achieved with one or the other. The unsatisfactory distance is then discarded.

## 95. Taping Techniques and Specifications

To achieve the various degrees of accuracy in survey, distances must be determined accurately to within certain specifications, depending on the method of survey used. Taping techniques and prescribed accuracies for the different methods of survey are as follows:

*a*. *Traverse.*

(1) 1:500—single-taped; checked by pacing.

(2) Fifth-order (1:1,000) — single-taped; checked by pacing.

(3) Fourth-order (1:3,000)—double-taped to a comparative accuracy of 1:5,000.

*b*. *Triangulation, Intersection, and Resection.*

(1) 1:500—double-taped to a comparative accuracy of 1:3,000.

(2) Fifth-order (1:1,000) — double-taped to a comparative accuracy of 1:3,000.

(3) Fourth-order (1:3,000)—double-taped to a comparative accuracy of 1:7,000.

## 96. Errors in Horizontal Taping

Horizontal taping errors fall into three categories, as follows:

*a.* Systematic errors.

*b.* Accidental errors.

*c.* Errors caused by blunders.

## 97. Systematic Errors

Systematic errors are errors which accumulate in the same direction.

*a.* The systematic errors encountered in horizontal taping cause distances to be measured longer or shorter than their true lengths. The principal causes of systematic errors are—

(1) Failure to aline the tape properly.

(2) Failure to apply sufficient tension to the tape.

(3) Kinks in the tape.

*b.* Systematic errors can be eliminated or minimized by strict adherence to proper procedures and techniques. Tapemen should be especially attentive to keeping the tape horizontal when taping on a slope and should break tape when necessary. They should avoid the tendency to hold the tape parallel to the slope. When taping in strong winds, tapemen must be especially careful to apply the proper tension to the tape. Tapes should be checked frequently for kinks. One of the chief causes for kinked tapes is improper use of the clamping handle.

*c.* Systematic errors can be due to improper repair of the tape (repaired too long or too short), causing taped distances to be longer or shorter than their true distances.

## 98. Accidental Errors

Accidental errors are errors which may accumulate in either direction. Accidental errors are usually minor errors. The principal accidental error encountered in taping is caused by small errors in plumbing. Tapemen should be careful in plumbing over points, and when taping in strong winds they must be especially careful to minimize swinging of the plumb bob cord. This can be accomplished by keeping the plumb bob close to the ground.

## 99. Errors Caused by Blunders

Blunders are major errors made by personnel.

*a.* The principal blunders made by tapemen are—

(1) An incorrect exchange in taping pins.

(2) An error in reading the tape.

(3) An omission of the half tape length when double-taping with two teams.

(4) Loss of a taping pin.

*b.* Blunders can be detected and eliminated by strict adherence to proper procedures and by adoption of a system of checks; e.g., by double-taping, by pacing each taped distance, and, in some cases, by plotting the grid coordinates of the stations on a large-scale map.

# Section II. TELLUROMETER MRA 1/CW/MV

## 100. General

The Tellurometer is an electronic distance-measuring device issued to artillery units required to perform fourth-order survey (fig. 14). The Tellurometer system consists basically of one master and two remote units. The major components for both the master and remote units are described in paragraph 101. Additional items used to complete a Tellurometer measurement include the altimeter (when stations are not intervisible), Tellurometer field record and computations forms, and logarithmic tables. Distance is determined by measuring the loop transit time of radio microwaves from the master unit to the remote unit and back and converting one-half of this loop transit time to distance. Optical line of sight is not required, but electrical line of sight between the instruments is required. The minimum range capability of the equipment is 152 meters, and the maximum capability is 64,000 meters (40 miles). Approximately 30 minutes is required to measure and compute a distance regardless of the length of the measurement. A distance can be measured during daylight or darkness and through fog, dust, or rain. A distance measured with the Tellurometer is used

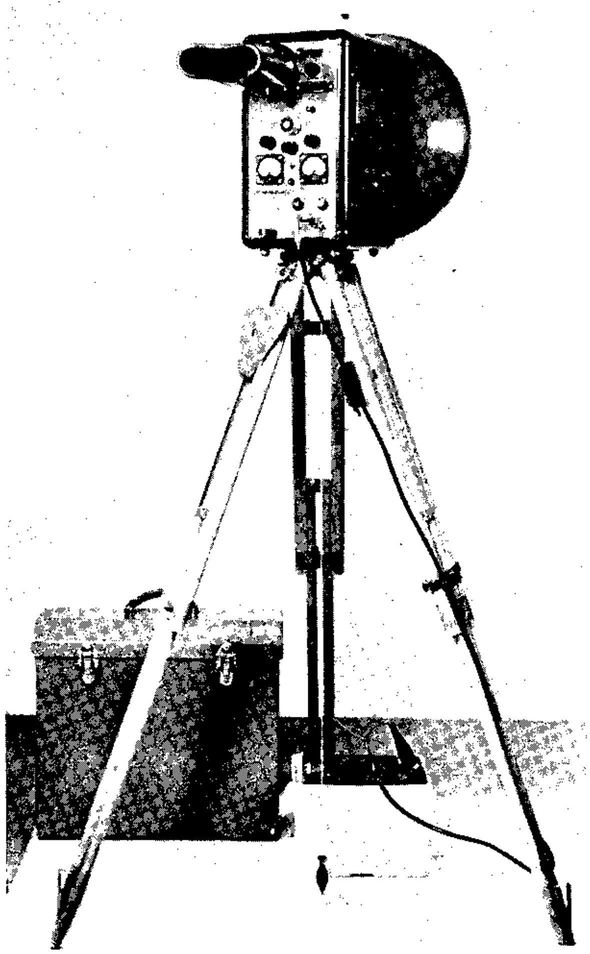


*Figure 14. Tellurometer station with operating equipment and carrying case.*

in computations in the same manner as a taped distance.

## 101. Description of Components

*a.* The master unit and the remote units are similar in appearance (figs. 15, 16, and 17) but neither the master nor the remote unit can be operated in a dual role because of the internal characteristics. The units have the same external dimensions (approximately 19 by 9 by 17 inches) and each weighs 27 pounds. Both units have parabolic reflectors, which are shown in the operating position in figure 17. The mirror surface of the reflectors radiates the received signal to the dipole. The dipole contains the transmitting and receiving antennas. Both units have identical built-in aerial and communication systems. A luggage-type handle facilitates carrying the instrument when it is removed from its case. The hinged door in the lower left corner of the control panel (figs. 15 and 16) opens into a compartment in which the radiotelephone handset is stored. A cathode-ray tube (CRT) visor (fig. 14) is mounted over the CRT scope to shut out light and make scope presentations more clearly visible.

*b.* The carrying case (fig. 14) is a lightweight, metal alloy, top-opening container. The lid is provided with a sponge rubber seal for protection against moisture. The case measures approximately 18 pounds; it is fitted with a luggage-type handle for carrying. The case also has a backstrap device which permits the operator to carry it on his back. The case is fitted to hold the instrument (master or remote) in place, and compartments are provided in the case for spare parts, the CRT visor, a plumb bob, a plastic rain cover, and a container of silica gel.

*c.* The universal tripod is issued with the Tellurometer; this tripod is interchangeable with the tripod used with the T16 and T2 theodolites.

*d.* Three different power sources may be used with the Tellurometer. A 12-volt, 40-ampere-hour battery or a 24-volt, 20-ampere-hour battery system may be cabled directly to a built-in powerpack (figs. 15 and 16). In addition, either a 115-volt, 60-cycle power supply or a 230-volt, 50-cycle power supply can be utilized by means of a mains converter (external powerpack). A fully charged battery will permit 4 to 6 hours of continuous operation. An 18-foot cable is provided so that the built-in powerpack can be connected to a vehicle battery for 24-volt operation.

*e.* The spare parts kit consists of a small metal box containing tubes, regulators, lamps, and fuzes. A list of these spare parts is provided in the metal container.

*f.* Additional accessories include a harness (backstraps) and pack, a CRT visor, a plastic rain cover, a screwdriver, a nonmetallic screwdriver, two power supply cables, an external powerpack, a handbook (Operation and Maintenance), and the Preliminary Maintenance Support Manual.

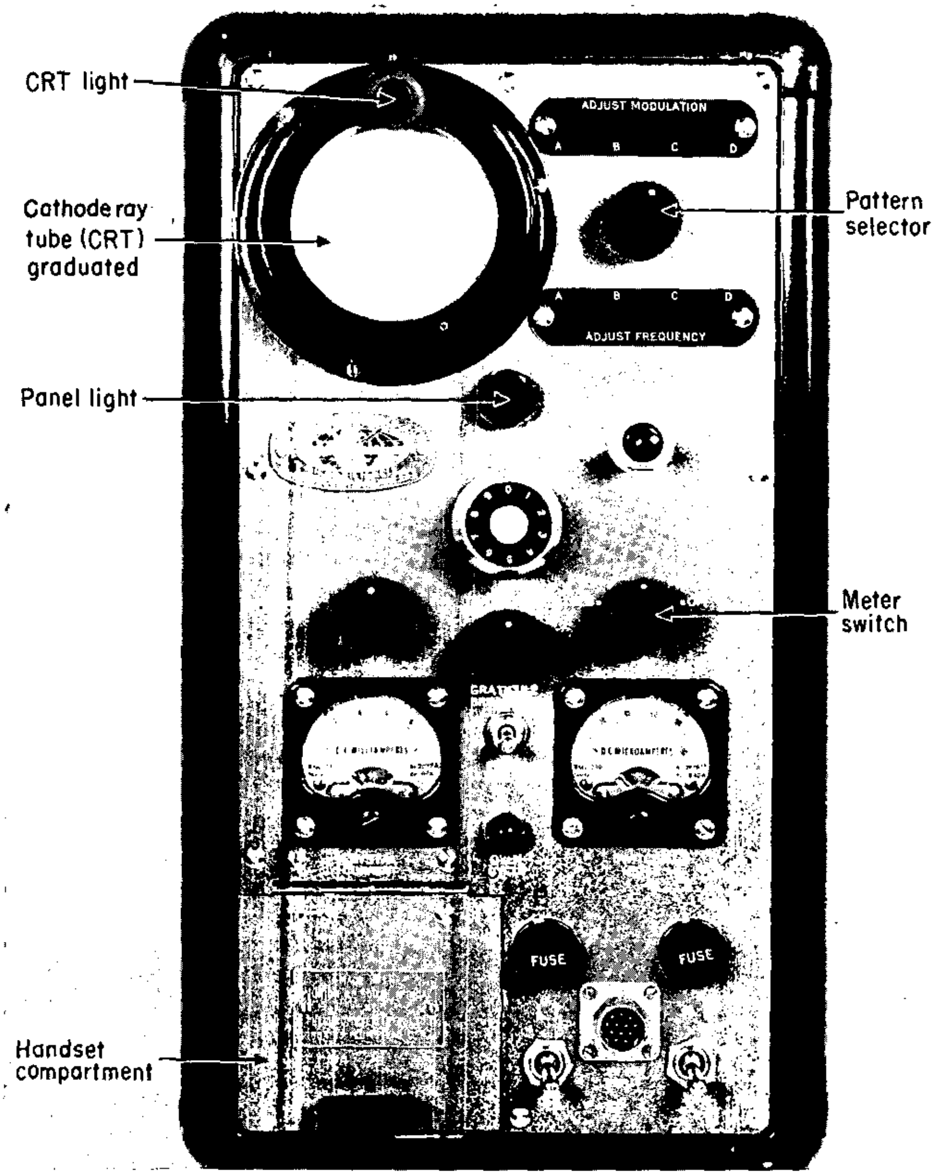



*Figure 15. Control panel, master unit.*

*g*. A surveying altimeter, issued as a separate TOE line item, should be available with each master and remote unit for the determination of difference in height when it is not possible to measure the vertical angle between the master and remote units with a theodolite. The vertical angle or difference in height is necessary to convert the slope distance measured with the Tellurometer to horizontal distance.

## 102. Notekeeping

Field notes of the Tellurometer survey are entered on DA Form 5–139, Field Record and Computations—Tellurometer. The computations for determining sea level distance are also accomplished on this form. The completed form, with field records and computations, should be filed with the associated survey computation.

## 103. Principles of Operation

*a*. When the Tellurometer system is used to perform a distance measurement, one master unit and one remote unit must occupy opposite ends of the line to be measured. A continuous

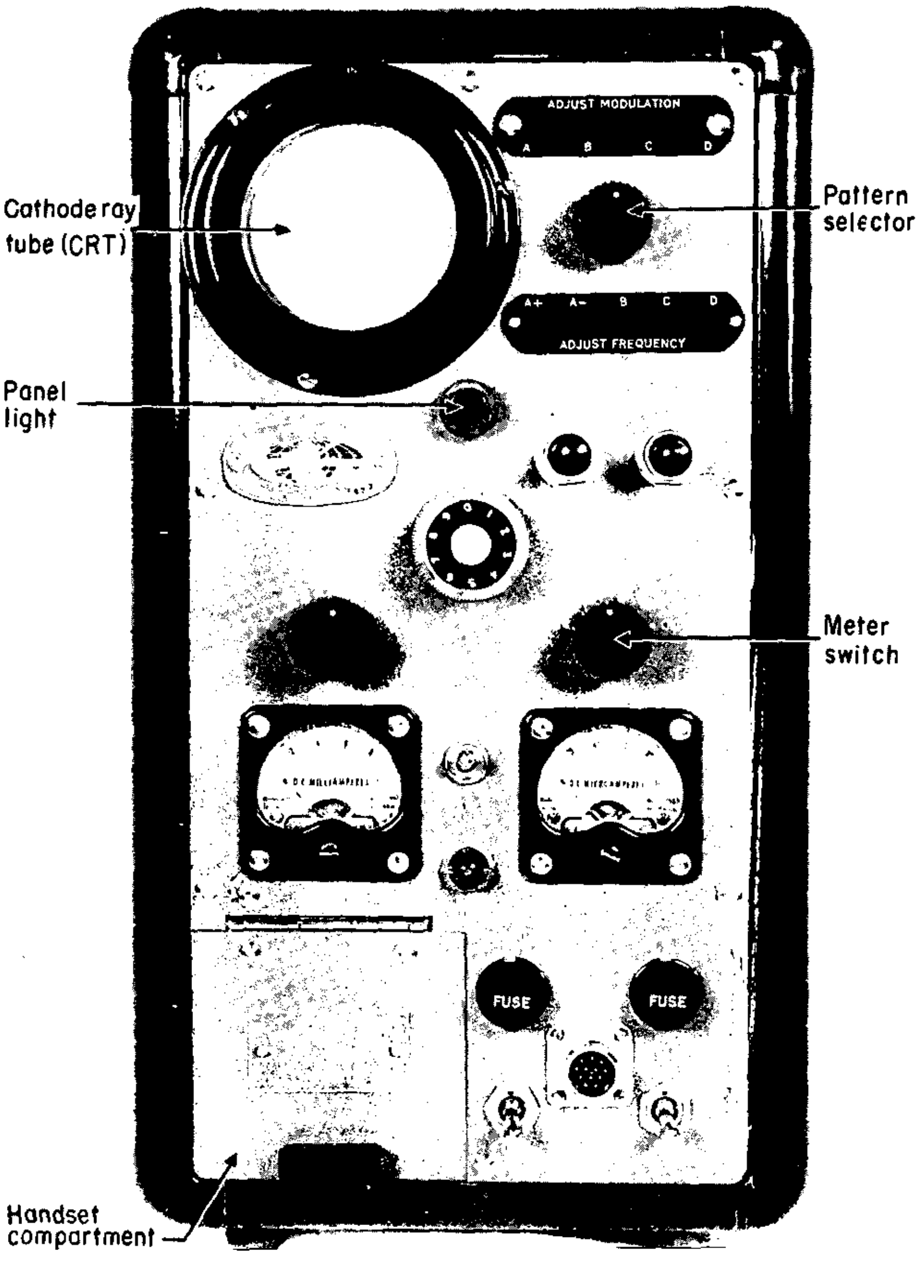



*Figure 16. Control panel, remote unit.*

radio wave of 10-centimeter (cm) wavelength (3,000 megacycles) is radiated from the master unit. This radio wave is modulated by what is referred to as pattern frequency. The modulated wave is received at the remote unit and reradiated from its transmitting system to the master unit.

*b.* At the master unit, the return wave is compared with the transmitted wave, and the phase comparison, or the difference in the two waves, is indicated on the circular sweep of the master unit cathode-ray tube (CRT) in the form of a small break, which marks the phase on a circular scale (fig. 18). The CRT circular scale is divided into 10 major and 100 minor graduations. The leading edge of the break in the circular sweep is read clockwise to the smallest minor graduation. The transit time, the time required by the wave to travel from the master unit to the remote unit and back, is

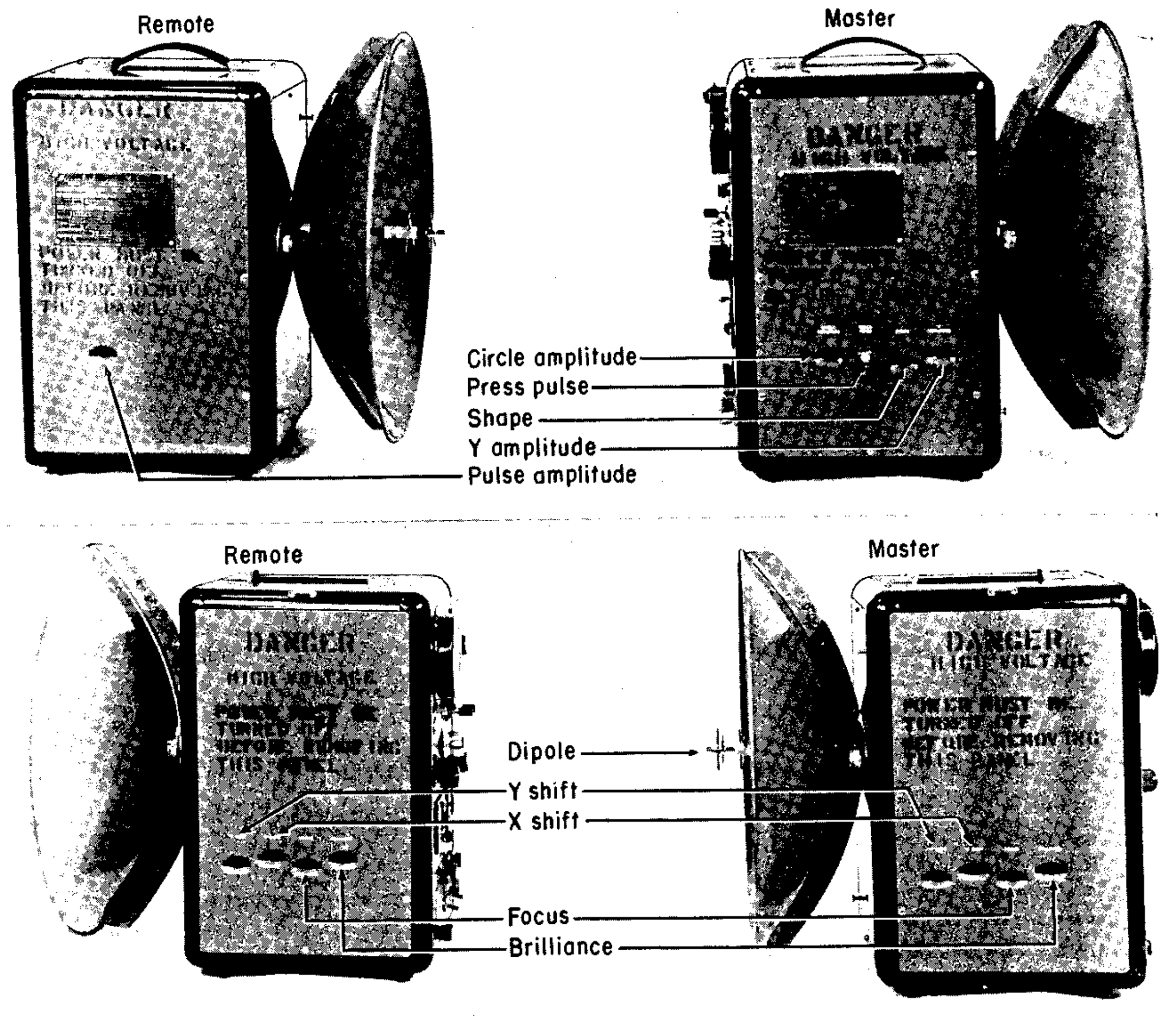



*Figure 17. Side views of master and remote units.*

determined from a series of readings on the cathode-ray tube of the master unit.

## 104. Selection of Stations

The optical line of sight between stations must be clear, or very nearly so, for a Tellurometer measurement; however, visibility is not absolutely essential. This condition is referred to as *electrical line of sight*. Large terrain features, such as hills, will block the line of site. The Tellurometer is used primarily in traverse, in which a theodolite is used to measure angles. Since line of sight is necessary for the measurement of angles with the theodolite, the proper selection of stations for the theodolite will provide line of sight for the Tellurometer. The best site for a Tellurometer station is on top of a high peak; however, the following factors must also be considered because of the effects caused by the reflection of microwaves:

*a.* The ground between the two stations should be broken and, preferably, covered with trees and vegetation to absorb ground waves and prevent them from interfering with the direct signal.

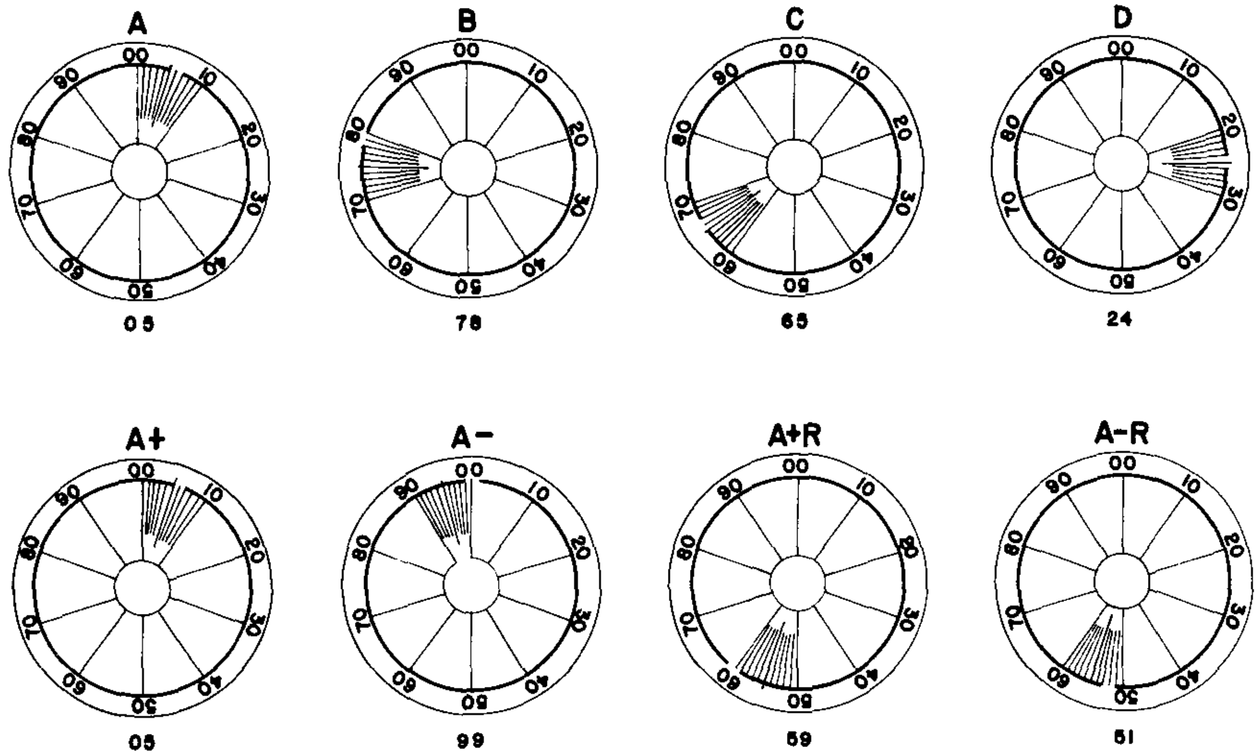



*Figure 18. Cathode-ray tube pattern reading.*

*b.* When possible, the ground should slope gradually away from each instrument.

*c.* If possible, measurements should not be made over highly reflective surfaces, such as smooth areas, desert sands, and water. Figure 19 illustrates the effect of the reflection of microwaves from water. An error, sometimes referred to as ground swing, is caused when the Tellurometer receives both the direct wave and the reflected wave. Some of the error is removed by the method of observing. The mean of the four fine readings, each at a different cavity tune setting, removes a part of the swing error.

*d.* The instruments should be set well back from the edge of the high land so that as much of the reflective area as possible becomes "dead ground" to the receiving instrument (fig. 19).

### 105. Instrument Controls

The controls for the operation of the master and remote units are classified into four functional groups—the *setting up controls,* used initially in setting up the instruments and establishing a satisfactory cathode-ray tube presentation; the *operating controls,* used during the measurement; the *monitoring controls,* used to check circuit operation; and the *preset controls,* which normally require no adjustment. Each of these functional groups includes a number of individual controls.

*a. Setting Up Controls.*

(1) The LT (LOW VOLTAGE) and the HT (HIGH VOLTAGE) switches are used to apply power to the master and remote units after they have been cabled to a power source. These switches are located in the lower portion of the control panel on the units.

(2) A BRILLIANCE control is located on the left side panel of each unit and is used to adjust the brightness of the presentation on the cathode-ray tube of each instrument.

(3) A FOCUS control is located on the left side panel of each unit and is adjusted in conjunction with the BRILLIANCE

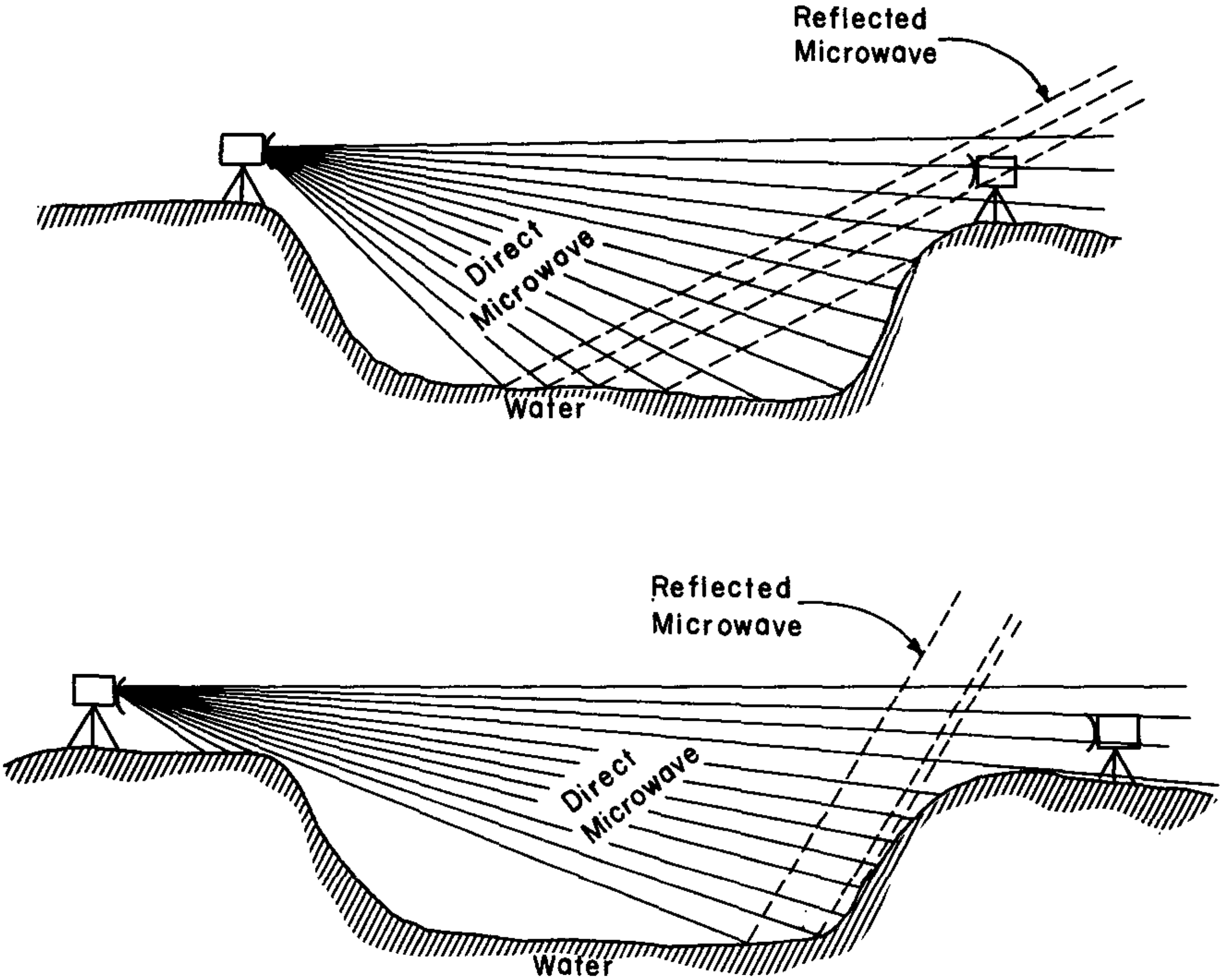



*Figure 19. Reflected microwaves.*

control until a bright, sharp trace appears on the cathode-ray tube.

(4) An X-SHIFT control is located on the left side panel of each unit, and it moves the trace in a horizontal direction across the face of the cathode-ray tube.

(5) A Y-SHIFT control is located on the left side panel of each unit, and it moves the trace in a vertical direction across the face of the cathode-ray tube.

(6) The CIRCLE AMPLITUDE control is located on the right side panel of the master unit and is used to adjust the diameter of the circular trace that is presented on the cathode-ray tube.

(7) The SHAPE control and the Y-AMPLITUDE control are located on the right side panel of the master unit and are adjusted together to achieve a circular trace on the cathode-ray tube.

*b. Operating Controls.*

(1) A PATTERN SELECTOR control is located in the upper part of the control panel of each unit and is used to select pattern A, B, C, or D, as required, during the measuring procedure. In addition, the PATTERN SELECTOR control on the remote unit selects the A+ or A− pattern upon instructions from the master unit operator.

(2) A MEASURE-SPEAK key is located in the center portion of the control panel of each unit and is used for switching from radiotelephone to measure and also for signaling during a measurement.

(3) A CAVITY TUNE dial is located in the center portion of the control panel of each unit and is used similarly to that of a program selector on a radio. Each CAVITY TUNE dial setting has a corresponding frequency.

(4) A REFLECTOR TUNE dial is located in the center portion of the control panel of each unit and is used for electrical tuning of the klystron. It should be adjusted at all times for maximum crystal current, which is indicated on the CRYSTAL CURRENT meter.

(5) The FORWARD-REVERSE reading key is located in the center portion of the control panel on the remote unit and is used to select the forward A+ or A− pattern or the reverse A+ or A− pattern, as instructed by the master unit operator.

(6) The PULSE AMPLITUDE control is located on the right side panel of the remote unit and is used to adjust the amplitude of the pulse being returned by the remote unit to the master unit.

*c. Monitoring Controls.*

(1) The PRESS PULSE control is located on the right side panel of the master unit and is used by the master unit operator to verify that a pulse of sufficient strength is being received from the remote unit. When the master unit operator presses the PRESS PULSE control, he is able to view on his cathode-ray tube the pulse pattern that is presented on the remote unit cathode-ray tube.

(2) A METER switch is located on the center portion of the control panel of each unit and is used in conjunction with the SWITCHED METER to check circuit operation. The switch is set to the REG position to check voltage regulators in the klystron circuit. It also indicates the state of charge of the battery. In the MOD position, the meter reading indicates that circuit pattern modulation is taking place. In the AVC position, the meter indicates the strength of the received signal. (The REFLECTOR TUNE control should always be adjusted to obtain a maximum AVC reading.) The three remaining switch positions are OFF positions, indicating that the SWITCHED METER (not the Tellurometer unit) is off.

(3) A CRYSTAL CURRENT meter is located in the center portion of the control panel of each unit and registers the crystal current. This reading should be kept at the maximum at all times by adjusting the REFLECTOR TUNE dial.

*d. Preset Controls.*

(1) The ADJUST MODULATION control plate located above the PATTERN SELECTOR switch on the control panel of each unit must be removed to adjust the modulation controls. A nonmetallic screwdriver is used to adjust the modulation level of pattern A, B, C, and D to read 40, 40, 40, and 36, respectively.

(2) The ADJUST FREQUENCY control plate located immediately below the PATTERN SELECTOR switch on the control panel of each unit must be removed to use the four controls for the adjustment of crystal frequencies. *This adjustment is performed only by a qualified technician.*

## 106. Setting Up the Tellurometer

Any attempt to operate a master unit and a remote unit while they are pointing at each other at a distance of 150 meters (500 feet) or less will result in damage to the units. The instructions contained in *a* through *k* below are applicable to both the master station and the remote station.

*a.* Set up the tripod over the point which identifies one end of the line to be measured, using the procedure outlined for setting up the aiming circle (para 148*a*).

*b*. Remove the instrument from the case and place it on the tripod head. Thread the tripod screw into the base of the instrument and tighten it to insure that the instrument is fixed to the tripod. Point the dipole in the approximate direction of the remote station. The Tellurometer radiates a conical beam of about 10°. In windy weather, the Tellurometer should be tied down so that it will not be blown over and damaged.

*c*. Dismount the parabolic reflector from its closed (travel) position and remount it in the open (operating) position, making sure that the fasteners fit properly and snugly. Failure to do so may result in damage to the unit.

*d*. Remove the power supply cable and the telephone handset from the storage compartment under the control panel. Hang the telephone handset on an improvised hook or bracket on the tripod. Never place the handset on top of the unit, because inaccuracies are created if the handset is left there during the measurement. *Place the LT and the HT switches in the OFF position.*

*e*. When a 12-volt battery is used, connect the *short* (8-foot) 12-volt power supply cable to INPUT. Connect the *red lead to the positive* post and the *black lead to the negative* post.

*f*. When a 24-volt battery is used, connect the *long* (18-foot) 24-volt power supply cable to INPUT. Connect the red lead to the positive post and the *black lead to the negative* post. *Do not use the short 12-volt power supply cable with a 24-volt battery*, because this will damage the unit.

*g*. The system is ready to be turned on after the completion of either *e* or *f* above. Place the LT switch in the ON (up) position. This provides a filament current to the tubes in the instrument, and it must be turned on 30 seconds before turning on the HT switch. Both the LT and HT switches must be in the ON position for operation of the instrument. The HT switch should be in the OFF position while waiting for the prearranged time of operation agreed upon by the master and remote operators.

*h*. Turn the METER switch to the REG (voltage regulator) position and the MEASURE-SPEAK key to MEASURE. The reading on the SWITCHED METER will vary with the strength of the battery. The reading should be at least 30 to permit a satisfactory measurement. A reading of less than 30 indicates that the charge in the battery is too low for operation.

*i*. Adjust the REFLECTOR TUNE dial for maximum crystal current. The CRYSTAL CURRENT dial should read above 0.2 for best operation. The lowest reading on the CAVITY TUNE dial will usually give the greatest CRYSTAL CURRENT reading.

*j*. Turn the METER switch to MOD (modulate) position and check the modulation level of each crystal. The PATTERN SELECTOR must be turned to each crystal, in turn. The correct readings, as viewed on the SWITCHED METER should be 40 on A, B, and C and 36 on D. If these readings are not approximated, remove the ADJUST MODULATION cover and adjust the modulation trimmers. The trimmers should be adjusted if the reading varies ± 2 from 40 or 36, depending on the crystal being checked. A nonmagnetic screwdriver should be used for this adjustment.

*k*. Switch the MEASURE-SPEAK key to SPEAK and move the METER switch to the AVC position. The SWITCHED METER should read about 20 microamperes without the two instruments being tuned and without the other set being turned on. Turn the REFLECTOR TUNE dial. If the SWITCHED METER needle moves, the receiver is working. If there is no movement of the indicator, trouble can be suspected in the receiver and a repairman should be consulted.

*l*. *This step is performed by the master unit only*. Switch the MEASURE-SPEAK key to SPEAK. There should be a spot of light near the center of the cathode-ray tube. Turn the CIRCLE AMPLITUDE control (right side panel) to make this spot as small as possible. Adjust the BRILLIANCE and FOCUS controls (left side panel) for a clear, sharp spot. Center the spot carefully in the graticule, using the X-SHIFT and Y-SHIFT controls (left side panel).

*m*. While the master unit operator is completing the adjustment in *l* above, the remote unit, with the MEASURE-SPEAK key in the SPEAK position, should present a spot of light near the center of the cathode-ray tube. If necessary, adjust the BRILLIANCE and FOCUS controls for a clear, sharp spot and center the spot in the cathode-ray tube by using the X-SHIFT and Y-SHIFT controls.

### 107. Tuning Procedures

The instrument tuning procedures follow the setting-up procedures and must be completed before a measurement is made. These procedures start with the MEASURE-SPEAK key in the SPEAK position and require coordination between the master unit and the remote unit operators. For this reason, the following instructions are arranged to insure that the proper sequence is followed. In each step, the following instructions are arranged to insure that the proper sequence is followed. In each step, the operation designated with the number 1 precedes the operation designated with the number 2.

*Master unit operator*

*a1.* Set the CAVITY TUNE dial two or three numbers below the previously agreed upon starting number (setting of remote). Place the METER switch in the AVC position. Increase the CAVITY TUNE dial setting until a maximum reading is indicated on the SWITCHED METER. A maximum AVC reading at this point indicates that the maser instrument is tuned to the remote instrument.

*b1.* Establish communications with remote operator.

*c1.* Direction find (DF) the instrument by traversing it on the tripod until the SWITCHED METER shows a maximum AVC reading. Check plumb after DF. Instruct the remote operator to direction find his instrument.

*d1.* Switch to MEASURE and turn the METER switch to the MOD position. Check modulation levels by turning the PATTERN SELECTOR to A, B, C, and D, in turn.

Announce each modulation reading to the recorder for entry in block VI of the field record and computations form (fig. 20). Request modulation readings from the remote operator and announce these to the recorder for appropriate entry on the field record and computations form.

Turn the METER switch to the AVC position.

*e1.* Announce the following information to the recorder for entry in block I of the field record and computations form (fig. 20): instrument numbers, station numbers, weather conditions, and operators' names.

*f1.* With the MEASURE-SPEAK key at MEASURE, adjust the CRT circle to a convenient reading size by using the CIRCLE AMPLITUDE, Y-AMPLITUDE, and SHAPE controls.

*g1.* Verify the maximum CRYSTAL CURRENT reading by turning the REFLECTOR TUNE dial. With the METER switch in the AVC position, readjust the CAVITY TUNE for a maximum AVC reading on the SWITCHED METER.

Inspect the circular trace on the CRT for a good clean break.

If a good break cannot be obtained or the pulse appears too weak or too strong, instruct the remote unit operator to adjust the PULSE AMPLITUDE.

*Remote unit operator*

*a2.* Set the CAVITY TUNE dial on the previously agreed upon starting number. Verify the maximum CRYSTAL CURRENT by using the REFLECTOR TUNE dial.

Place the METER switch in the AVC position and watch the SWITCHED METER for a maximum reading as a signal that the master operator has tuned his set.

*b2.* Answer the master operator's call.

*c2.* When instructed to do so, direction find the instrument by traversing it on the tripod until the SWITCHED METER shows a maximum AVC reading. Check plumb after DF.

*d2.* Switch to MEASURE and turn the METER switch to the MOD position. Check the modulation levels by turning the PATTERN SELECTOR to A, B, C, and D, in turn. Note the values of the modulation levels.

When requested to do so, report the modulation readings to the master operator.

*e2.* Stand by. If requested to do so, provide information to the master operator.

*f2.* Switch the MEASURE-SPEAK key to MEASURE and stand by.

*g2.* If requested to do so, adjust the PULSE AMPLITUDE.

*Note.* The Tellerometer system is now ready for distance measuring.

## 108. Operating Temperature

*a.* The Tellurometer is designed to operate in temperatures ranging from $-40°$ F to $+104°$ F (manufacturer's estimate). The crystals of both the master and remote units are mounted in an oven which automatically maintains operating temperature. The operation of the oven begins as soon as the power source is connected, regardless of whether the LT or the HT is on or off.

*b.* Readings should not be taken until the OVEN CYCLE lamp has gone off for the first time. The OVEN CYCLE lamp will then blink on and off while automatically maintaining operating temperature.

*c.* Approximately 30 minutes is required for the crystals to reach operating temperature at $-40°$ F air temperature; less than 15 minutes is required at $+25°$ F air temperature. If the Tellurometer is operated in cold, extremely windy weather, a light windbreak around the instrument will reduce warmup time.

## 109. Measurement Procedure

A Tellurometer measurement consists of one set of initial coarse readings, four sets of fine readings, and one set of final coarse readings. The readings are taken in this order and are recorded on the field record and computations form (fig. 20) as they are taken. The completed form constitutes a record of the distance measured and the system operation during one measurement. This form should be retained to make up a permanent log for the operation of the system. A coarse reading consists of readings on the A+, A−, B, C, and D patterns, in that order. A fine reading consists of A+ forward, A− forward, A− reverse, and A+ reverse pattern readings taken in that order for convenience in switching. If both operators know and follow this sequence for reading the patterns, the need for radiotelephone conversation will be reduced. As the reading in each pattern is completed, the master unit operator signals for a change to the next crystal setting by depressing the MEASURE-SPEAK key twice. This signal can be detected on the remote unit CRT by a change in the presentation and can be heard on the remote unit radiotelephone as a break in the measuring tone. All readings are made at the master unit and are read in a clockwise direction at the leading edge of the break. For one complete set of readings, all of the patterns should be read without moving the CAVITY TUNE dial. If any adjustment is necessary to improve the circle break, it should be made with the REFLECTOR TUNE knob in conjunction with the PRESS PULSE sequence discussed in paragraph 107*g*. If a good break does not appear at this time, the leading edge of the flexing point on the circle may be used to determine a reading. The REFLECTOR TUNE knob and the CAVITY TUNE dial should be tuned simultaneously to maintain maximum AVC and CRYSTAL CURRENT readings between sets. The measuring procedures require coordination between the operators of the master and the remote units. In each step, the operation designated with the number 1 precedes the operation designated with the number 2.

| *Master unit operator* | *Remote unit operator* |
|---|---|
| *a1.* Switch to SPEAK and advise the remote unit operator that the initial coarse reading will be taken in the prescribed order (A+, A−, B, C, D). Switch to MEASURE, turn the PATTERN SELECTOR to position A, and read the value on the CRT to the nearest division (fig 18). Announce the value to the recorder for entry in block II of the field record and computations form (fig 20).<br>Flick the MEASURE-SPEAK key twice to indicate to the remote unit operator that the reading of the A+ pattern is complete and that a reading is desired on the next (A−) pattern.<br>When the A− pattern appears on the CRT, read the value and announce it to the recorder for entry in block II of the field record and computations form.<br>For the A− pattern, continue to read the clockwise edge of the break. | *a2.* When instructed that the initial coarse readings will start, switch to MEASURE. Each time the master unit operator signals by flicking the key, switch to the next pattern frequency.<br>The master unit operator's signal will appear as a flick on the remote unit CRT and as a break in the measuring tone on the radiotelephone. |

| *Master unit operator* | *Remote unit operator* |
|---|---|
| Flick the MEASURE-SPEAK key twice to indicate to the remote unit operator that the reading of the A— pattern is complete and that a reading is desired on the next (B) pattern. Turn the PATTERN SELECTOR to position B and proceed as with the previous readings. After each reading, flick the switch to indicate readiness to read the next pattern. When the C and D pattern readings have been completed, return the PATTERN SELECTOR to position A. This completes the initial coarse readings. | |
| *b1.* Switch to SPEAK and advise the remote unit operator that each fine reading will be taken in the prescribed order (A+, A—, A— reverse, A+ reverse). | *b2.* Switch to SPEAK and wait for instructions. When advised that fine readings will be taken, turn the METER switch to the AVC position and set the CAVITY TUNE dial to the announced setting. |
| Normally four sets of fine readings are taken. The frequency interval between sets should be the maximum allowable (i.e., 3, 5, 7, and 9) over the range of the CAVITY TUNE dial. When making the reverse readings, continue to read the clockwise leading edge of the break. Announce to the remote unit operator the remainder of the CAVITY TUNE dial settings. | The CAVITY TUNE dial setting should be the same as that on which the initial coarse readings were taken. |
| *c1.* Adjust the CAVITY TUNE dial, if necessary, for maximum AVC readings. Check the REFLECTOR TUNE dial for maximum CRYSTAL CURRENT. Announce MEASURE to the remote unit operator and switch to MEASURE. Check the circle sweep for focus, brilliance, size, shape, and circle break. If the circle break is not apparent, adjust it with the REFLECTOR TUNE dial and PRESS PULSE. If the adjustment fails to produce a break communicate with the remote unit operator and request a high PULSE AMPLITUDE setting. | *c2.* When instructed to do so, increase or decrease the PULSE AMPLITUDE. On instructions from the master operator, switch the MEASURE-SPEAK key to MEASURE. |
| *d1.* Take the four sets of fine readings at the previously announced CAVITY TUNE dial intervals. Flick the MEASURE-SPEAK key to signal the remote unit operator. Announce the value read for each pattern during the measurement of each set to the recorder for entry in block III of the field record and computations form (fig. 20). After taking the A+ reverse reading of each set, the master unit operator should pause momentarily before proceeding and allow the recorder to check the recorded values for possible reading errors. | *d2.* For each of the four sets of fine readings, use the following procedure: When signaled by the master unit operator that the A+ reading is complete, switch the PATTERN SELECTOR to the A— position. On the second signal from the master unit operator, depress the FORWARD-REVERSE key. When the FORWARD-REVERSE key is in the REVERSE position, the master unit operator reads the A-reverse pattern. On the third signal, switch the PATTERN SELECTOR to the A+ position. This presents the A+ reverse pattern to the master unit operator. On the fourth signal, raise the FORWARD-REVERSE key and wait for instructions. When instructed to do so, switch to SPEAK and advance the CAVITY TUNE dial to the next setting. |
| *e1.* Repeat the procedures in *c1* and *d1* above with different CAVITY TUNE dial settings for the required number (four) of sets of fine readings. | *e2.* Follow instructions from the master operator as indicated in *c2* and *d2* above. |
| *f1.* Switch to SPEAK and advise the remote unit operator that final coarse readings will be taken. Follow the procedure in *a1* above at the last CAVITY TUNE dial setting. As the readings are made, announce the values to the recorder for entry in block IV of the field record and computations form (fig. 20). | *f2.* Follow the procedure in *a2* above at the last CAVITY TUNE dial setting. |

| *Master unit operator* | *Remote unit operator* |
|---|---|
| *g1.* Compare the interpreted initial and final coarse readings for agreement (blocks II and IV of the field record and computations form). If a significant disagreement is evident (para 113), take additional coarse readings until the error is isolated. | |
| *h1.* Advise the remote unit operator that the measurement is complete and give further instructions. Instructions must be explicit and thoroughly understood, since at this point the instruments will be turned off and communications severed. | *h2.* Proceed as instructed. |
| If at any time in tuning to a new CAVITY TUNE dial setting, communications cannot be made with the remote unit, return to the last CAVITY TUNE dial setting at which contact was made and issue instructions. | If at any time in tuning to a new CAVITY TUNE dial setting communications cannot be made with the master unit, return to the last CAVITY TUNE dial setting at which contact was made and await instructions. |

## 110. Computing a Tellurometer Distance Measurement

*a.* Computations required for a Tellurometer distance measurement are performed in the following order:

(1) Interpret the initial coarse readings.

(2) Interpret the fine readings.

(3) Interpret the final coarse readings.

(4) Resolve the transit time in millimicroseconds from correctly interpreted pattern differences.

(5) Compute the slope distance in meters from a transit time in millimicroseconds.

(6) Reduce the slope distance to a horizontal sea level distance in meters.

*b.* Tellurometer distance measurements are normally computed at the master station before party personnel depart for subsequent survey operations. This permits the verification of the distance determined by map scaling and the resolution of ambiguous pattern differences if they occur. Figure 20 illustrates the recording of readings on a field record and computations form (DA Form 5–139) and is used as a reference for the discussions on computations in paragraphs 111 through 117.

## 111. Interpreting the Initial Coarse Readings (Block II)

*a.* The phase difference is determined by subtracting the coarse readings B, C, D, and A− from the A+ reading. If the A+ reading is smaller than the B, C, D, and A− readings, as in figure 20, 100 is added to the A+ reading before subtracting.

*b.* The difference between A+ and A— is divided by 2 and the result is compared with the A+ reading; 50 is added to the result, if necessary to keep it at approximately the same value as the original A+ reading. If the values do not compare within 4 millimicroseconds, the coarse measurements must be reobserved. In figure 20, this value (03.0) is within 2 millimicroseconds of the A+ reading (05), which is satisfactory.

## 112. Interpreting the Fine Readings (Block III)

After the fine readings are taken and recorded in block III, the mean differences and the mean fine reading are computed. In the example below, one set of the fine readings in figure 20, block III, is meaned:

| *Set* | *Remote dial* | *Forward* | *Reverse* |
|---|---|---|---|
| 1 | 3 | A+ 05 | A+ 59 |
| | | A− 99 | A− 51 |
| | | 06 | 08 |

06 + 08 = 14 ÷ 2 = 07 mean difference

07 ÷ 2 = 3.50 mean fine reading

A+ (initial coarse) = 05.00 (block II)

Mean fine reading = 03.50

Zeroing error = 1.50 millimicroseconds

## FIELD RECORD AND COMPUTATIONS - TELLUROMETER
(TB ENG 23)

### BLOCK I - STATION DATA

| STATION | | HEIGHT METERS | INST. NO. | OPERATOR | WEATHER: CLEAR-WARM | |
|---|---|---|---|---|---|---|
| MASTER: STERLING | 1 | 449.1 | 238 | LECLAIR | RECORDER: BURK | |
| REMOTE: APACHE | 2 | 412.6 | 239 | POLLARD | APPROX. DIS.: MILES 2.3 | METERS 3500 |
| 3 | HEIGHT DIFF: (1)&(2) 36.5 | 4 | SUM OF HEIGHTS (1)+(2) 861.7 | 5 | MEAN HEIGHT (4) ÷ (2) 430.8 M | |

### BLOCK II - INITIAL COARSE READINGS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A+ | 05 | A+ | 05 | A+ | 05 | A+ | 05 |
| B | 78 | C | 65 | D | 24 | A− | 99 |
| DIFF | 27 | DIFF | 40 | DIFF | 81 | DIFF | 06 / 2 |
| | | | | | COMPARE WITH A+ | | 03.0 |

### BLOCK IV - FINAL COARSE READINGS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A+ | 07 | A+ | 07 | A+ | 07 | A+ | 07 |
| B | 79 | C | 66 | D | 25 | A− | 99 |
| DIFF | 28 | DIFF | 41 | DIFF | 82 | DIFF | 08 / 2 |
| | | | | | COMPARE WITH A+ | | 04.0 |

### BLOCK III - FINE READINGS

| SET | REMOTE DIAL | A | FORWARD | REVERSE | MEAN DIFF |
|---|---|---|---|---|---|
| 1 | | + | 05 | 59 | |
| | 3 | − | 99 | 51 | |
| | | DIFF | 06 | 08 | 14 / 7.0 |
| 2 | | + | 09 | 57 | |
| | 5 | − | 02 | 50 | |
| | | DIFF | 07 | 07 | 14 / 7.0 |
| 3 | | + | 08 | 56 | |
| | 7 | − | 03 | 51 | |
| | | DIFF | 05 | 05 | 10 / 5.0 |
| 4 | | + | 07 | 59 | |
| | 9 | − | 99 | 50 | |
| | | DIFF | 08 | 09 | 17 / 8.5 |
| SUM MEAN DIFF | | | | | 27.5 |
| DIVIDE BY NUMBER OF SETS TIMES 2 | | | | | 03.44 |
| MEAN FINE READING (COMPARE WITH A+) | | | | | 03.44 |

### BLOCK V - TRANSIT TIME (III, IV & X)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| APPROX DIS MILES (X) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FINAL COARSE READING: A+,B DIFF | | 2 | 8 | 0 | 0 | 0 | 0 | 0 |
| A+,C DIFF | | | 4 | 1 | 0 | 0 | 0 | 0 |
| A+,D DIFF | | | | 8 | 2 | 0 | 0 | 0 |
| MEAN FINE READING III | | | | | 0 | 3 | 4 | 4 |
| BRING DOWN UNRESOLVED TRANSIT TIME | 0 | 2 | 4 | 8 | 0 | 3 | 4 | 4 |
| RESOLVED TRANSIT TIME | 0 | 2 | 3 | 8 | 0 | 3 | 4 | 4 |

### BLOCK VI - METER READINGS

| | | MASTER | | REMOTE |
|---|---|---|---|---|
| AVC | | 50 | | 48 |
| REGULATOR | | 50 | | 55 |
| MODULATION | A | 40 | A | 40 |
| | B | 39 | B | 40 |
| LEVELS | C | 41 | C | 39 |
| | D | 36 | D | 36 |

### BLOCK VII - SLOPE DISTANCE, METERS

| | | | | |
|---|---|---|---|---|
| 1 | LOG CORRECTED TRANSIT TIME (V) | 4 | 376 | 6397 |
| 2 | LOG 1/2 V/N METERS | 9 | 175 | 6509 |
| 3 | LOG SLOPE DISTANCE METERS (1)+(2) | 3 | 552 | 2906 |

### BLOCK IX - SEA LEVEL DISTANCE METERS

| | | | | |
|---|---|---|---|---|
| 1 | LOG SLOPE DISTANCE METERS (VII) | 3 | 552 | 2906 |
| 2 | LOG COS VERTICAL ANGLE (VIII) | 9 | 999 | 9772 |
| 3 | (1)+(2) LOG HORIZONTAL DISTANCE METERS | 3 | 552 | 2678 |
| 4 | LOG SEA LEVEL COEFFICIENT (XI) | 9 | 999 | 9727 |
| 5 | (3)+(4) LOG SEA LEVEL DISTANCE METERS | 3 | 552 | 2405 |
| 6 | SEA LEVEL DISTANCE METERS | 3566.49 | | |

### BLOCK VIII - VERTICAL ANGLE


| | | | | |
|---|---|---|---|---|
| 1 | DIFFERENCE HEIGHT METERS | 36.5 | | |
| 2 | LOG (1) | 1 | 562 | 2929 |
| 3 | LOG SLOPE DISTANCE METERS (VII) | 3 | 552 | 2906 |
| 4 | (2)−(3) LOG SIN VERT ANGLE | 8 | 010 | 0023 |
| 5 | VERTICAL ANGLE EQUAL TO LOG SIN (4) | | 10 | 43.1 |

### BLOCK X - FIRST FIGURE (TRANSIT TIME)

| APPROX DISTANCE MILES (I) | FIRST FIGURE |
|---|---|
| 0–10 | 0 |
| 10–20 | 1 |
| 20–30 | 2 |
| 30–40 | 3 |

| | | | |
|---|---|---|---|
| COMPUTER KEUTHAN | CHECKER BLOXOM | SHEET OF | SHEETS |
| NOTEBOOK REFERENCE | AREA | DATE | |

DA FORM 1 JUN 60 5-139

*Figure 20. Field record and computations form.*

BLOCK XI - SEA LEVEL COEFFICIENT

The height used to determine log sea level coefficient is height of known station to the nearest 100 meters. Mean height should be used if the heights of both stations are known.

| HEIGHT METERS | LOG SEA LEVEL COEFFICIENT |
|---|---|
| -100 | 0.0000068 |
| -50 | 0.0000034 |
| 00 | 0.0000000 |
| 50 | 9.9999966 |
| 100 | 9.9999931 |
| 200 | 9.9999863 |
| 300 | 9.9999795 |
| 400 | 9.9999727 |
| 500 | 9.9999659 |
| 600 | 9.9999590 |
| 700 | 9.9999522 |
| 800 | 9.9999453 |
| 900 | 9.9999386 |
| 1000 | 9.9999317 |
| 1100 | 9.9999249 |
| 1200 | 9.9999181 |
| 1300 | 9.9999112 |
| 1400 | 9.9999044 |
| 1500 | 9.9998976 |
| 1600 | 9.9998908 |
| 1700 | 9.9998839 |
| 1800 | 9.9998770 |
| 1900 | 9.9998703 |
| 2000 | 9.9998634 |
| 2100 | 9.9998566 |
| 2200 | 9.9998498 |
| 2300 | 9.9998429 |
| 2400 | 9.9998361 |
| 2500 | 9.9998292 |
| 2600 | 9.9998225 |
| 2700 | 9.9998156 |
| 2800 | 9.9998088 |
| 2900 | 9.9998020 |
| 3000 | 9.9997951 |
| 3100 | 9.9997883 |
| 3200 | 9.9997815 |
| 3300 | 9.9997747 |
| 3400 | 9.9997678 |
| 3500 | 9.9997609 |
| 3600 | 9.9997542 |

**NOTE:**

The above values were computed for a northing of 3 200 000 and azimuth of 45 degrees and can be used anywhere on the UTM grid without causing an error greater than 1:250,000.

GIVEN:

Height of station - METERS.

FIELD DATA:

a. Approximate distance in both miles and meters.
b. Corrected transit time.
c. Height if not available.
d. Vertical angle *(compute if not possible to measure)*.

GUIDE:

a. BLOCKS II, III & IV - If A+ is less than B, C or A−, add 100 to A+ before determining the difference.
b. BLOCKS II, III & IV - "Compare with A+" means that this figure must compare ± 4 MUS with A+ in the final coarse reading. If necessary add 50.
c. BLOCK VIII *(5)* - Measured or computed vertical angle.

LIMITATIONS:

This form may be used for obtaining artillery survey accuracies.

RESULTS:

A sea level distance is determined which should be treated the same as a taped distance.

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*Figure 21. Back of field record and computations form.*

*a.* In the *forward readings,* the A− is subtracted from the A+. Because the A+ is smaller than the A−, it is necessary to add 100 to 05 before subtracting (100 + 05 = 105; 105 − 99 = 06). The 100 is added to A+ only when it is smaller than A−.

*b.* In the *reverse readings,* the A— is subtracted from the A+ (59 — 51 = 08). If the A+ is smaller than the A—, it is necessary to add 100 to the A+ before subtracting.

*c.* The difference in the forward readings is added to the difference in the reverse readings, and the sum is divided by 2 to obtain the mean difference (06 + 08 = 14 ÷ 2 = 07).

*d.* The mean difference is divided by 2 to obtain the mean fine reading (07 ÷ 2 = 3.50).

*e.* The procedure in *a* through *d* above is used to correct for the zeroing error at the remote dial setting of 3. Essentially the same procedure is used for the readings taken at the remote dial settings of 5, 7, and 9, except that, in block III of the form, the sum of the mean differences for the four dial settings is divided by 2 times the number of sets taken to determine the mean fine reading for all of the sets. This mean fine reading is computed (to the nearest hundredth) and compared with the initial A+ reading in block II. The difference in the two values (adding 50 to the mean fine reading if necessary) should compare within 4 millimicroseconds. If they do not agree within this tolerance, each set of fine readings and the initial coarse A+ reading should be inspected for any obviously erratic values. If the mean difference of any set of fine readings varies from the mean of the four sets by more than 8 millimicroseconds, that set should be repeated at the same remote dial setting. If the difference persists, the remote unit operator should be instructed to move to another frequency (a move of one-half or one full graduation in the remote dial setting is sufficient). The master unit operator should then retune and take a new set of fine readings. If the inspection of the fine readings reveals no erratic readings, then the initial coarse A+ reading should be verified. In figure 20, the mean fine reading (3.44) is compared with A+ (05) in block II and is satisfactory because it is within 4 millimicroseconds.

*f.* Four sets of fine readings are made using all parts of the CAVITY TUNE dial; i.e., 3, 5, 7, and 9. The use of all parts of the CAVITY TUNE dial will reduce the reflection error until it is so small that it will seldom affect artillery survey accuracies.

## 113. Interpreting the Final Coarse Readings (Block IV)

The final set of coarse readings is taken as a check on the initial coarse readings and is used to resolve the transit time in block V. The final coarse readings are interpreted and the differences are resolved in the same manner as the initial coarse readings. When the differences are resolved, the final coarse differences are compared with the initial coarse differences. If the differences between the patterns of the two sets exceed that shown below, a third set of coarse readings is taken and the pattern differences are resolved and compared with the first two sets. Of the two sets that compare most favorably, the last set taken is accepted for the final coarse readings and is used to resolve a transit time.

| *Pattern Difference* | *Maximum Difference* |
|---|---|
| A+, A− | 4 |
| A+, B | 3 |
| A+, C | 3 |
| A+, D | 2 |

## 114. Resolving the Transit Time From Pattern Differences (Block V)

*a.* In the spaces provided in block V (fig. 20), enter the *final coarse reading differences* from block IV, the mean fine reading (to the nearest hundredth) from block III, and the first figure (transit time) from block X (approximate distance in miles).

*b.* On the line for unresolved transit time, bring down the first digit appearing on each line in block V and the complete value of the mean fine reading and enter them as the unresolved transit time.

*c.* Determine the resolved transit time by successive comparison and enter the value on the line for resolved transit time (fig. 20). The method of comparison used to resolve a corrected transit time is illustrated in figure 22. The resolved transit time represents the travel

BLOCK V - TRANSIT TIME (III, IV, & X)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Obtained from approximate distance in miles (block X) | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | From block X, enter 0 on line for resolved transit time (Approx. dis. miles from map scale = 2.3 miles) |
| Final | A+B Diff | | 2 | 8 | 0 | 0 | 0 | 0 | 0 | To compare with A+B Diff consider 33803.44, (23803.44), 13803.44 = value closest to 28000; enter 2 on line for resolved transit time |
| Coarse | A+C Diff | | | 4 | 1 | 0 | 0 | 0 | 0 | To compare with A+C Diff consider 5803.44, 4803.44, (3803.44) = value closest to 4100; enter 3 on line for resolved transit time |
| Readings (block IV) | A+D Diff | | | | 8 | 2 | 0 | 0 | 0 | To compare with A+D Diff consider 903.44, (803.44), 703.44 = value closest to 820; enter 8 on line for resolved transit time |
| Mean fine reading (block III) | | | | | | 0 | 3 | 4 | 4 | Use this value to compare with A+D Diff. Enter the mean fine reading from block III. This value will not change. |
| Unresolved transit time (block III) | | 0 | 2 | 4 | 8 | 0 | 3 | 4 | 4 | Unresolved transit time |
| Resolved transit time (block III) | | 0 | 2 | 3 | 8 | 0 | 3 | 4 | 4 | Resolved transit time |

*Figure 22. Resolving a transit time.*

time in millimicroseconds of the electromagnetic wave transmitted from the master unit to the remote unit and return.

### 115. Computing Slope Distance in Meters (Block VII)

*a.* The resolved transit time in millimicroseconds is a time measurement which must be corrected for the refraction of atmosphere and converted to a one-way slope distance in meters. The log of the resolved transit time is entered in line 1 of block VII.

*b.* A mean refractive index is used in artillery survey for the refraction correction. This index eliminates the requirement for meteorological observations during a measurement and simplifies computations. This index has been applied to the velocity of a radio wave per millimicrosecond to provide a constant. The logarithm of one-half the constant is added to the log of the resolved transit time to produce the logarithm of a one-way slope distance in meters. This logarithm appears on line 2, block VII (fig. 20), and is added to the logarithm on line 1; the resulting sum is the logarithm of the slope distance in meters (line 3, block VII).

*c.* The use of a mean refractive index will provide an accuracy greater than 1:10,000 at air temperatures of −40°F to +120°F, at elevations of −1,000 to + 10,000 feet, and under all conditions of humidity.

### 116. Determining the Vertical Angle (Block VIII)

*a.* In block VII, the logarithm of the slope distance was determined, and this distance must be converted to an equivalent horizontal distance to be used in artillery survey. The horizontal distance can be computed by using the slope distance and the vertical angle or the slope distance and the difference in height.

*b.* When the vertical angle is measured, it is entered on line 5 in block VIII (fig. 20). The vertical angle should be measured reciprocally or corrected for curvature, when measuring over a long distance. The vertical angle may be expressed in either degrees, minutes, and seconds or in mils, depending on the type of theodolite used to make the measurement.

*c.* If the vertical angle is not measured, then it must be computed by using the slope distance and the difference in height. The difference in height is obtained from line 3, block I, at the top of the form. The vertical angle is computed in block VIII.

*d.* The heights of the master station and the remote station are entered on lines 1 and 2, respectively, in block I. The heights are obtained from known data or determined with the altimeter (chap 11).

## 117. Reducing Slope Distance to Sea Level Distance (Block IX)

*a.* The slope distance is reduced to sea level distance by computations, using the slope distance, vertical angle, and sea level coefficient. The computations are made by following the instruction in block IX (fig. 20).

*b.* The instructions for the use of the sea level coefficient are on the back of the form in block XI (fig. 21).

*c.* The computations on the field record and computations form (fig. 20) end with sea level distance in block IX. To carry the computations further would be a duplication of effort, since most Department of the Army artillery survey forms provide for the application of the log scale factor to convert to universal transverse mercator grid distance.

## 118. Personnel Requirements

One man can operate either the master or the remote unit. However, in order to take advantage of the accuracy and speed of a Tellurometer survey, two men—an instrument operator and a recorder—are required for each unit. As in all artillery survey operations, two independent computations must be made.

## 119. Tellurometer Traverse

*a.* The primary use of the Tellurometer in artillery survey is to measure distance for a traverse. However, it can be used to measure any required distance between 150 meters and approximately 64,000 meters (40 miles). The main advantages of determining distance with a Tellurometer rather than with a tape are:

(1) Greater accuracy.
(2) Greater ease in measuring over rough terrain.
(3) Less time required to measure long distances.

*b.* Short distances can usually be determined in less time with a tape than with the Tellurometer. Because of the necessity of distributing survey control throughout an area of operations, the average distance measured in a Tellurometer traverse is from 1 to 5 miles.

*c.* A set of Tellurometer equipment consists of one master unit and two remote units. In Tellurometer traverse, the master station is the midstation and the remote units are located at the forward and rear stations. The master unit occupies alternate stations and measures the distance to the rear station and the forward station each time it is set up. Horizontal and vertical angles are measured at each Tellurometer station. When measurements are complete at the first three stations, the master station and the rear remote station are moved to the next successive stations (fourth and fifth stations, respectively). The former forward remote station remains in position and becomes the rear remote station. The procedure is continued with the master station being positioned between two remote stations until measurements are completed.

*d.* The theodolite is the angle-measuring instrument used with the Tellurometer. Generally, the Tellurometer is used in artillery fourth-order survey, using fourth order specifications. If the Tellurometer is used for artillery fifth-order survey, distances are measured in the same manner as for artillery fourth-order survey, and angles are measured to fifth-order specifications. In either case, one theodolite is provided with each master and remote unit. An altimeter is also provided with each master and remote unit for the determination of height when a vertical angle cannot be measured.

*e.* The tripod should be set up over the station and used for both the Tellurometer and the theodolite. The instrument operator and the recorder perform both distance measurements and angle measurements.

### 120. Trilateration by Tellurometer

*a.* Trilateration is another method of survey for which the Tellurometer may be used. Trilateration is the measurement of the length of the sides of a triangle.

*b.* Trilateration may be performed when poor visibility prohibits the use of an angle-measuring instrument, thus eliminating Tellurometer traverse as a means of extending survey control. When trilaterating under these conditions, height is established by altimetry and azimuth is determined with the azimuth gyro.

*c.* Generally, trilateration will not be used when a Tellurometer traverse is possible, because in most tactical situations and conditions of terrain, a Tellurometer traverse is faster, more accurate, less complicated, and requires fewer computations and less reconnaissance.

### 121. Care and Maintenance of the Tellurometer

*a.* The number of artillery surveyors with a sufficient knowledge of electronics to perform all adjustments and repairs of the Tellurometer is limited. For this reason, the operator's maintenance should be confined to a level suitable for personnel accustomed to conventional survey equipment.

*b.* The Tellurometer is a relatively delicate instrument. Unlike conventional survey equipment, the Tellurometer is susceptible to many effects besides those caused by rough handling.

*c.* TM 5–6675–202–15 is the operator's manual for the Tellurometer. This manual clearly defines the extent of care and the maintenance responsibilities from the operator level to the highest maintenance category. The operator should consult this manual regularly in performing his maintenance. *Maintenance experimentation by operating personnel is prohibited.*

## Section III. SURVEYING INSTRUMENT, DISTANCE MEASURING, ELECTRONIC

### 122. General

The DME (distance-measuring equipment), an electronic distance-measuring device replaces the Tellurometer as an item of issue in tables of organization and equipment of artillery units required to perform fourth-order survey (fig. 23). The DME system consists of two units which may serve either as a measurer or a responder by means of a selector switch. In the DME system, units are designated as measurer or responder, depending on the mode selected, and correspond respectively to the master and remote functions in the Tellurometer system. Measurements with the DME *cannot* be made through land masses or large obstructions, such as houses, which are directly in the line of sight and close to either of the units. However, measurements can be made when small, distant objects, such as trees, brush, chimneys, or small buildings, lay on line of sight. Visibility is not required for measurements with the DME as it is for an optical instrument. The minimum range capability of the DME is 200 meters; the maximum range capability, 50 kilometers (approximately 35 miles). Approximately 30 minutes are required to measure and compute a distance regardless of the length of the line. A distance can be measured during daylight or darkness and through fog, dust, or rain.

### 123. Description of Components

*a.* The dimensions of the DME are 15 by 14 by 10 inches; it weighs 34.5 pounds. The unit has a built-in aerial and communication system for use during the setup and measurement periods. A luggage-type handle on the instrument permits the instrument to be carried when it is removed from its carrying case.

*b.* The instrument is contained in a metalized fiberglass case.

*c.* The tripod issued with the DME is similar to, and interchangeable with, the tripod used with the Tellurometer, the T16 and T2 theodolites.

*d.* The units may be operated from either a 12- or a 24-volt, DC power source or a 110-volt, 60-cycle AC source with a converter or a self-contained 12-volt nickel cadmium battery.

*Figure 23. DME station with operating equipment.*

*e.* Additional accessories include—

(1) A Set of Allen wrenches.
(2) A screwdriver-type wrench.
(3) A screwdriver.
(4) A 24-volt cable (25 feet).
(5) A 12-volt cable (6 feet).
(6) A connector for the internal battery.
(7) A headset.
(8) A nickel cadmium battery.
(9) An instructional manual.

## 124. Selection of Stations

Electrical line of sight is required between the two units of the DME system. The principles to be considered in selecting the stations for the DME are the same as those for the Tellurometer (para 104).

## 125. Operator Training

*a.* An instrument operator qualified to operate conventional surveying instruments, especially the Tellurometer, can acquire in approximately 30 minutes an adequate knowledge of the DME to perform and supervise all the activities required to complete a field observation and to perform the necessary computations for the determination of a distance.

*b.* Continued operation of the DME will provide the operator with sufficient knowledge to perform a limited amount of maintenance.

## 126. Instrument Controls

The physical locations of the DME controls are shown in figure 24. The functions of the individual controls are as follows:

*a. ON-OFF-STANDBY Switch.* The ON-OFF-STANDBY switch is used to apply power to the equipment. This switch is located in the lower left section of the control panel. When the switch is—

(1) In the OFF position (horizontal), none of the circuits are energized.
(2) In the STANDBY position (down), the klystron filament and the crystal oscillator oven are energized. This permits the instrument to warm to operating temperature.
*Caution:* **Do not switch from OFF or STANDBY to ON until the warming cycle has been completed.**
(3) In the ON position (up), all circuits required for distance measurement are energized.

*b. VOLUME Control.* The VOLUME control is located next to the ON-OFF-STANDBY switch. This control adjusts the gain of the circuits driving the headset earphones. The control may be turned down to zero.

*c. ILLUMINATION Control.* The ILLUMINATION control is located approximately in the center of the control panel. This control adjusts the brightness of the seven lamps on the control panel. The lamps are turned off in the fully counterclockwise position of the control.

*d. MEASURE-TALK Switch.* The MEASURE-TALK switch is located just above the ILLUMINATION control. When the switch is in the TALK position, voice communication between the units is possible. When the switch is in the MEASURE position, the circuits that determine the distance between units are connected.

*e. MONITOR Meter.* The MONITOR meter is located in the upper left corner of the control panel. After the minimum meter reading is determined, the responder instructs the measurer to rotate his instrument in azimuth to also determine a minimum meter reading. In the TALK mode, the meter deflection is proportional to voltages in the circuits being monitored.

*f. MONITOR Switch.* The MONITOR switch is a seven-position switch located just below the MONITOR meter. The switch positions and the circuits monitored are listed below.

| *Switch position* | *Circuit monitored* |
|---|---|
| OVEN | Oven heater current |
| RF | Mixer crystal current |
| AFC | Output of AFC amplifier |
| SIG | Sample of AGC voltage |
| −12 | −12 volt supply |
| +12 | +12 volt supply |
| DC IN | DC input voltage |

*g. FREQUENCY Control.* The FREQUENCY control is in the center of the top row of controls on the control panel. This control is used to tune one instrument to the frequency of the other instrument.

*h. HIGH-LOW Switch.* The HIGH-LOW switch is located below and to the right of the FREQUENCY control. It is controlled only by the responder unit. In the HIGH position, frequency tuning is attained when the responder frequency is about two units *higher* than that of the measurer. In the LOW position, frequency tuning is attained when the responder frequency is about two units *lower* than that of the measurer.

*i. CHANNEL Switch.* The CHANNEL switch is located in the upper right-hand corner of the control panel. This switch is used to select the measurer or responder mode of operation. Those positions marked "M" allow the unit to operate in the MEASURE mode, and those positions marked "R" allow the unit to operate in the responder mode. There are six channels in either mode which are used to resolve each digit of the distance being measured.

*j. COUNTER Dial.* The COUNTER dial is located near the center of the control panel. The COUNTER dial has a range of 000 to 999. The COUNTER dial is geared to the COUNTER control.

*k. COUNTER Control.* The COUNTER control is located to the right of the COUNTER dial. This control is geared to both the COUNTER dial and the resolver. During measurements the COUNTER knob is rotated clockwise until the MONITOR meter needle also moves in a clockwise direction and is nulled (rests at zero). The value which appears on the COUNTER dial is then extracted as observed field data.

## 127. Setting-Up Procedure

The procedures for setting up the DME are as follows:

*a.* Before going into the field, determine—

(1) The time at which contact will be established.

(2) Which operator will initially be the measurer.

(3) The approximate locations of the stations and the direction toward each other.

*b.* Place the tripod over the station with one tripod leg pointing to the station at the other end of the line to be measured. This is important because the front leg will be used later to elevate the instrument through a vertical angle during the orienting procedure. A plumb bob should be used to center the tripod approximately, but exact plumbing is unnecessary at this time, since the instrument will be moved slightly during orientation.

*c.* Remove the instrument from its case and place it on the tripod head. Thread the tripod screw into the base of the instrument. Do not tighten the screw completely. Point the dipole in the approximate direction of the opposite unit. In windy weather, the DME should be tied down so that it will not be blown over and damaged.

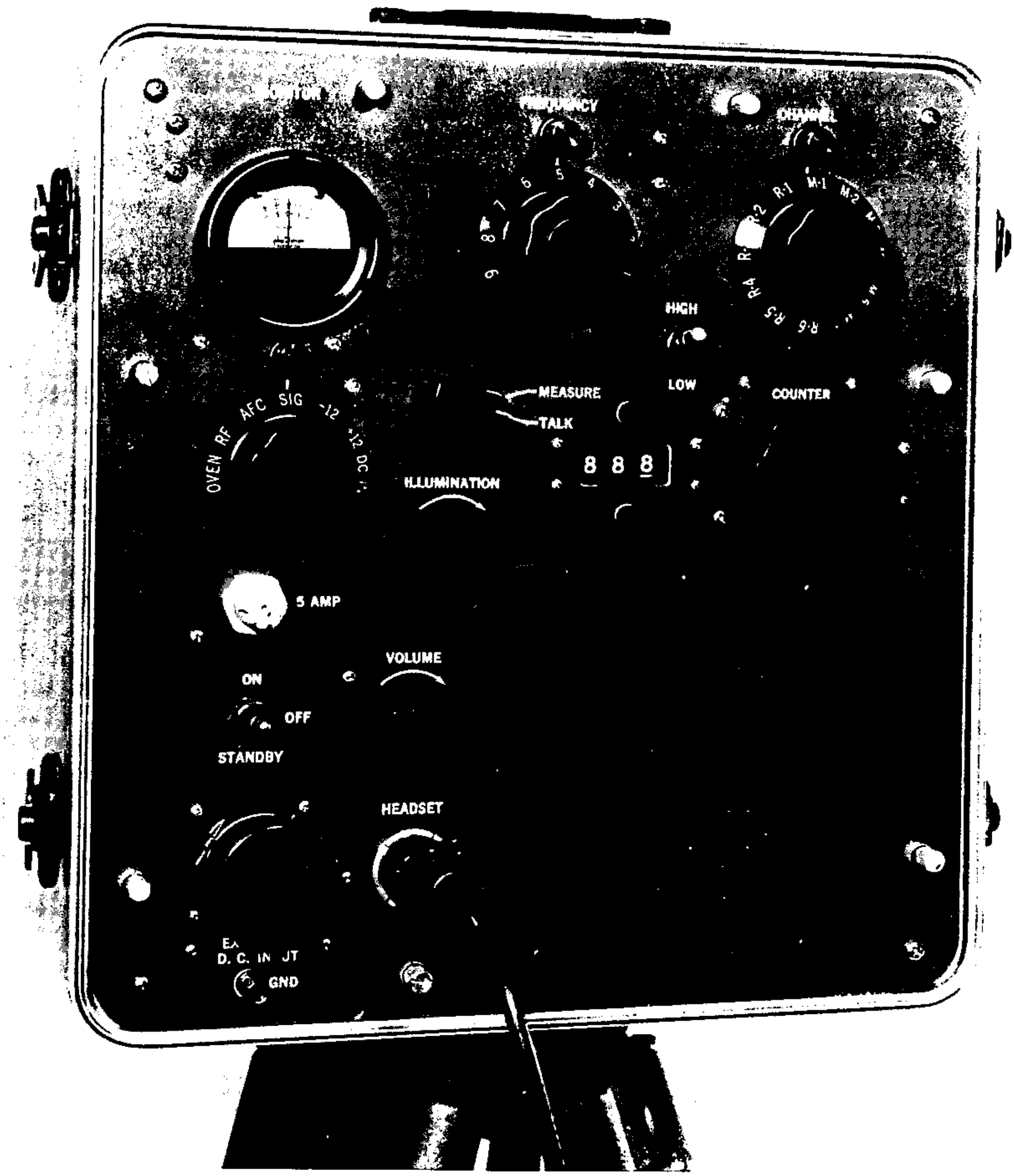



*Figure 24. Control panel of the DME.*

*d.* Remove the control panel cover and the antenna cover.

*e.* Set the controls and switches in the following positions:

| *Controls* | *Measurer* | *Responder* |
|---|---|---|
| ON-OFF-STANDBY switch | OFF | OFF |
| MONITOR switch | OVEN | OVEN |
| MEASURE-TALK switch | TALK | TALK |
| HIGH-LOW switch | HIGH | HIGH |
| CHANNEL switch | M6 | R6 |
| FREQUENCY control | 1 | 3 |
| VOLUME control | Clockwise | Clockwise |
| ILLUMINATION control | Clockwise, as required. | Clockwise, as required. |

*f.* Select the power cable or connector suitable for the power source being used:

| *Power source* | *Cable or connector* |
|---|---|
| 12V DC internal battery | Connector |
| 12V DC external battery | 6-ft cable |
| 24V DC external battery | 25-ft cable |

*Note.* The connector is an accessory device which routes current from the internal battery to the circuitry of the instruments.

*g.* Connect the power cable or connector to the EXTERNAL DC INPUT receptacle on the control panel. If an external source is to be used, connect the power cable clips to the power source. *Connect the clip with the black insulator to the negative terminal of the power source and the clip with the red insulator to the positive terminal of the power source.*

*Note.* A chassis ground terminal is provided on the control panel. Under normal usage, no connection is required.

*h.* Connect the headset plug to the HEADSET receptacle on the control panel.

*i.* Set the ON-OFF-STANDBY switch to STANDBY. The unit must remain in the STANDBY mode at least 2 minutes in moderate weather, and up to 15 minutes in extreme cold weather, to allow the crystal oven heaters in the oven boost cycle to warm to the proper operating temperature. When a 12-volt battery is being used, the MONITOR needle initially rests at the extreme left, beyond the 10 graduation; completion of the boost cycle is indicated when the needle drops abruptly to 8. When a 24-volt battery is being used, the MONITOR needle initially rests at the 8 graduation; completion of the boost cycle is indicated when the needle drops abruptly to 4.

*Note.* Only the monitor functions OVEN and DC IN can be checked while the unit is in the STANDBY mode.

*j.* After the oven boost cycle has been completed, set the ON-OFF-STANDBY switch to ON. Rotate the MONITOR switch through the RF, −12, +12, and DC IN positions and observe the MONITOR meter readings. The meter readings should be as follows:

| *Position* | *Required meter reading* |
|---|---|
| RF | Between +3 and +10 |
| −12 | +10 |
| +12 | +10 |
| DC IN | +10 |

*k.* Adjust the VOLUME control until background noise is audible in the headset.

## 128. Tuning Procedures

The instrument tuning procedures follow the setting-up procedures and must be completed prior to making a measurement. Contact between the two stations is achieved when the antennas of both units are directed toward each other and the panel controls are set properly. Contact can be established at more than one FREQUENCY control setting. False indications are more probable at shorter distances. The remote operator should search for the strongest SIG indication (lowest reading on the MONITOR meter) in order to eliminate all false indications. After the instrument has been set up (para 127)—

*a.* Set the MONITOR switch to the SIG position on both units.

*b.* (Responder only.) At the predetermined time, rotate the FREQUENCY control approximately one division each way while observing the MONITOR meter and listening to the headset. Contact with the other unit will be indicated by a simultaneous decrease in the meter readings and a decrease in the background noise in the headset. At this time, voice communication is possible.

*c.* (Responder only.) Set the MONITOR switch to the AFC position. Null the meter at zero, midscale, by rotating the FREQUENCY control slowly clockwise if the meter reads to the left or counterclockwise if the meter reads to the right of zero. If contact is lost, repeat the steps in *a* through *c*.

*d.* (Responder only.) Set the MONITOR switch to SIG and slowly rotate the instrument in azimuth for the strongest signal (minimum meter reading). When the minimum reading has been obtained, instruct the measurer to slowly rotate his instrument in azimuth for the strongest signal strength.

*e.* (Responder only.) Slowly rotate the instrument in elevation by adjusting the forward tripod leg for a minimum reading (strongest signal) on the MONITOR meter. Instruct the measurer to slowly move his instrument in elevation until he receives the strongest signal.

*f.* At this time, the plumb bob on the tripod may be off the station point. Loosen the tripod screw and reposition the plumb bob by slowly moving the instrument; then retighten the screw.

*g.* All operations necessary for contact between stations are now accomplished. If contact is lost, responder is responsible for reestablishing contact with the measurer. To reestablish contact, the responder readjusts the FREQUENCY control and repeats the steps in *b* and *c* above.

*h.* If contact is *not* established after the procedure in *a* through *e* above has been executed, follow the steps in (1) through (3) below.

(1) (Responder only.) Rotate the instrument in azimuth approximately 100 mils and repeat the steps in *b* through *f* above.

(2) (Responder only.) Repeat the step in (1) above until contact is established or until the instrument has been moved plus and minus 800 mils (45°) in azimuth from the initial direction. Return the instrument to the original azimuth.

(3) If contact has not been established within 20 minutes after the predetermined contact time, the measurer should follow the steps in (1) and (2) above. While the measurer is changing the direction of the antenna, the responder should continue searching in FREQUENCY.

## 129. Measuring Procedure

A DME measurement consists of two complete sets of readings in both the forward and reverse directions. In the forward direction, frequencies 1 and 5, with the responder's HIGH-LOW switch in the HIGH position, are used, respectively, for the two sets. In the reverse direction, frequencies 5 and 9, with the responder's HIGH-LOW switch in the LOW position are used. If communication is lost at any time during measurements, the responder is responsible for reestablishing contact, not the measurer.

*a.* (Responder.) After establishing communication, inform the measurer by announcing MEASURE.

*b.* (Both operators.) Set the MEASURE-TALK switch to the MEASURE position. Listen for a tone in the headset. This is the measuring tone, and it should always be audible when the instrument is operating properly.

*c.* (Measurer.) Rotate the COUNTER knob clockwise until the MONITOR meter needle also moves clockwise. Stop the needle at zero. This is called nulling the meter. If the needle moves counterclockwise, the reading obtained on the COUNTER dial will be 500 units in error.

*d.* (Measurer.) Read the COUNTER dial and announce its value to the recorder.

*e.* (Measurer.) Switch the CHANNEL switch to M5. This will eliminate the measure tone and cause the responder's MONITOR meter needle to deflect.

*f.* (Responder.) Upon hearing the loss of tone, switch the CHANNEL switch to R5.

*g.* (Measurer.) Repeat *c*, *d*, and *e* above.

*h.* (Measurer to responder.) Repeat *c* through *f* above for the remaining channels, M4 and R4 through M1 and R1.

*i.* (Measurer.) After recording the M1 reading, switch the MEASURE-TALK switch to TALK and announce FREQUENCY 5. This indicates that the measurer will change his frequency to 5.

*j.* (Measurer.) Set the FREQUENCY control to 5 and the CHANNEL switch to M6.

*k.* (Responder.) Set the CHANNEL switch to R6 and repeat the tuning procedure in *b* and *c* above.

*l.* (Measurer and responder.) Repeat *a* through *i* above to obtain another set of readings.

*Note.* The modes of operation will now be reversed; that is, the measurer will become the responder and the responder will become the measurer.

*m.* (Measurer.) Set the CHANNEL switch to R6 and the HIGH-LOW switch to LOW.

*n.* (Responder.) Set the CHANNEL switch to M6 and the FREQUENCY control to 5.

*o.* (New measurer and responder.) Repeat *a* through *i* above to obtain the first set of readings in the opposite direction.

*p.* (New measurer and responder.) Repeat *a* through *i* above to obtain the second set of readings in the opposite direction, but use frequency 9.

*Note.* This completes two sets in each direction.

## 130. Computing a DME Distance Measurement

DME distance measurements are normally computed at the station acting as the measurer. The reverse distance is obtained from the opposite station after measurement, and both stations compute the final sea level distance before party personnel depart for subsequent survey operations. This permits the verification of the distance determined by map scaling and the resolution of ambiguous readings if they occur. Figure 25 illustrates the recording of readings on DA Form 2972 (Field Record and Computations—DME) and is used as a reference for the discussions on computations in paragraphs 131 through 138.

## 131. DME Form (Block I)

Block I is used to record all station information and elevations determined by altimetry. In space A, the instrument number, operator's name, and height of the station in meters (if altimetry is used) refer to the measurer station. The same data in space B refers to the responder station. On the right side of block I, spaces are provided for listing weather conditions and the name of the recorder at the measuring station.

## 132. Initial Readings (Block II)

Block II is provided for recording counter readings observed in each of the channels M6 through M1, at frequency 1. In addition, space is provided for recording the differences M6 minus M1 through M2 minus M1. Since the operator begins observations in channel M6 and selects the next lower channel for each succeeding observation, the readings will be entered from left to right, M6 through M2. The M1 reading is then subtracted from each of the other readings. In some cases the M1 reading will be larger than the other channel reading from which it is to be subtracted. For example, the difference M5 minus M1 equals 093 minus 413 (fig. 25). If the M1 reading is larger than the channel reading from which it is to be subtracted, 1,000 is added to the smaller number before subtracting in the normal manner (1,093 — 413 = 680).

## 133. Final Readings (Block III)

*a.* The second set of readings taken in a given direction are recorded in block III and referred to as final readings. The first three lines are used exactly as those in block II. The differences obtained in block II are then transferred to block III. The initial and final differences are added and the sum is divided by 2 to obtain the mean difference.

*b.* In the remaining row of spaces in block III, the uncorrected resolved distance is entered. This entry requires a process of resolution, as follows:

(1) Accept the mean M2 minus M1 difference and enter it in the last three spaces of the *resolved distance.* The entry thus far is referred to as a partial resolved distance (fig. 25).

(2) Add 50 to and subtract 50 from the next channel difference, M3 minus M1. In figure 25, this is 487 plus and minus 50 = 537 and 437.

(3) Find a number between 537 and 437 which ends in the first two digits of the partial resolved distance. In figure 25, the partial resolved distance is 126

## FIELD RECORD AND COMPUTATIONS-DME

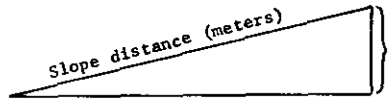
### BLOCK I-STATION DATA

| | Station | Inst. No. | Operator | Height Meters | |
|---|---|---|---|---|---|
| | | | | | Weather: CLEAR BRIGHT |
| A | HARRY | 431 | SP4 KLINE | 452 | Recorder: SP4 LAWSON |
| B | CHARLIE | 446 | SP4 BLAIR | 439 | Vertical Angle (if measured) |
| | | | Height difference | 13 | ← Enter in Block IV |

### BLOCK II-INITIAL READINGS

| Frequency | M6 | M5 | M4 | M3 | M2 |
|---|---|---|---|---|---|
| | 754 | 093 | 486 | 899 | 537 |
| Minus $M_1$ | 413 | 413 | 413 | 413 | 413 |
| Initial Difference | 341 | 680 | 073 | 486 | 124 |

### BLOCK IV-VERTICAL ANGLE




| | | | | |
|---|---|---|---|---|
| 1 | Difference height meters | | 13 | 0 |
| 2 | Log (1) | 1 | 113 | 9434 |
| 3 | Log mean slope distance (III) | 4 | 568 | 8011 |
| 4 | (2)-(3) Log sin vertical angle | 6 | 545 | 1423 |
| 5 | Vertical angle [log sin (4)] | 0' | 000 | 36 |

NOTE: Directions for resolving the distance are given on reverse side of form.

### BLOCK III-FINAL READINGS

| Frequency | M6 | M5 | M4 | M3 | M2 |
|---|---|---|---|---|---|
| | 764 | 095 | 494 | 903 | 543 |
| Minus $M_1$ | 415 | 415 | 415 | 415 | 415 |
| Difference | 349 | 680 | 079 | 488 | 128 |
| Initial Difference | 341 | 680 | 073 | 486 | 124 |
| Sum of Differences | 690 | 1360 | 152 | 974 | 252 |
| Mean of Difference | 345 | 680 | 076 | 487 | 126 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Resolved distance (See note) | 3 | 7 | 0 | 5 | 1 | 2 | 6 |
| Calibration constant | | | | | – | 1 | 6 |
| Slope distance A to B | 3 | 7 | 0 | 5 | 1 | 1 | 0 |
| Reverse slope distance B to A | 3 | 7 | 0 | 5 | 1 | 1 | 2 |
| Mean slope distance (meters) | 3 | 7 | 0 | 5 | 1 | 1 | 1 |

### BLOCK V - SEA LEVEL DISTANCE METERS

| | | | | |
|---|---|---|---|---|
| 1 | Log mean slope distance (IV-3) | 4 | 568 | 8011 |
| 2 | Log cos vertical angle (I) | 0 | 000 | 0000 |
| 3 | (1)+(2) = Log horizontal distance | 4 | 568 | 8011 |
| 4 | Log sea level coefficient (VI) | 9 | 999 | 9659 |
| 5 | (3)+(4) = log sea level distance | 4 | 568 | 7670 |
| 6 | Sea level distance - meters (If necessary) | | | |

### BLOCK VI - SEA LEVEL COEFFICIENT

Use height of station or mean height between stations to nearest 100 meters

| Height meters | Log sea level coefficient | Height meters | Log sea level coefficient | Height meters | Log sea level coefficient | Height meters | Log sea level coefficient | Height meters | Log sea level coefficient |
|---|---|---|---|---|---|---|---|---|---|
| -100 | 0.0000068 | 500 | 9.9999659 | 1300 | 9.9999112 | 2100 | 9.9998566 | 2900 | 9.9998020 |
| - 50 | 0.0000034 | 600 | 9.9999590 | 1400 | 9.9999044 | 2200 | 9.9998498 | 3000 | 9.9997951 |
| 00 | 0.0000000 | 700 | 9.9999522 | 1500 | 9.9998976 | 2300 | 9.9998429 | 3100 | 9.9997883 |
| 50 | 9.9999966 | 800 | 9.9999453 | 1600 | 9.9998908 | 2400 | 9.9998361 | 3200 | 9.9997815 |
| 100 | 9.9999931 | 900 | 9.9999386 | 1700 | 9.9998839 | 2500 | 9.9998292 | 3300 | 9.9997747 |
| 200 | 9.9999863 | 1000 | 9.9999317 | 1800 | 9.9998770 | 2600 | 9.9998225 | 3400 | 9.9997678 |
| 300 | 9.9999795 | 1100 | 9.9999249 | 1900 | 9.9998703 | 2700 | 9.9998156 | 3500 | 9.9997609 |
| 400 | 9.9999727 | 1200 | 9.9999181 | 2000 | 9.9998634 | 2800 | 9.9998088 | 3600 | 9.9997542 |

| | | |
|---|---|---|
| Computer SP5 CLIFTON | Checker SP5 BURK | Sheet 1 of 2 sheets |
| Notebook Reference | Area APACHE GATE | Date 21 NOV 64 |

DA FORM 1 MAY 65 2972

*Figure 25. DA Form 2972, Field Record and Computations—DME.*

and its first two digits are 12. The only number between 537 and 437 ending in 12 is 512. This is the resolved channel difference.

(4) Prefix the first digit of the resolved channel difference to the partial resolved distance to obtain a new partial resolved distance.

(5) Repeat this process for all succeeding channel differences, using the previously determined new partial resolved distance with each. Resolution of all channel differences provides the uncorrected slope distance.

*c.* The electronic distance does not coincide with the distance between stations, thus, a small correction must be applied to find the true slope distance. The correction constant is always minus 0.16 meter.

*d.* The slope distance measured in the opposite direction at the other end of the line is entered on the next line, and the mean of the forward and reverse distances is entered on the following line.

### 134. Determining the Vertical Angle Between Stations

*a.* In block III the slope distance was determined; however, *horizontal* distance is required for artillery survey. Therefore, the slope distance must be converted to horizontal distance. In order to accomplish the conversion, the vertical angle from station A to station B must be determined. The slope distance is considered to be the hypotenuse of a right triangle. The horizontal distance may be computed by using the slope distance and the vertical angle or the slope distance and the difference in height (block IV).

*b.* When the vertical angle is measured, it is entered in block I and on line 5 in block IV. The vertical angle should be measured reciprocally or corrected for curvature when a long distance is being measured. The vertical angle may be expressed in mils or degrees, minutes, and seconds, depending on the type of theodolite used to make the measurement.

*c.* If the vertical angle is not measured, it must be computed by using the slope distance and the difference in height. The difference in height is obtained from block I. The heights of stations A and B are entered in block I. These heights are obtained from known data or determined with the altimeter (chap 11).

### 135. Reducing the Distance Measured From Slope Distance to Horizontal Distance to Sea Level Distance

*a.* The slope distance is reduced to sea level distance by computations, using the mean slope distance, vertical angle, and sea level coefficient. The computations are made by following the step-by-step instructions in block V.

*b.* The instructions for the use of the sea level coefficient are given in block VI.

*c.* The computations on the field record and computations form end with sea level distance. To carry the computations further would be a duplication of effort, since most Department of the Army artillery survey forms provide for the application of the log scale factor to convert to universal transverse mercator grid distance.

### 136. Personnel Requirements

The composition of the survey party and the duties of the personnel for the DME traverse are the same as those for the Tellurometer traverse (para 118).

### 137. DME Traverse

The principles of conducting a traverse with the DME are the same as those for conducting a traverse with the Tellurometer (para 119).

### 138. Trilateration

The DME is used in trilateration in the same manner as the Tellurometer (para 120).

### 139. Care and Maintenance of the DME

The operator's manual for the DME clearly defines the extent of care and the maintenance responsibilities from the operator to the highest maintenance category. The operator should consult this manual regularly while performing his maintenance. *Maintenance experimentation by operating personnel is prohibited.*

## 140. Troubleshooting

Operators are not permitted to make any repairs on the DME, but they must be able to recognize symptoms of malfunction or faulty operation. A list of symptoms, possible causes, and corrective actions that do not constitute repairs is given below.

| *Symptom* | *Possible cause* | *Corrective action* |
|---|---|---|
| No DC IN meter reading. | Power cable is not firmly connected. Cable clamps are not making contact at battery terminals because of surface corrosion or foreign matter. | Check cable to see that it is secure. Rotate clamps slightly so that terminal is scratched slightly for better contact. |
| | Dead battery | Change battery. |
| | Connector is not attached (when internal battery is used). | Attach connector. |
| | Connector is not securely attached | Check to see that connector is screwed completely on and is not crooked. |
| | Cable circuitry is incomplete | If, or when available, use a cable which has been recently used and is known to be good. |
| Blows fuse | ON-OFF-STANDBY switch was switched to ON position before completion of oven boost cycle. | Replace fuse and wait for completion of oven cycle before switching from STANDBY to ON. |
| | Cable connections to battery are reversed (wrong polarity). | Check polarity. Change if reversed and replace fuse. |
| | 24-volt battery is connected to 12-volt cable | Connect proper cable. |
| Any improper meter reading. | | Check DC IN and if faulty refer to possible causes for "No DC IN meter reading." |
| AFC cannot be nulled | HIGH-LOW switch is in wrong position | Set HIGH-LOW switch to proper position. |
| No output from headset | Headset unplugged | Plug in headset. |
| | Headset plug is not seated properly | Check headset plug to see that it is not crooked and that it is firmly engaged. |
| | Defective headset | Try a headset which has been used recently and is known to be good. |
| No tone in measure | TALK-MEASURE switch is in TALK position. | Switch to MEASURE. |
| | Channel switch is in wrong position | Set switch to proper channel. |
| Difficulty in establishing communications. | Antenna cover has not been removed | Remove antenna cover. |
| Resolved distance is obviously in error (i.e., the measured distance is much less, or greater, than the known approximate distance). | M2 and M1 readings have been reversed or an M2 has been repeated as M1 when responder failed to switch from M2 to M1. | Contact responder and check M2 and M1 readings. |
| | Readings were entered in reverse order | Contact responder and check readings. |

# CHAPTER 7

# ANGLE DETERMINATION

## Section I. FIELD NOTES

### 141. General

The field notes of a survey should contain a complete record of all measurements made during the progress of the survey, with sketches, descriptions, and remarks made where necessary to clarify the notes. The best survey fieldwork is of little value if the notes are not accurate, legible, and complete. The notes are the only record of the fieldwork that is available after the survey is finished.

### 142. Field Notebook

The field notebook (DA Form 5–72) is a hardback, permanently bound book for recording measurements as they are made in the field. Attached to the flyleaf inside the front of the book are instructions for its return if lost. The flyleaf contains space for the identification of the notebook (fig. 26). Each set of facing pages inside the notebook comprises one numbered page. The page number appears in the upper right corner. The first two numbered pages should be reserved for the index that is maintained as field data entries are made in the notebook (fig. 27).

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

LEVEL, TRANSIT AND GENERAL SURVEY

RECORD BOOK

1ST HOW BN 1ST ARTY

LOCALITY

ADVANCED UNIT TRAINING

PROJECT

BOOK 1 OF 3

0.2 MIL THEODOLITE (T16) NR 1380

INSTRUMENT

SFC T.L. BROWN

CHIEF OF PARTY

*Figure 26. Example of data placed on flyleaf of field notebook.*

### 143. Forms of Recording

*a.* Field note recording consists of a combination of tabulation of data, sketches, and descriptions, so that the total information in the field notebook provides a clear and understandable picture of the survey work performed. This information should include descriptions of the starting and closing stations, the area or locality in which the work is performed, the nature and purpose of the work, and weather or other conditions that may be factors in evaluating the results. The information in the field notes should be complete to the extent that anyone not familiar with the particular survey operation can take the notebook, return to the locality, and recover or reconstruct any portion of the fieldwork.

*b.* Tabulation of data in the field notebook is the recording of the measured data in columns according to a prescribed plan. Sufficient spaces are also provided to permit entry of mean values.

*c.* Sketches should be used when needed to assist in clarifying field notes. The sketches may be drawn to an approximate scale, or important details may be exaggerated for clarity. A notation should be included to indicate grid north. Normally, a sketch of the locality, showing the general survey plan, should provide suf-

DESIGNATION INDEX DATE 19 60

| PAGE | DATE | TITLE |
|---|---|---|
| 1 | – | Index |
| 2 | – | Index continued |
| 3 | 15 JUL | Position Area Survey |
| 4 | 16 JUL | Position Area Survey |
| 5 | 17 JUL | Position Area Survey |
| 6 | 18 JUL | Connection Survey |
| 7 | 19 JUL | Sun Observation-Altitude Method |
| 8 | 20 JUL | Connection Survey |
| 9 | 21 JUL | Triangulation |
| 10 | 22 JUL | Sun Observation-Altitude Method |
| 11 | 23 JUL | Star Observation Hour Angle Method |
| 12 | 24 JUL | Traverse |
| 13 | 25 JUL | Triangulation |
| 14 | 25 JUL | Triangulation (cont.) |
| 15 | 26 JUL | Sun Observation. Altitude Method |
| 16 | 27 JUL | Star Observation Hour Angle Method |
| 17 | 28 JUL | Simultaneous Obsr. Master |
| 18 | 28 JUL | Simultaneous Obsr. Flank |

| PAGE | DATE | TITLE |
|---|---|---|
| | | |

*Figure 27. Example of the index of the field notebook.*

ficient information to recover or reconstruct the fieldwork when the sketch is used in conjunction with the description of the starting and closing stations. Sketches are also used when necessary to indicate survey signal heights and points sighted upon other than instrument height when observing vertical angles. A small straightedge and a protractor should be used as aids in making the sketch. The sketch should be legible, should be drawn clearly and large enough to be understandable.

*d.* Descriptions should be used to supplement the information provided in the tabulated data and sketches. Descriptions normally will identify the area in which the fieldwork is performed and provide a description of the starting and closing stations and any other information that is required to make a complete record of the fieldwork. Remarks may be made to clarify measurements, weather and observing conditions, and any other factors that could be of significance.

## 144. Recording

*a.* Each numbered page of the field notebook (fig. 28) provides space for recording data and information pertinent to the survey. The type of survey, the date, the weather conditions, the type and serial number of the instrument, the names of the party personnel, and similar information are entered across the top of the page. The left half of the page is used for recording measured data, and the right half below the double line, is used for remarks, sketches, and descriptions.

*b.* All entries in the field notebook should be printed in a neat and legible manner with a sharp, hard-lead pencil (3H or harder), with enough pressure to indent the paper and insure

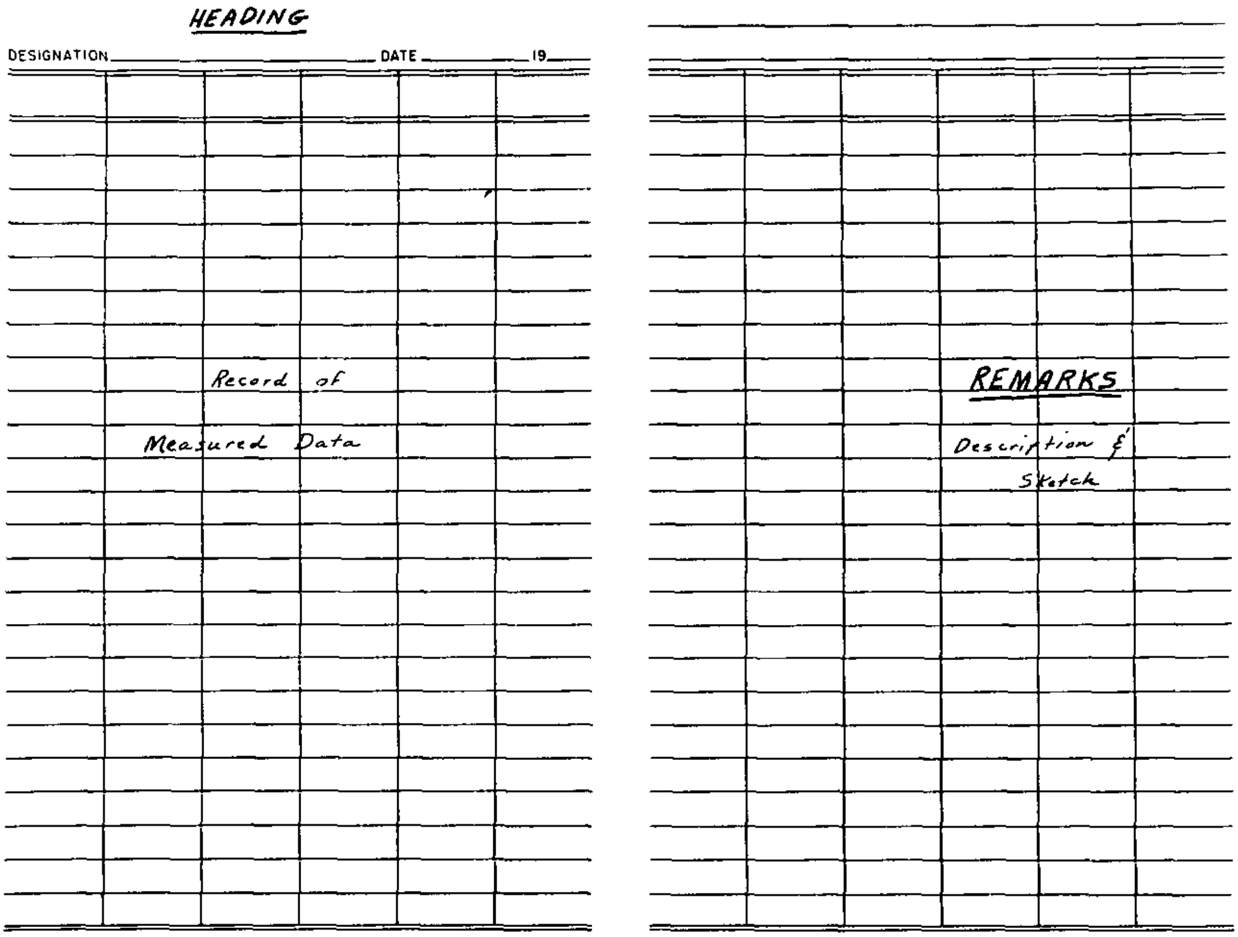



*Figure 28. Page of field notebook.*

a permanent record. Numerals and decimal points should be legible and distinct so that only one interpretation of the data is possible. The recorder accompanies the instrument operator and records the data in the field notebook as it is announced to him; he then reads it back to insure the correctness of the data. Field data are entered directly in the notebook and not on scraps of paper for later transcription. As the field data entries are made in the notebook, the recorder computes and records mean values and, for ease of identification, encircles the data that is to be furnished to the computers as they request it. Station descriptions, sketches, and any necessary remarks are entered in the notebook as time permits during the progress of survey operations. To minimize recording errors, the chief of party should check all entries and initial each numbered page. Data pertaining to different survey operations should not be recorded on the same page.

*c.* Erasures are not permitted in the field notebook. When incorrect data has been entered in the notebook, it is corrected by drawing a single line through the incorrect data and entering the correct data immediately above the incorrect data. When a page is filled with data that will not be used because of a change in plans, etc., the page is crossed out by drawing diagonal lines between opposite corners of the page and printing the word VOID in large letters across the page.

*d.* The format for recording field data is illustrated in the chapters in which the various instruments and survey methods are discussed.

## Section II. AIMING CIRCLE M2

### 145. General Description

The aiming circle M2 (fig. 29) is a small, lightweight instrument that is used in the firing battery and in artillery survey operations executed to an accuracy of 1:500. Basically, it consists of a low-power, fixed-focus telescope mounted on a body that permits unlimited horizontal and limited vertical rotation of the telescope. Horizontal and vertical angle measurements are recorded on graduated scales and micrometers. The aiming circle has two horizontal rotating motions. The upper (recording) motion changes the readings of the azimuth scales of the instrument; the lower (nonrecording) motion does not. The aiming circle is equipped with leveling screws, level vials, and a magnetic compass. The instrument is mounted on a base plate that serves as the base of the

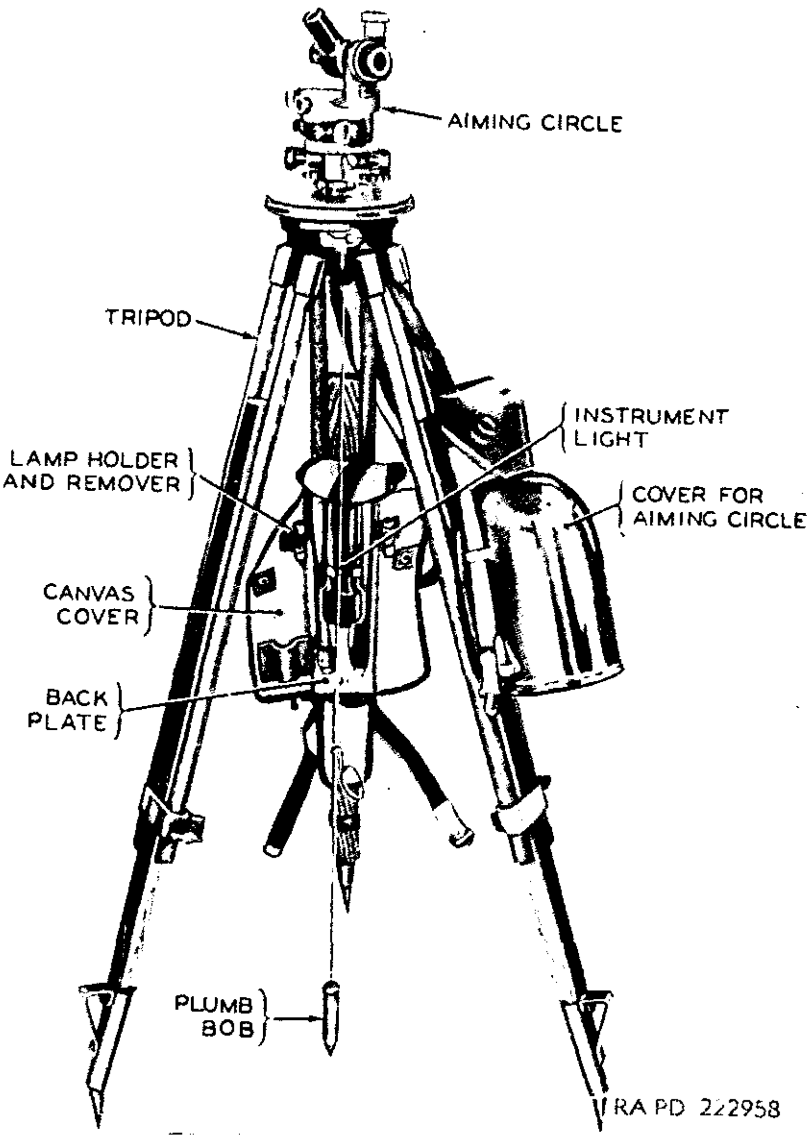



*Figure 29. Aiming circle with accessory equipment.*

carrying case and is also used in mounting the instrument on a tripod. The aiming circle M2 consists of the aiming circle body and the accessory equipment. The aiming circle without accessory equipment (para 147) weighs 8 pounds 2 ounces and with accessory equipment weighs 22 pounds.

### 146. Aiming Circle Body

The aiming circle body is made up of four principal parts—the telescope body assembly, the body assembly, the worm housing, and the base plate assembly (fig. 30).

*a. Telescope Body Assembly.* The telescope body assembly consists of the optical system, the vertical level vial, the reflector, and a filter for solar observations.

(1) *Optical system.* A 4-power, fixed-focus telescope forms the optical system of the aiming circle. The telescope reticle is formed by a glass etched with a

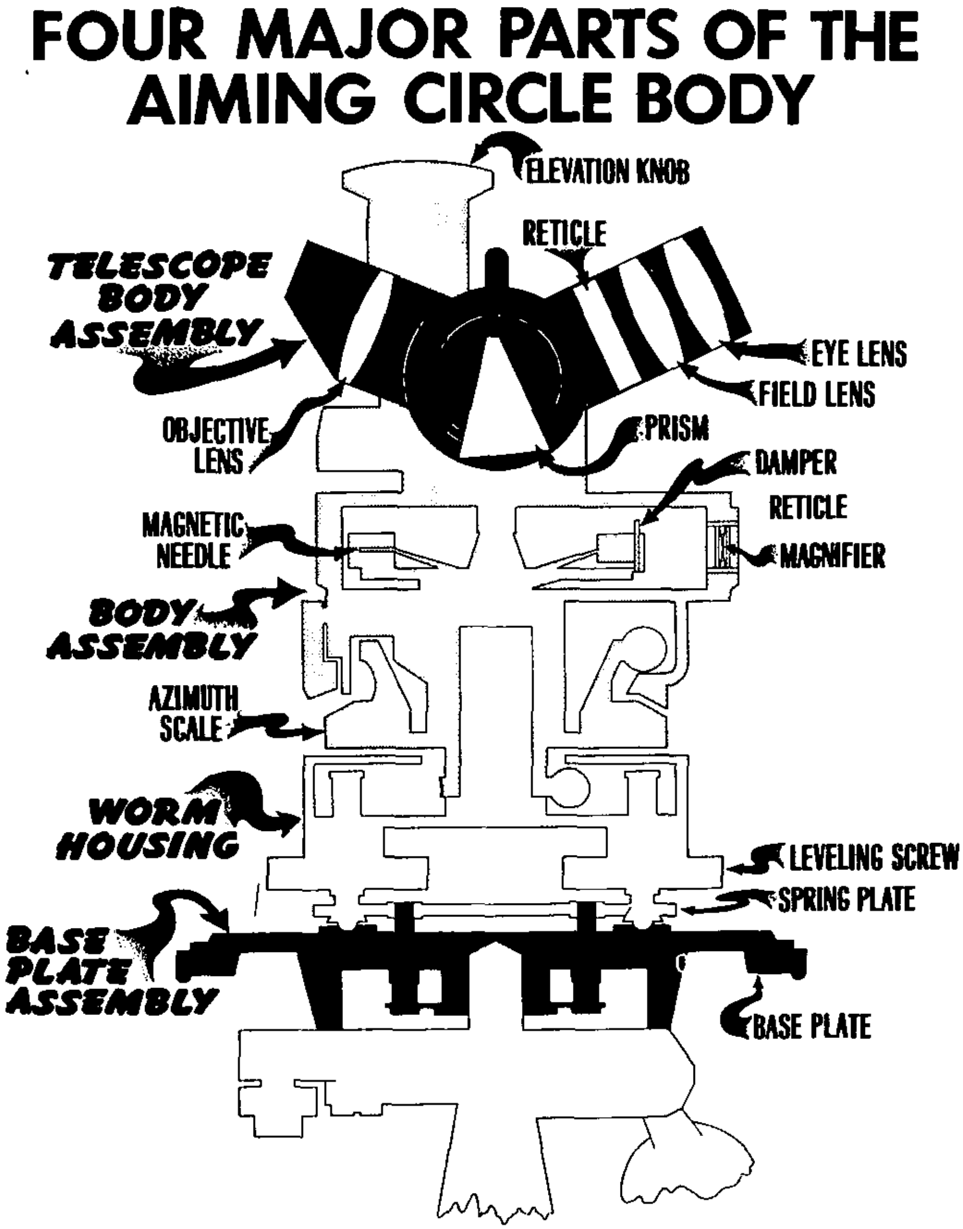



*Figure 30. Cutaway drawing of aiming circle showing composite parts.*

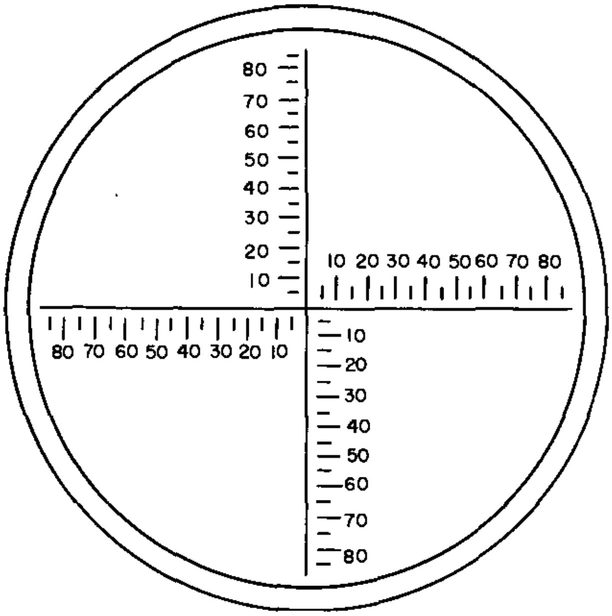



*Figure 31. Telescope reticle.*

horizontal and a vertical crossline intersecting at the center of the telescope. These crosslines are graduated at 5-mil intervals from the center. The graduations range from 0 to 85 mils and are numbered every 10 mils (fig. 31). These graduations are used to measure relatively small horizontal and vertical deviations from a reference line (e.g., in a high-burst registration). The telescope eyepiece (fig. 32) is inclined upward at an angle of 45° from the axis of the telescope to permit the observer to look down into the telescope while standing erect. Located on top of the inclined portion of the telescope is a machined slot for attaching the instrument light. The objective end of the telescope is beveled to form a permanent sunshade.

(2) *Telescope level vial.* The telescope level vial is located on the left side of the telescope. This level is used to establish the horizontal axis of the telescope in a true horizontal plane. The lugs supporting the telescope level vial are shaped to form an open sight for approximate alinement of the telescope on a station. The telescope level is not used in artillery survey.

(3) *Reflector.* The reflector is a plastic signal post mounted on top of the telescope at the vertical axis of the instrument. The reflector is used as an aim-

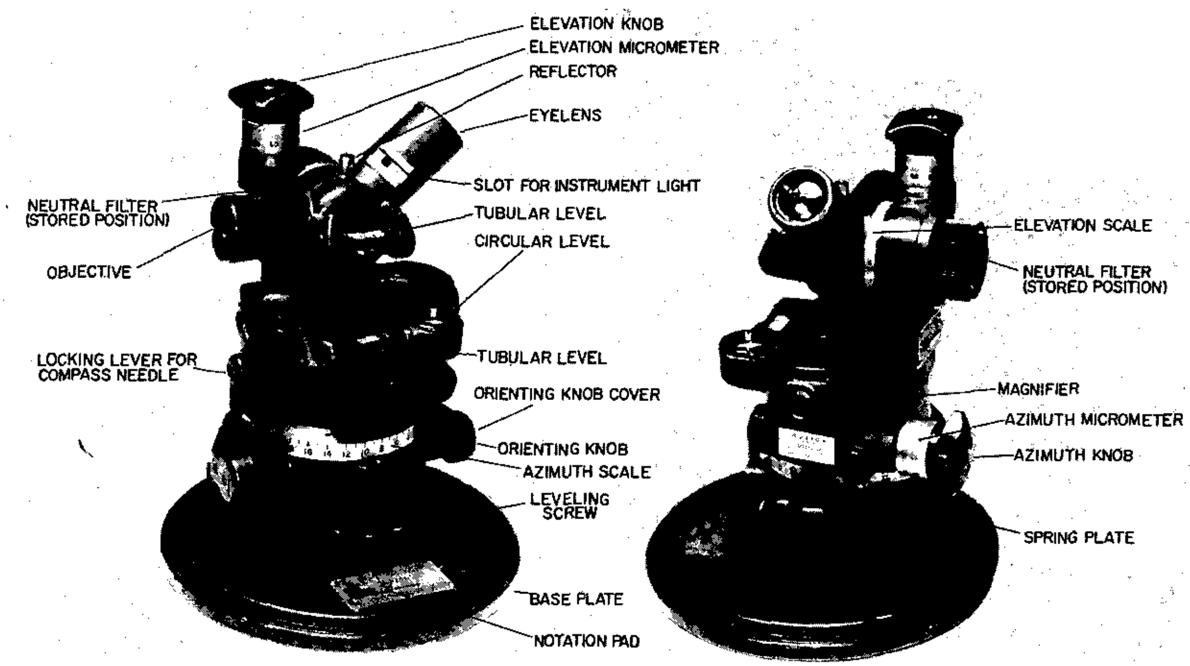



*Figure 32. Aiming Circle M2.*

ing point for other instruments sighting on the aiming circle M2. At night the reflector can be illuminated externally by use of the instrument light.

(4) *Filter.* A filter is provided for viewing the sun directly when astronomic observations are being made. The filter is slipped onto the eyepiece end of the telescope when the sun is being observed and is attached to the side of the telescope body when not in use.

*b. Body Assembly.* The body assembly consists of the azimuth and elevation worm mechanisms; the magnetic compass, with reticle and needle actuating lever; and two horizontal plate levels.

(1) *Azimuth mechanism.* The azimuth mechanism (upper motion) of the instrument has both a fast and a slow motion. Lateral movement of the azimuth knob permits fast motion. Horizontal angles are read in two parts; the hundreds of mils are read from the azimuth scale, and the tens and units of mils are read from the azimuth micrometer. The azimuth scale is graduated in 100-mil increments from 0 to 6,400 mils and is numbered every 200 mils. The portion of the azimuth scale from 3,200 mils through 6,400 mils has a second scale numbered in red from 0 to 3,200 below the primary scale. The graduations of the primary (upper) scale are used for survey. The second (lower) scale is used for laying the weapons of the firing battery. *This lower scale is not used in survey.* The azimuth micrometer scale is located on the azimuth knob. It is graduated in 1-mil increments from 0 to 100 mils and is numbered every 10 mils.

(2) *Elevation mechanism.* The elevation mechanism of the aiming circle is similar to the azimuth slow motion mechanism. Stop rings in the mechanism prevent the telescope from striking the body assembly when it is depressed. Vertical angles from minus 440 mils to plus 805 mils can be measured with the aiming circle. Vertical angles are read in two parts; the hundreds of mils are read from the elevation scale, and the tens and units of mils are read from the elevation micrometer scale. The elevation scale is graduated and numbered in 100-mil increments from minus 400 mils to plus 800 mils. The plus and minus symbols are not shown, but the minus numerals are printed in red and the plus numerals are printed in black. The elevation micrometer scale is graduated in 1-mil increments from 0 to 100 mils. The scales are numbered every 10 mils from left to right in black numerals and from right to left in red numerals. The red numerals on the elevation micrometer scale are used in conjunction with the red numerals on the elevation scale. The black numerals on the micrometer scale are used with the black numerals on the elevation scale.

(3) *Magnetic compass.* The magnetic compass is located in the oblong recess in the top of the body assembly. The magnetic needle is limited in movement to approximately 11° of arc and is provided with copper dampers to aid in settling the needle quickly. A small glass magnifier and a reticle with three vertical etched lines are at one end of the recess to aid in alining the south end of the needle. On the opposite end of the recess is a lever which locks or unlocks the magnetic needle. When the lever is in a vertical position, the needle is locked. When the lever is turned either right or left to the horizontal position, the needle is unlocked.

(4) *Horizontal plate levels.* Located on the body assembly at the left side of the magnetic needle recess are two horizontal plate levels; one is a circular level vial that may be used for rough leveling of the instrument, the other is a tubular level vial that is used to accurately level the instrument.

*c. Worm Housing.* The worm housing is that portion of the aiming circle below the azimuth

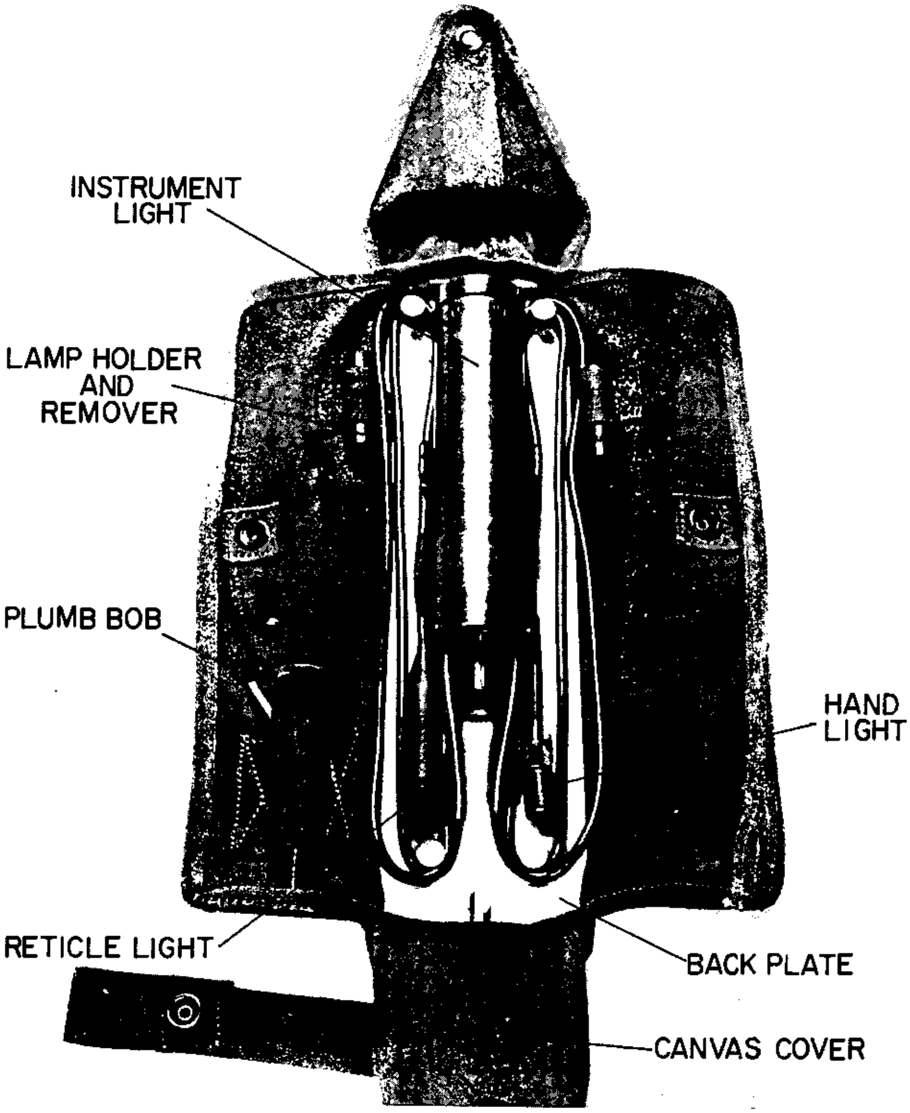



*Figure 33. Accessory kit.*

scale and above the base plate. It contains the worm gear of the orienting (lower or nonrecording) motion, the leveling screws, and the spring plate. The orienting knob controlling the nonrecording motion of the aiming circle is similar in operation to the azimuth (recording) motion of the aiming circle in that lateral movement of one orienting knob permits fast movement in the orienting motion of the aiming circle. The two orienting knobs should be used simultaneously for slow movement of the orienting motion. Caps are provided for the orienting knobs to preclude use of the orienting motion by mistake. Each of the three leveling screws is fitted into a threaded socket in the worm housing and attached to the base plate by means of the spring plate.

*d. Base Plate Assembly.* The base plate assembly is the base of the instrument when it is mounted on the tripod and it also serves as the base of the carrying case. It is a flat circular plate to which the instrument is attached by the spring plate. A rectangular shaped notation pad is located on the base plate and is used for recording the declination constant and the vertical angle correction. An instrument-fixing screw is threaded into a socket on the underside of the base plate assembly to attach the instrument to the tripod. The socket is kept clean and free of obstructions by a spring-loaded cover that remains closed when the instrument is not attached to the tripod. The base plate is fitted with a rubber gasket that makes a watertight seal when the cover is latched to it.

## 147. Aiming Circle Accessory Equipment

The accessory equipment for the aiming circle consists of the tripod, the carrying case cover, and the accessory kit. The accessory kit (fig. 33) contains the instrument light, plumb bob, lampholder and remover, and backplate and canvas cover.

*a. Tripod.* The tripod (fig. 29) has three telescoping legs, an aluminum head and cover, and a carrying strap. The legs are adjusted for length and held in place by means of leg clamp wing screws. The leg hinges at the tripod head are adjusted for friction by clamping screws. The ends of the legs of the tripod are fitted with an aluminum boot and a bronze spike for ease in embedding the legs in the ground. A strap holds the legs together in the retracted position. An adjustable strap is provided for carrying the tripod when the legs are retracted and strapped together.

*b. Backplate and Cover.* The backplate and cover (fig. 33) serves as the carrying case for the instrument light, plumb bob, and lampholder and remover. It is fastened to one of the tripod legs by two clamps.

*c. Instrument Light.* The instrument light consists of a battery tube containing two flashlight batteries and two flexible cords. One of these cords carries the current to the telescope through a lamp bracket assembly that fits into a machined slot on top of the telescope assembly. The other cord is attached to a hand light assembly for general illumination around the instrument (leveling and reading the scales) and to illuminate the reflector. The light intensity is regulated by a rheostat located on the end of the battery tube. The battery tube is fastened to the backplate by means of a clamp.

*d. Plumb Bob.* The plumb bob is suspended from a hook in the instrument-fixing screw when it is used to aline the instrument over a point on the ground. When the plumb bob is not in use, it is stored in a loop in the canvas cover of the accessory kit.

*e. Lampholder and Remover.* The lampholder and remover is a small, rubber tubular accessory in which spare lamp bulbs are stored; it can also be used for removing burned out bulbs from their sockets.

*f. Carrying Case Cover.* The cover of the carrying case is a lightweight dome-shaped aluminum cover that can be clamped to the base plate to provide a waterproof case for the instrument. The cover is provided with a carrying strap and two strong clamps for securing the cover to the base plate.

## 148. Setting Up the Aiming Circle M2

*a. Setting Up the Tripod.* The procedure for setting up the tripod is as follows:

(1) Upend the tripod and place the tripod head on the toe of the shoe. Unbuckle the restraining strap and secure the strap around the leg to which it is attached.

(2) Loosen the leg clamp wing screws and extend the tripod legs to the desired length. Tighten the leg clamp wing screws.

(3) Turn the tripod to its upright position and test the adjustment of each tripod leg by elevating each leg, in turn, to a horizontal position and then releasing it. If the leg is properly adjusted, it should fall to about 45° and stop. If it does not, the tripod leg should be adjusted by tightening or loosening the tripod clamping nut. The test should be repeated until successful.

(4) Spread the legs and place the tripod over the station to be occupied, with one leg approximately bisecting the angle(s) to be measured. The head of the tripod should be set up at a height which will place the telescope at a convenient height for the operator.

(5) Insert the plug-in sleeve of the plumb bob into the instrument-fixing screw

and extend the plumb bob so that it will hang about an inch above the station. Center the tripod approximately over the station.

(6) Firmly embed the tripod legs, making sure that the plumb pob is within one-half inch (laterally) of being centered over the station and that the tripod head is approximately level when the legs are embedded.

(7) Remove the tripod head cover and secure it to the tripod leg.

*b. Attaching the Aiming Circle to the Tripod.* To attach the aiming circle to the tripods open the spring-loaded cover on the base plate and thread the instrument-fixing screw into the socket until the aiming circle is firmly attached to the tripod. Unsnap the aiming circle cover latches, remove the cover, and hang it on the tripod head cover.

*c. Plumbing and Leveling the Aiming Circle.* The procedure for plumbing and leveling the aiming circle is as follows:

(1) Loosen the fixing screw slightly and carefully move the instrument around on the head of the tripod until the point of the plumb bob is centered exactly over the station.

(2) Tighten the instrument to the tripod head, making sure that the point of the plumb bob remains centered over the station.

***Caution:*** **Excessive tightening of the fixing screw will bend the slotted arm and damage the tripod head.**

(3) Loosen the leveling screws to expose sufficient threads (3/8" to 1/2") on the three screws to permit the instrument to be leveled. Rotate the instrument until the axis of the tubular level is parallel to any two of the three leveling screws. Center the bubble by using these two leveling screws. Grasp the leveling screws between the thumb and forefinger of each hand and turn the screws simultaneously so that the thumbs of both hands move either toward each other or away from each other at the same time. This movement tightens one screw as it loosens the other. The bubble always moves in the same direction as the left thumb.

(4) Rotate the instrument 1,600 mils; this places one end of the plate level over the third leveling screw. Using this screw, center the bubble.

(5) Return the instrument to the first position ((3) above) and again center the bubble.

(6) Return the instrument to the second position ((4) above) and again center the bubble.

(7) Repeat (5) and (6) above until the bubble remains centered in both positions.

(8) Rotate the instrument 3,200 mils from the first position. If the bubble remains centered in this position, rotate the instrument 3,200 mils from the second position. If the bubble remains centered in this position, rotate the instrument throughout 6,400 mils. The bubble should remain centered; if it does, the instrument is level.

(9) If the bubble is not centered when the instrument is rotated 3,200 mils from the first position ((8) above), the level vial is out of adjustment. To compensate, move the bubble halfway back to the center of the level vial, using the same leveling screws that were used for the first position. Rotate the instrument 3,200 mils from the second position and move the bubble halfway back to the center of the level vial, using the one remaining leveling screw. The instrument is now level, and the bubble will come to rest in its vial at the same offcenter position regardless of the direction in which the instrument is pointed. The level vial should be adjusted at the first opportunity.

## 149. Taking Down the Aiming Circle

The procedure for taking down the aiming circle is as follows:

*a.* Tighten the leveling screws to their stops.

*b.* Check to insure that the magnetic needle is locked.

*c.* Cover the level vials.

*d.* Place the azimuth knob over the notation pad.

*e.* Unhook the plumb bob and replace it in the backplate cover. Close the backplate cover.

*f.* Place the carrying case cover over the aiming circle and latch the cover locks.

*g.* Unscrew the instrument-fixing screw and remove the instrument from the tripod.

*h.* Replace the tripod head cover.

*i.* Collapse the tripod legs and tighten the wing screws.

*j.* Strap the tripod legs together.

## 150. Measuring Horizontal Angles

In artillery survey, horizontal angles are measured at the occupied station in a clockwise direction from the rear station to the forward station. Pointings for horizontal angles are always made to the lowest visible point at the rear and forward stations. In sighting on a station, the vertical crossline is placed so that it bisects the station marker. When angles are measured with the aiming circle, two repetitions of the angle are taken and the accumulated value is divided by 2 to determine the mean value of the angle. The procedure for measuring horizontal angles is as follows:

*a.* Set up and level the aiming circle.

*b.* Zero the azimuth and micrometer scales.

*c.* Sight approximately on the rear station by using the lower (nonrecording) fast motion.

*d.* Place the crossline exactly on the rear station by using the lower slow motion. The last motion coming onto the station should be from left to right to reduce backlash due to the play in the worm gear mechanism. Check the azimuth and micrometer scales to insure that they are still at zero. Close the orienting knob covers.

*e.* With the upper (recording) fast motion, rotate the aiming circle to bring the crosslines near the forward station, but keep them to the left of the station.

*f.* With the upper slow motion, bring the crosslines exactly to the point, rotating the instrument from left to right.

*g.* Read and record the value of the angle on the azimuth and micrometer scales to the nearest 0.5 mil.

*h.* With this value still on the scales, repeat *c* through *f* above.

*i.* Read and record the accumulated value of two measurements of the angle to the nearest 0.5 mil.

*j.* Divide the accumulated value in *i* above by 2. If the accumulated value of the angle (*i* above) is smaller than the first value (*g* above), add 6,400 to the accumulated value before dividing by 2. The mean value determined should agree with the first value within 0.5 mil; if not, the angle must be remeasured.

## 151. Measuring Vertical Angles

The vertical angle to a point is measured from the horizontal plane passing through the horizontal axis of the telescope of the instrument. The vertical angle is expressed as plus or minus, depending on whether the point is above (plus) or below (minus) the horizontal plane. Usually, the vertical angle is measured each time a horizontal angle is measured. Vertical angles are measured twice, and the mean value is determined. Vertical angles, if possible, are measured to the height of instrument (HI) at each forward station. The height of instrument is determined by measurement on a ranging pole. If the instrument operator consistently sets the instrument up at approximately the same height, then the same height of instrument may be used throughout the fieldwork for measuring vertical angles. The procedure for measuring vertical angles is as follows:

*a.* Set up and level the aiming circle.

*b.* When the first measurement of the horizontal angle is completed (para 150*g*), elevate or depress the telescope to place the horizontal crossline at the height of instrument on the forward station.

*c.* Read and record the value of the vertical angle to the nearest 0.5 mil. If the black numerals are used, the vertical angle is plus; if the red numerals are used, the vertical angle is minus.

*d.* After the second measurement of the horizontal angle is completed (para 150*i*), measure the vertical angle a second time.

*e.* Determine the mean vertical angle by adding the first and second readings of the vertical angle and dividing the sum by 2. The mean vertical angle should agree with the first reading within 0.5 mil.

## 152. Determining Vertical Angle Correction

To obtain correct measurements of vertical angles with the aiming circle, the horizontal axis of the telescope must lie in a true horizontal plane when the elevation scale is at zero. If it does not, a vertical angle correction (VAC) must be determined and applied to each vertical angle measured with the aiming circle. A vertical angle correction is determined at the same time that the declination constant is determined. Two methods may be used to determine the vertical angle correction—the comparison method and the alternate method.

*a. Determination of Vertical Angle Correction by Comparison Method.* The vertical angle between two points is measured with the aiming circle and compared with the correct vertical angle between those points. The correct vertical angle can be determined by measurement with a theodolite or by computation, using the distance and difference in height between the points. Whenever a declination station is established, the vertical angle to each azimuth mark should be determined so that the vertical angle correction can be checked at the time the aiming circle is declinated. The vertical angle correction is determined by the comparison method as follows:

(1) After determining the declination constant, check the level of the instrument. Measure the vertical angle to each azimuth mark to which the vertical angle is known. Read and record the values to the nearest 0.5 mil.

(2) Verify the level of the instrument and measure the vertical angle to each azimuth mark a second time. Record the values.

(3) Mean the vertical angles measured to each azimuth mark and compare the mean of each with the corresponding known vertical angle. Determine the differences (±). If the differences agree within 1 mil of each other, determine the mean difference to 0.1 mil and record this value on the notation pad with the declination constant (e.g., VAC + 1.6).

*Note.* If the differences do not agree within 1 mil, repeat (1) through (3) above.

*Example:*

| | |
|---|---|
| +23.0 mils | = known vertical angle to azimuth mark 1 |
| +21.5 mils | = mean measured vertical angle to azimuth mark 1 |
| + 1.5 mils | = correction to bring measured vertical angle to known vertical angle |
| − 9.0 mils | = known vertical angle to azimuth mark 2 |
| −10.8 mils | = mean measured vertical angle to azimuth mark 2 |
| + 1.8 mils | = correction to bring measured vertical angle to known vertical angle |
| + 1.5 mils | = correction at azimuth mark 1 |
| + 1.8 mils | = correction at azimuth mark 2 |
| + 3.3 ÷ 2 | = + 1.6 mils = mean vertical angle correction |

*b. Determination of Vertical Angle Correction by Alternate Method.* Two stations are established approximately 100 meters apart and properly marked. It is not necessary to know the coordinates and height of the stations or the distance between them. The aiming circle is set up at one of the stations, and the height of instrument is measured and marked on a range pole with a pencil. The range pole is placed vertically over the second station. The vertical angle to the mark on the range pole is then measured with the aiming circle. The aiming circle is then moved to the second station and set up. The height of instrument at the second station is marked on the range pole. The pole is then set up over the first station, and the vertical angle from the second station to the first station is measured. The vertical angles measured at the two stations are compared. If they are numerically equal but have opposite signs (e.g., +7.0 and −7.0), the instrument is in correct adjustment and the vertical angle correction is zero. If the values are not numerically equal, a vertical angle correction must be determined. The correction is numerically equal to one-half of the algebraic sum of the two angles. *The sign of the correction is opposite to the sign of the algebraic sum of the two angles.* For example, if one angle were +22.0 mils and the other were —24.0 mils, the vertical angle correction would be +1.0 mil. The vertical angle correction must be applied to all vertical angle measurements made with the aiming circle.

### 153. Determining Grid Azimuth With the Aiming Circle

The magnetic compass of a declinated aiming circle can be used to determine a grid azimuth. The procedure for determining a grid azimuth is as follows:

*a.* Set up and level the aiming circle in the prescribed manner.

*b.* Using the upper motion, set the declination constant on the scales of the instrument.

*c.* Release the magnetic needle and center it, using the lower motion.

*d.* Lock the magnetic needle.

*e.* Using the upper motion, rotate the instrument and sight on the desired point.

*f.* Read and record the measured grid azimuth as indicated on the scales of the aiming circle to the nearest 0.5 mil.

*g.* Repeat the procedure and determine the grid azimuth a second time. If the two azimuth determinations agree within 2 mils, mean and record the measured grid azimuth to the nearest 0.1 mil. If they do not agree, repeat the entire procedure.

### 154. Orienting the Aiming Circle by Magnetic Compass on a Required Azimuth

A declinated aiming circle can be oriented on a required grid azimuth by use of the magnetic needle. The procedure for orienting on a required azimuth is as follows:

*a.* Set up and level the aiming circle in the prescribed manner.

*b.* Using the upper motion, set the declination constant on the scales of the instrument.

*c.* Release the magnetic needle and center it, using the lower motion.

*d.* Lock the magnetic needle.

*e.* Using the upper motion, set the required grid azimuth on the scales of the instrument. The scope of the instrument is now oriented on the required azimuth.

### 155. Care of the Aiming Circle

Proper care of an instrument will prolong its life and insure better results to the user. Listed below are several precautions which should be observed while the aiming circle is being used.

*a. Screw Threads.* To prevent damage to the screw threads, do not tighten the adjusting, clamping, or leveling screws beyond a snug contact.

*b. Lenses.* The lenses should be cleaned only with a camel's-hair brush and lens tissue. The brush should be used first to remove any dust or other abrasive material from the lens, and then the lens should be cleaned with the lens tissue. Any smudge spots remaining on the lens after the lens tissue is used can be removed by slightly moistening the spot and again cleaning with the lens tissue. Care should be taken not to scratch the lens or remove the bluish coating. The bluish coating reduces the glare for the observer.

*c. Tripod Head.* The tripod head should be wiped clean of dirt and moisture and should be examined for nicks or burrs before the instrument is attached to the tripod.

*d. Magnetic Needle.* The magnetic needle should be locked when not in use.

*e. Azimuth Knob.* The azimuth knob should be positioned over the notation pad before the instrument is put in its case.

*f. Worm Gears.* Movement of the worm gears should never be forced. In disengaging the fast motion, of the azimuth mechanism, be sure that the gear is free before the instrument is rotated. To reengage the worm gear, move the instrument back and forth slightly until the gear of the azimuth mechanism meshes with that of the lower (nonrecording) motion.

*g. Lubrication.* The aiming circle should not be lubricated by unit personnel. All parts requiring lubrication are enclosed and should be lubricated only by ordnance instrument repair personnel. The instrument should be checked periodically by an ordnance maintenance unit.

*h. Cleaning.* The instrument should be kept clean and dry. Metal parts should be cleaned of grease and oil with mineral spirits paint thinner and then wiped dry. Care must be taken to insure that the threads of the leveling screws are clean and turn smoothly. The polished surfaces should be given a thin coat of light grade aircraft instrument lubricating oil to prevent rust. Electrical parts should be cleaned with trichloroethylene. Rubber parts, other than electrical parts, should be cleaned with warm soapy water. After the rubber parts are dry, a coating of powdered technical talcum should be used to preserve the rubber. Canvas should be cleaned with a dry brush or by scrubbing with a brush and water.

## 156. Maintenance Checks and Adjustments

Maintenance checks should be made as described in *a* through *e* below. If any check, other than the micrometer adjustment check in *c* below, indicates that adjustment is necessary, the aiming circle should be turned in to the supporting ordnance maintenance unit for repair. The checks in *a* through *e* below should be performed before the instrument is used.

*a. Level Vial Check.* After the aiming circle has been set up and leveled, rotate the instrument through 6,400 mils. If the bubbles in the horizontal plate level vials (circular and tubular) do not remain centered, the instrument should be turned in for repair at the first opportunity.

*b. Tilted Reticle Check.* After the aiming circle has been set up and leveled, place the vertical crossline on some well-defined point. Elevate and depress the telescope. If the vertical crossline moves off the point as the telescope is elevated or depressed, the instrument should be turned in for repair.

*c. Micrometer Adjustment Checks.* The only adjustments that may be made by using unit personnel are the adjustments of the micrometers so that they read zero when the main scales with which they are associated read zero.

(1) *Checking and adjusting the azimuth micrometer.* The azimuth micrometer is checked and adjusted as follows:

(*a*) Set the zero of the azimuth scale opposite the index mark.

(*b*) If the zero of the azimuth micrometer is opposite the index, no adjustment is necessary. If the zero is not opposite the index, loosen the screws on the end of the azimuth knob and slip the micrometer scale until the zero is opposite the index.

(*c*) Hold both the azimuth knob and the micrometer scale in position and tighten the azimuth knob screws.

(*d*) Check to insure that the zero of both the azimuth scale and the micrometer scale are still opposite their respective index marks after the screws are tightened.

(2) *Checking and adjusting the elevation micrometer.* The elevation micrometer is checked and adjusted as follows:

(*a*) Set the zero of the elevation scale opposite the index mark.

(*b*) If the zero of the elevation micrometer is opposite the index, no adjustment is necessary. If the zero is not opposite the index, loosen the screws on the end of the elevation knob and slip the elevation micrometer scale until the zero is opposite the index.

(*c*) Hold both the elevation knob and the micrometer scale in position and tighten the micrometer knob screws.

(*d*) Check to insure that the zero of both the elevation scale and the micrometer scale are still opposite their respective index marks after the screws are tightened.

*d. Level Line Check.* The purpose of the level line check is to determine whether correct values are obtained when vertical angles are measured with the aiming circle. If correct vertical angle values are not obtained with the instrument and there is not adequate time to turn the instrument in for repair, a vertical angle correction should be determined. The performance of the level line check and the procedure for determining a vertical angle correction are discussed in detail in paragraph 152. After the elevation micrometer check (*c*(2) above) has been performed and any necessary adjustments have been made, the level line check must be performed before a vertical angle is measured with the aiming circle.

*e. Magnetic Needle Check.* To check the magnetic needle, set up and level the aiming circle. Release the magnetic needle and center it in the reticle of the magnetic needle magnifier. To test the needle for sluggishness, move an iron or steel object back and forth in front of the aiming circle to cause the needle to move on its pivot. Permit the needle to settle. If the needle does not return to center in the reticle, the instrument should be turned in for repair. This check should be performed prior to using the magnetic needle to establish a direction or to orient the instrument.

## Section III. THEODOLITE, T16

### 157. General

The T16 theodolite (fig. 34) is a compact, lightweight, dustproof, optical-reading, direction-type instrument equipped with a horizontal circle (repeater) clamp. It is used to measure both horizontal and vertical angles for artillery fifth-order survey. The horizontal and vertical scales of the theodolite are inclosed and are read by means of a built-in optical system. The scales, graduated in mils, can be read directly to 0.2 mil and by estimation to the nearest 0.1 mil. The scales may be illuminated by either sunlight or artificial light.

### 158. Nomenclature of the T16 Theodolite

*a. Tribrach.* The tribrach is that part of the theodolite which contains the three leveling screws and the circular level. The leveling screws are completely inclosed and dustproof. The tribrach is detachable from the theodolite and is secured to the theodolite by three tapered locking wedges controlled by the tribrach clamp lever.

*b. Horizontal Circle Housing.* The horizontal circle housing assembly contains the horizontal circle; the vertical axis assembly; the receptacles, contacts, and connections for electric illumination; and the three spike feet for securing the theodolite to the tribrach. The following controls are located on the horizontal circle housing:

(1) *Horizontal circle clamp.* The horizontal circle clamp is located on the upper part of the horizontal circle housing and is beneath the telescope eyepiece when the telescope is in the direct position. This clamp is used by the operator to lock the horizontal plate to the alidade in any given position for orienting the instrument.

(2) *Horizontal clamping screw.* The horizontal clamping screw is located on the side of the horizontal circle housing. This control locks the alidade in any desired position about its vertical axis.

(3) *Horizontal tangent screw.* The horizontal tangent screw is located adjacent to the horizontal clamping screw on the side of the horizontal circle housing. This control provides precision adjustment in the horizontal positioning of the telescope.

*c. Alidade.* The alidade, the upper part of the theodolite, includes the telescope and microscope assemblies and the vertical circle assembly. Located on the alidade are the following:

(1) *Levels.* The theodolite has a plate level and vertical circle level (split bubble) in addition to the circular level on the tribrach. The plate level

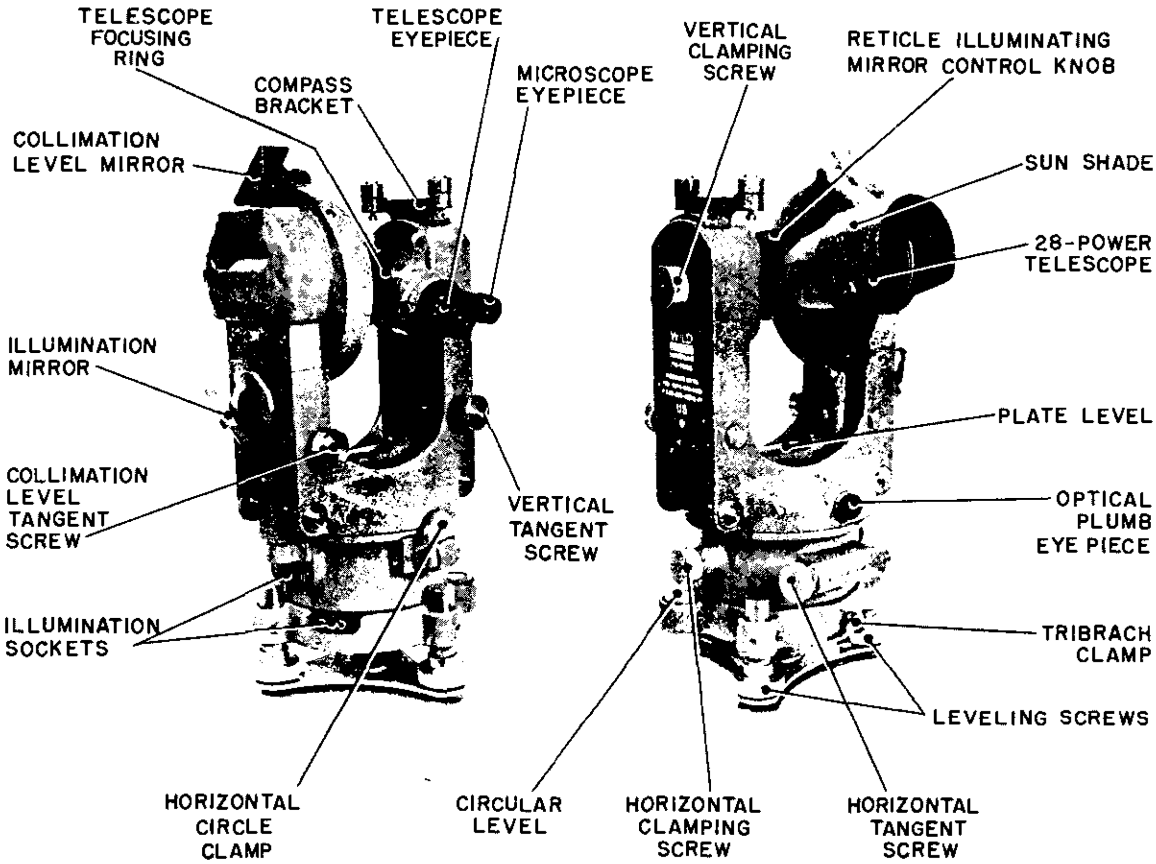



*Figure 34. T16 theodolite.*

is located at the bottom of the opening between the standards on the alidade and is graduated to aid the operator in the precise leveling of the instrument. The vertical circle level is completely built in and is located adjacent to the vertical circle.

(2) *Telescope.* The 28-power telescope of the T16 theodolite can be rotated vertically about the horizontal axis of the theodolite. Objects appear inverted when viewed through the telescope. The reticle of the telescope is etched on glass and consists of horizontal and vertical crosslines, a solar circle for making pointings on the sun, and stadia lines. The reticle crosslines are focused by rotating the eyepiece; the image, by rotating the knurled focusing ring. Two horizontal pull-action screws are provided for correcting the horizontal collimation error. A knob located on top of the telescope controls a small mirror inside the telescope for illuminating the reticle when electric illumination is used.

(3) *Circle-reading microscope.* Attached to the telescope is a microscope for viewing the images of the horizontal and vertical circles. A segment of both circles is presented in the microscope, with the horizontal circle (marked "Az") appearing below the vertical circle (marked "V"). The image of the circles is brought into

focus by rotating the knurled microscope eyepiece.

(4) *Illumination mirror.* A tilting mirror is located on the side of the standard below the vertical circle for illuminating the horizontal and vertical circles. The intensity of the light on the circles can be adjusted by rotating and tilting the mirror until proper lighting is achieved. For artificial illumination, this mirror is removed and replaced by a lamp assembly.

(5) *Vertical clamping screw.* The vertical clamping screw is located on the standard opposite the vertical circle. This control allows the telescope to be rotated vertically about its axis or to be locked in a fixed vertical position.

(6) *Vertical tangent screw.* The vertical tangent screw is located on the lower portion of the same standard as the vertical clamping screw. This control provides precision adjustment in the vertical positioning of the telescope.

(7) *Collimation level tangent screw.* The collimation level tangent screw is located below the vertical circle and on the same standard. This control is used for precise leveling of the vertical circle level (split bubble) by bringing the image of the ends of this bubble into coincidence. A tilting mirror is provided above the vertical circle for viewing the position of the bubble.

(8) *Optical plumb.* An optical plumb system is provided on the theodolite for centering the instrument over a station. The optical plumb is a small prismatic telescope that contains either a small circle or crosslines as a reticle, depending on the model. The focus of the optical plumb telescope is adjusted by rotating the knurled eyepiece located in the base of the alidade.

*d. Carrying Case.* The carrying case for the T16 theodolite consists of a base plate and a steel, dome-shaped hood. When mounted in the base, the instrument rests on supports by means of four studs and is locked to the supports by two clamping levers. A desiccant is located in the base plate. A padded wooden box is also furnished for transporting the theodolite in its case.

*e. Accessory Equipment.*

(1) *Electric illumination device.* An electric illumination device is issued with the T16 theodolite. In the lower housing of the theodolite that fits into the tribrach is a socket for a connector plug from the battery case. A second socket in the horizontal circle housing is connected to the first socket by an internal contact ring. A connector plug is inserted in the second socket to accommodate a plug-in lamp, which replaces the illumination mirror. When the current is on, this lamp illuminates both circles, both the horizontal and vertical level vials, and the telescope reticle. A rheostat is provided on the battery case for adjusting the intensity of the light. A hand lamp is attached to a second cord from the battery case and is used to provide general illumination around the instrument.

(2) *Diagonal eyepieces and sun filter.* Standard equipment includes diagonal eyepieces that screw directly into the telescope and the reading telescope eyepieces. A sun filter is provided for the telescope eyepiece.

(3) *Compass.* A circular compass is issued as an accessory item for the T16 theodolite. When the circular compass is used, it is mounted in the compass bracket located on the standard opposite the vertical circle. The compass is used only to provide a rough check on an azimuth, to orient the sketch in the field notes, or to obtain a direction for assumed control. The compass should always be placed in the pocket of the accessory case with the dial down to prevent breaking the cover glass.

*f. Tripod.* The universal tripod is issued with the theodolite. This tripod has extension legs and accessory case. The accessory case is made of leather and is mounted on the tripod with wood screws. The case contains a plumb bob with a plug-in sleeve and a wrench for the tripod legs.

### 159. Setting Up the Theodolite

*a. Setting Up the Tripod.* The tripod used with the T16 theodolite is similar to that used with the aiming circle M2, and the same procedure is used for setting up the tripod (para 148*a*).

*b. Removing the Theodolite from its Case.* To remove the theodolite from its case—

(1) Grasp the carrying strap with both hands just above the two clamping levers and pull outward to release the clamping levers from the base assembly.

(2) Lift the dome-shaped cover directly off the instrument and lay it to one side.

(3) Pull upward on the two base clamping levers that secure the theodolite to the base assembly. Grasp the theodolite by the standard that has the trademark inscribed on it and lift the theodolite off the base.

(4) Attach the instrument to the tripod head by screwing the fixing screw snugly into the base of the tribrach.

(5) Replace the cover on the base of the case to prevent dust and moisture from entering the case.

*c. Plumbing and Leveling the Theodolite.* The procedure for plumbing and leveling the T16 theodolite is the same as that for the M2 aiming circle (para 148*c*). After the instrument is leveled, check the optical plumb to insure that the instrument is centered exactly over the station. If it is not, center the instrument over the station by shifting it on the tripod head, and again check the level of the instrument. If necessary, repeat the leveling process and again check the optical plumb. Repeat this process until the instrument is level and centered over the station.

### 160. Taking Down the Theodolite

When observations are completed at a station, the theodolite and tripod are march ordered as follows:

*a.* Place the telescope in a vertical position with the objective lens down and tighten the vertical clamping screw.

*b.* Turn each leveling screw to the same height.

*c.* Position the horizontal clamping screw directly over one of the leveling screws and tighten it.

*d.* Grasp the instrument by its right standard and unscrew the instrument-fixing screw. Lift the theodolite from the tripod and secure it in the carrying case. Replace the dome-shaped cover.

*e.* Replace the tripod head cover, collapse the tripod, and strap the tripod legs together.

### 161. Reading and Setting Horizontal and Vertical Circles

*a.* With the T16 theodolite prepared for observing as described in paragraph 159, open the illumination mirror and adjust the light so that both the horizontal and vertical circles are uniformly illuminated when viewed through the circle-reading microscope. Adjust the focus of the microscope until the image of the circles appears sharp and distinct.

*b.* When the circles are viewed through the circle-reading microscope (fig. 35), the vertical circle (marked "V") appears above the horizontal circle (marked "Az"). Both circles are graduated from 0 to 6,400 mils with a major graduation each 10 mils. Unit mils and tenths are viewed on an auxiliary scale graduated in 0.2-mil increments from 0 to 10 mils. Circle readings are estimated to the nearest 0.1 mil. The scale reading is taken at the point where the major (10-mil) graduation (gageline) is super-imposed on the auxiliary scale. When the telescope is not in a horizontal position, the scales will appear to be tilted, with the amount of tilt depending on the inclination of the telescope.

*c.* All horizontal angle measurements with the T16 theodolite should be started with an initial reading of 1.0 mil on the horizontal circle. For practical purposes, this reading precludes working with a mean of the direct and reverse (D&R) pointings on a starting station of less

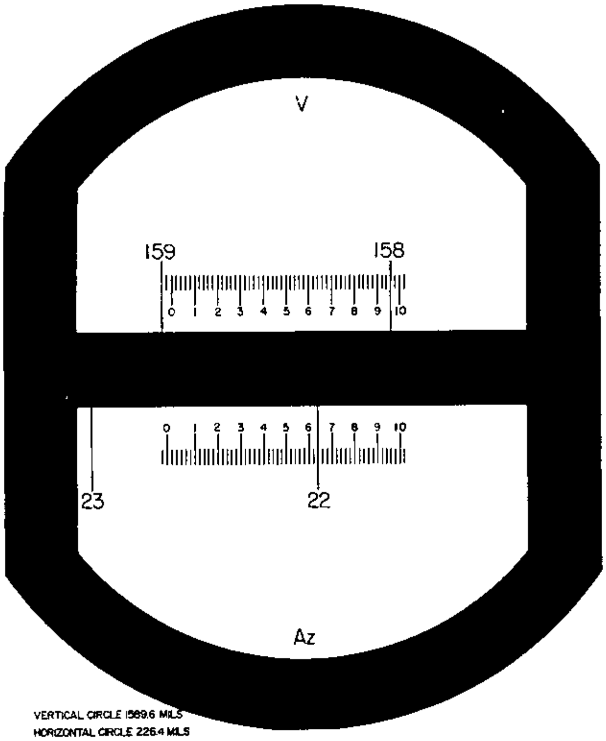



*Figure 35. Scale images viewed through the circle reading microscope.*

than 0 mil. To set this value on the horizontal circle release the horizontal clamping screw and rotate the instrument until the major graduation 0 appears on the horizontal circle. Clamp the horizontal clamping screw and use the horizontal tangent screw to set the 0 gageline directly over the 1.0-mil graduation on the auxiliary scale. Firmly engage the horizontal circle clamp by folding it downward. The horizontal circle is now attached to the alidade of the instrument, and the reading of 1.0 mil will remain on the horizontal circle regardless of the direction in which the instrument is pointed.

## 162. Focusing the Telescope To Eliminate Parallax

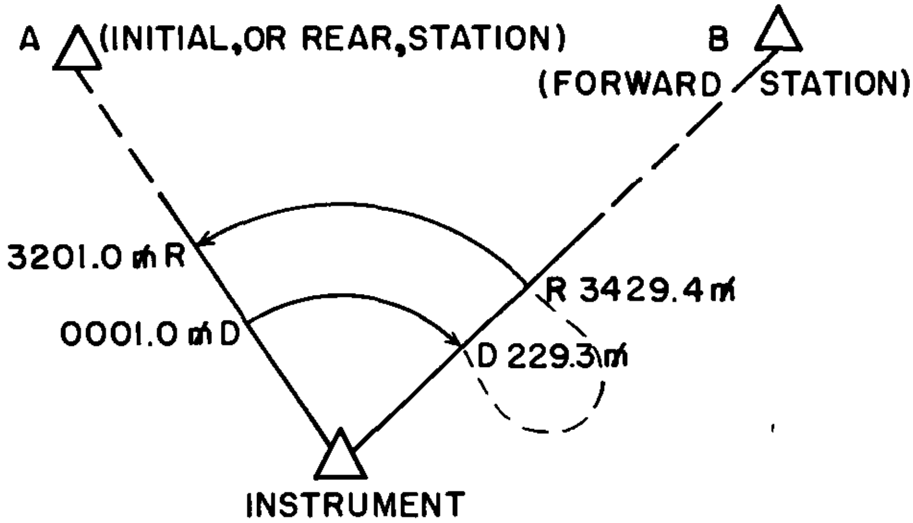
Before a theodolite is used for measuring angles, the telescope must be focused to eliminate parallax by bringing the focus of the eyepiece and the focus of the objective lens to the plane of the reticle (crosslines). This is accomplished as follows: Point the telescope toward the sky or a neutral background and rotate the knurled ring on the telescope eyepiece until the reticle crosslines are sharp, distinct lines. (In doing this, the observer should be very careful to focus his eye on the crosslines, not the sky.) Next, point the telescope toward a well-defined distant point and, still focusing the eye on the crosslines, bring the point into a clear, sharp image by rotating the knurled focusing ring on the telescope. Use the horizontal tangent screw to center the vertical crossline on the point. To check for elimination of parallax, move the eye horizontally back and forth across the eyepiece. If the parallax has been eliminated, the crossline will remain fixed on the object as the eye is moved. If all parallax has not been eliminated, the crossline will appear to move back and forth across the object. To eliminate any remaining parallax, change the focus of the eyepiece slightly to bring the crosslines into sharper focus, and refocus the telescope accordingly until there is no apparent motion. Each time an angle is to be measured, the telescope should be focused to eliminate parallax, since accurate pointings with the instrument are not possible if parallax exists.

## 163. Measuring Horizontal Angles

*a.* In artillery survey, the T16 theodolite is used as a direction-type instrument, and the horizontal circle clamp is used only to set the initial circle setting on the horizontal circle prior to making a pointing on the initial station. The method of measuring horizontal angles consists of determining, at the occupied station, the horizontal circle readings to each observed station, beginning with an initial (rear) station. The angle between two observed stations is the difference between the mean horizontal circle readings determined for each of the observed stations. The mean horizontal circle readings used to determine the angles are determined from two pointings (circle readings) on each observed station (fig. 36).

*b.* With the telescope in the direct (D) position, the initial circle setting of 1.0 mil on the horizontal circle, and the horizontal circle clamp down, a pointing is made on the initial station. This establishes the direction of the staton at 1.0 mil with respect to the horizontal circle. The value of the direct reading on station A is recorded in the field notes (fig. 36).




| STATION | T | HORIZONTAL ∡ MILS | MEAN | VERTICAL READING | VERTICAL ∡ |
|---|---|---|---|---|---|
| A | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| INST | MN | 228.4 | | | +1.4 |
| | | | | | |
| B | D | 229.3 | | 1598.5 | +1.5 |
| | R | 3429.4 | 229.4 | 4801.4 | +1.4 |
| | | | | | |
| | | | | | |

*Figure 36. Extract from field notebook and sketch of pointings in measuring horizontal angles.*

Release (up) the horizontal circle clamp; this causes the horizontal circle to detach itself from the alidade and remain in its fixed position. A pointing is then made on each station around the horizon in a clockwise sequence. After the pointing is made on the last station, the telescope is plunged to the reverse (R) position, and pointings are made on each station in a counterclockwise sequence, beginning with the last station and ending with the initial station.

*c.* When pointings are being made, the horizontal and vertical clamping screws (fast motion) are used to place the crosslines approximately on the object marking the station. The horizontal and vertical tangent screws are then used to place the crosslines exactly on the object. The final direction of rotation of the tangent screws must be clockwise.

*d.* The telescope should be plunged to the direct postion, after the reverse pointing on the initial station, and a direct pointing should be made on the intial station wth the horizontal circle clamp released (up). Although it is not a part of the angle measurement, the instrument will be approximately zeroed in order to save time in setting the initial circle setting for the next angle measurement.

### 164. Measuring Vertical Angles

*a.* Normally, each time a horizontal angle is measured, a vertical angle is measured to the forward station. If possible vertical angles are measured to the height of the instrument (HI).

*b.* Vertical angles cannot be measured directly with the theodolite. The vertical circles of the theodolite reflect readings of 0 mil at the zenith, 1,600 mils horizontal direct, 3,200 mils at nadir (straight down), and 4,800 mils horizontal reverse. Hence, the values read from the vertical circle are not vertical angles but are circle readings that must be converted to vertical angles. When the collimation level bubble is centered, vertical circle readings are measured from a line which is, in effect, an upward extension of the plumbline of the theodolite (fig. 37). One value of the vertical angle is computed from the vertical circle reading obtained with the telescope in the direct position and pointed at the station. With the telescope in the direct position, a vertical circle reading of less than 1,600 mils indicates that the station observed is above the horizontal plane of the theodolite and the vertical angle is plus; a vertical circle reading greater

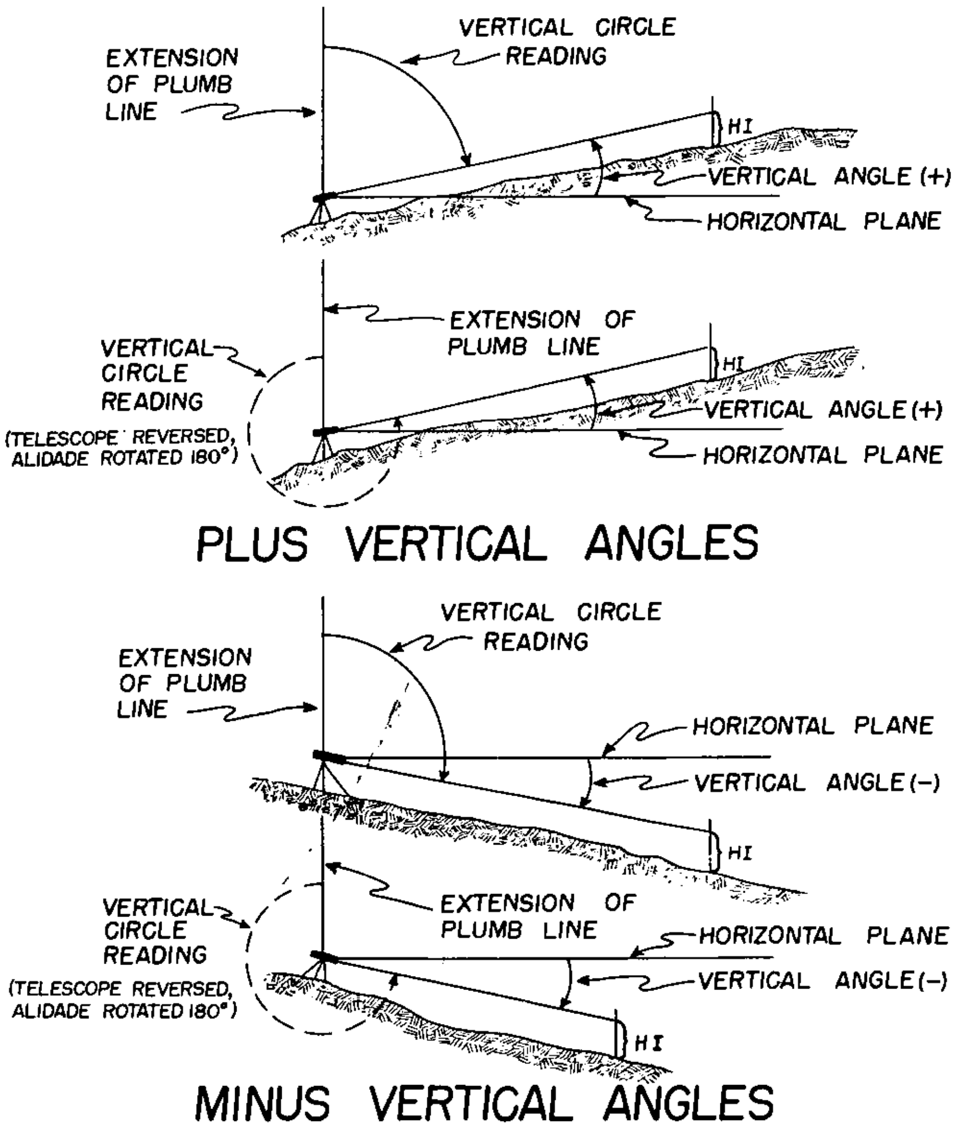



*Figure 37. Relation of vertical circle readings and vertical angles.*

than 1,600 mils indicates that the station observed is below the horizontal plane of the theodolite and the vertical angle is minus. The value of a *plus* vertical angle is determined by subtracting the vertical circle reading from 1,600 mils. The value of a *minus* vertical angle is determined by subtracting 1,600 mils from the vertical circle reading. A second value of the vertical angle is computed from the vertical circle reading obtained with the telescope in the reverse position and pointed at the station. With the telescope reversed, a vertical circle reading greater than 4,800 mils indicates a plus vertical angle and a vertical circle reading less than 4,800 mils indicates a minus vertical angle. The value of a *plus* vertical angle is determined by subtracting 4,800 mils from the vertical circle reading, and the value of a *minus* vertical angle is determined by subtracting the vertical circle reading from 4,800 mils. The two values of the vertical angle are then meaned to obtain the vertical angle to the observed station.

*c.* After the crosslines have been placed on the station, the telescope is elevated (or depressed) until the horizontal crossline is exactly on the point to which the vertical angle is desired. After the telescope is positioned on the station, the bubble of the collimation level (split bubble) is centered in its vial by rotating the collimation level tangent screw until the images of the ends of the bubble coincide. A vertical circle reading is then taken in the circle-reading microscope.

## 165. Computing Horizontal and Vertical Angles

*a.* After the direct and reverse pointings have been made and the horizontal and vertical circle readings recorded in the field notes (fig. 36), the size of the angles are determined. To determine the horizontal angle between stations A and B (fig. 36), the mean of the pointings on each station are first determined by mentally subtracting 3,200 mils from the reverse reading and then taking the mean of the direct and reverse readings. The results are entered in the field notes in the appropriate column. The horizontal angle between the stations is then determined by obtaining the difference in the mean circle readings. In figure 36, the mean pointing on station A is 0001.0; on station B, 229.4. Therefore, the horizontal angle from station A to station B is 228.4 mils.

*b.* In the field notes in figure 36, the direct pointing on station B resulted in a vertical circle reading of 1,598.5 mils, or a vertical angle of +1.5 mils. With the telescope reversed, the vertical circle reading on station B was 4,801.4 mils, or a vertical angle of +1.4 mils. Hence, rounding this value to the nearest even 0.1 mil, the mean vertical angle from the instrument to station B is +1.4 mils.

## 166. Care of the Theodolite

The T16 theodolite is a delicate instrument, and care must be taken not to drop it or bump it against any object. If the instrument gets wet, it must be dried before it is returned to the carrying case. As soon as possible, the instrument should be placed in a dry room or tent. It should be removed from the carrying case so that it may dry completely. If left in the closed carrying case, it will absorb the humidity in the air if there is an increase in temperature. Should the temperature drop afterwards, the moisture will condense on the interior of the instrument and may render the instrument inoperative. In moving the instrument from station to station, a man on foot may carry the instrument, mounted on the tripod, with the tripod under one arm and a hand supporting the theodolite itself. All motions should be clamped with the telescope in the vertical position. When the theodolite is carried over rough terrain, the instrument should be transported in its carrying case. When transported in a vehicle, the theodolite should be in the dome-shaped carrying case, and the case should be in the padded box. For short distances, the carrying case may be held in an upright position on the lap of the instrument operator.

## 167. Cleaning the Theodolite

The theodolite must be kept clean and dry. During use, as necessary, and after use, the instrument should be cleaned as follows:

*a.* Painted surfaces should be wiped with a clean cloth.

*b.* The lenses should be cleaned only with a camel's-hair brush and lens tissue. The lens should be cleaned first with the brush to remove any dust or other abrasive material and then with the lens tissue. Any smudge spots remaining after the lens tissue is used can be removed by slightly moistening the spot and again cleaning with the lens tissue. Care should be taken not to scratch the lens or remove the coating. The coating reduces glare for the observer.

*c*. All metal parts of the tripod should be cleaned with a cloth moistened with an approved cleaning solvent and wiped dry. The wooden parts should be cleaned with a soft cloth moistened with water and dried thoroughly. The leather strap should be cleaned with a suitable leather cleaner.

## 168. Repair of Theodolite

Adjustment (except as explained in paragraphs 169 through 173) and repair of the T16 theodolite must be performed by qualified instrument repair personnel. Theodolites in need of adjustment or repair should be turned in to the engineer unit responsible for providing maintenance service. TM 5–6675–200–15 outlines the categories of maintenance.

## 169. Adjustment of Theodolite

*a*. The theodolite must be kept in correct adjustment if accurate results are to be obtained. There are four tests and adjustments of the T16 theodolite that should be made periodically by the instrument operators. The adjustments are performed in the sequence in which they are discussed in paragraphs 170 through 173. When a test indicates that an adjustment is necessary, this adjustment should be made and the instrument should be tested for accuracy before the next test is made.

*b*. The four tests and adjustments of the theodolite are made with the instrument mounted on its tripod. For these tests and adjustments, the instrument should be set up in the shade on firm ground with the head of the tripod as nearly level as possible. The theodolite should be protected from the wind.

*c*. If handled properly, an instrument will remain in adjustment indefinitely. The adjustments should be made only by qualified personnel, and they should be made in a deliberate, careful manner. Needless and excessive movement of the adjusting screws will cause the screws to become worn, and the instrument will not hold an adjustment.

## 170. Plate Level Adjustment

*a*. *Purpose*. The purpose of the plate level adjustment is to make the vertical axis of the theodolite truly vertical when the bubble of the plate level is centered in its vial.

*b*. *Test*. To test the adjustment of the plate level, place the axis of the bubble parallel to two of the three leveling screws. With these two leveling screws, center the bubble. Rotate the instrument 1,600 mils and again center the bubble, using the third leveling screw. Repeat these steps until the bubble remains centered in both positions. Carefully center the bubble in the first position, and then rotate the instrument 3,200 mils. If the bubble does not remain centered, adjustment is required. The discrepancy noted in the position of the bubble is the apparent error, or twice the actual error, of the plate level.

*c*. *Adjustment*. To adjust the plate level, use the adjusting pin and remove one-half of the apparent error (actual error) by turning the capstan adjusting screw, which is located in the right support 1½ inches above the horizontal clamping screw. Repeat the test to detect and adjust, if necessary, any error remaining in the adjustment of the plate level. The plate level is in proper adjustment when the bubble remains centered throughout 6,400 mils.

## 171. Optical Plumb Adjustment

*a*. *Purpose*. The purpose of the optical plumb adjustment is to make the vertical axis of the theodolite pass through the station mark when the theodolite is properly leveled and the station mark is centered in the reticle of the optical plumb.

*b*. *Test*. To test the optical plumb, set up the instrument over a station that is clearly marked by a cross or other well-defined point and accurately level the instrument. The image of the point should be centered exactly in the center of the optical plumb. Rotate the instrument 3,200 mils about its vertical axis. If the image of the point does not remain centered in the reticle, the amount of displacement is the apparent error, or twice the actual error, of the optical plumb.

c. *Adjustment.* To adjust the optical plumb, one-half of the displacement (the actual error) is corrected by turning the two optical plumb adjusting screws. Access to the adjusting screws is obtained by removing the cover screws, located 1¼ inches to the right and left of the optical plumb eyepiece. By very small movements of the distance toward the station mark. (The last movement of the adjusting screws must be clockwise to compress a counterspring.) Check the adjustment by again leveling and centering the instrument over the station mark and then rotating the instrument through 6,400 mils. If the image of the reticle does not remain centered on the station mark throughout the circle, repeat the adjustment. After the adjustment is completed, replace the cover screws.

## 172. Horizontal Collimation Adjustment

a. *Purpose.* The purpose of the horizontal collimation adjustment is to make the line of sight perpendicular to the horizontal axis of the telescope.

b. *Test.* To test the horizontal collimation, select a well-defined point at least 100 meters from the instrument and at approximately the same height as the instrument. With the telescope in the direct position, center the vertical crossline on the selected point and read the horizontal circle. Plunge the telescope to the reverse position and take a second reading on the same point. The instrument operator should repeat both readings to insure that no error was made in reading the instrument. These two readings should differ by 3,200 mils. Assuming no error in the pointings or readings, any discrepancy between the actual differences in the two readings and 3,200 mils is the apparent error, or twice the horizontal collimation error. If this discrepancy exceeds plus or minus 1 mil, the horizontal collimation adjustment should be performed.

c. *Adjustment.* For the purpose of illustration, assume that the horizontal circle reading in the direct position is 150.7 mils and in the reverse position is 3,352.9 mils. With the telescope in the direct position and using the horizontal tangent screw, set the circle to the mean value of the direct and reverse pointings (151.8). In doing so, the vertical crossline of the telescope reticle is moved off the point. Move the vertical crossline back to the point by turning the two pull-action capstans adjusting screws that are arranged horizontally and on opposite sides of the telescope near the eyepiece. If the reticle must be moved to the right, loosen the left screw slightly and tighten the right screw a corresponding amount. If the adjusting screw is tightened an excessive amount, it will cause the retical to get out of adjustment later on. Repeat the test to insure that the proper adjustment has been made.

*Note.* This adjustment can also be made with the telescope remaining in the reverse position and using the mean value for the reverse pointing; i.e., 3,351.8.

## 173. Vertical Collimation Adjustment

a. *Purpose.* The purpose of the vertical collimation adjustment is to make the line of sight horizontal when the vertical circle reads 1,600 mils with the telescope in the direct position (4,800 mils with the telescope in the reverse position) and the ends of the collimation level bubble are in alinement.

b. *Test.* To test the vertical collimation, select a well-defined point at least 100 meters from the instrument. With the telescope in the direct position, take a vertical circle reading on the point, making sure that the collimation level bubble is precisely alined. Plunge the telescope to the reverse position and again take a vertical circle reading to the same point. The collimation level bubble must be precisely alined before, and checked after, each vertical circle reading. Repeat these two measurements to insure that no error was made. The sum of the direct and reverse readings should equal 6,400 mils, and any difference between the sum of the two readings and 6,400 mils is the apparent (index) error, or twice the collimation level error. If the difference exceeds plus or minus 1 mil, the collimation level should be adjusted.

c. *Adjustment.* To adjust the vertical level, compute the correct vertical circle reading by applying one-half of the index error of the vertical circle to the direct reading. If the sum of the two readings is greater than 6,400 mils, subtract one-half the index error from the direct reading; if the sum is less than 6,400 mils, add one-half of the index error to the direct reading. Place the instrument in the direct position and accurately sight on the point. With the telescope sighted on the point, use the collimation level tangent screw to place the correct reading on the vertical circle scale. With the telescope sighted on the point and the correct reading on the vertical circle scale, the collimation level bubble will not be centered. Bring the split bubble into coincidence by turning its adjusting screw. Access to the adjusting screw is gained by removing the cover of the vertical circle level. Repeat the test to insure that the proper amount of adjustment has been made.

*Example:*

| | |
|---|---|
| Vertical circle reading for direct pointing | 1,479.3 |
| Vertical circle reading for reverse pointing | 4,919.5 |
| Sum | 6,398.8 |

Apparent (index) error = 6,400 — 6,398.8 = 1.2 mils

Collimation error = 1.2 ÷ 2 = 0.6 mil

Correct vertical circle reading (direct) = 1.479.3 + 0.6 = 1,479.9

With the telescope in the direct position, accurately sight on the point. Use the collimation level tangent screw and place the correct reading (1,479.9) on the vertical circle scale. Bring the split bubble into coincidence by turning its adjusting screw.

*Note.* This adjustment can also be made with the telescope in the reverse position, using the mean value for the reverse pointing; i.e., *4,919.5 +0.6 = 2,920.1 mils.*

### 174. Verticality Adjustment

The T16 theodolite is constructed so that the vertical crossline remains vertical, and no adjustment is required.

## Section IV. THEODOLITE, T2

### 175. General

*a.* The T2 theodolite, mil-graduated (fig. 38), is the authorized angle-measuring instrument for artillery fourth-order survey. The theodolite, having only one spindle, is a direction-type instrument and is used to measure both horizontal and vertical angles. It has interior scales which are read by means of a built-in optical system. The scales, graduated in mils, are readable directly to 0.002 mil and by estimation to the nearest 0.001 mil. The scales may be illuminated by sunlight or by means of a built-in wiring system using artificial light. All components of the instrument which can be seriously damaged by dust or moisture are enclosed.

*b.* Units may be equipped with another model, the sexagesimal T2 theodolite, to use for artillery fourth-order survey. The two models are identical except for the graduation of the horizontal and vertical scales. The scales of the sexagesimal theodolite are graduated in degrees, minutes, and seconds and can be read directly to 1 second.

*c.* The T2 theodolite is issued with a canvas accessory case containing diagonal eyepieces for the telescope and reading microscope, a sun filter, a jeweler's screwdriver, two adjusting pins, a camel's-hair brush, a plastic instrument head cover, two lamp fittings for artificial illumination; a battery case containing lighting devices and spare bulbs; and a universal tripod with a plumb bob, plug-in sleeve, and tripod key in a leather pouch attached to the tripod. The accessories of some models of the theodolite are stored in the base of the carrying case.

### 176. Nomenclature of the T2 Theodolite

*a. Tribrach.* The tribrach is that part of the theodolite which contains the three leveling screws and the circular level. The leveling screws are inclosed and dustproof. On models manufactured subsequent to 1956, the tribrach is detachable. On these models, the tribrach is secured to the theodolite by three tapered locking wedges controlled by the tribrach clamp lever. An optical plumb system is located in the tribrach for accurately centering the theodolite over a station.

*b. Horizontal Circle Housing.* The horizontal circle housing assembly contains the horizontal circle, the vertical axis assembly, prisms for

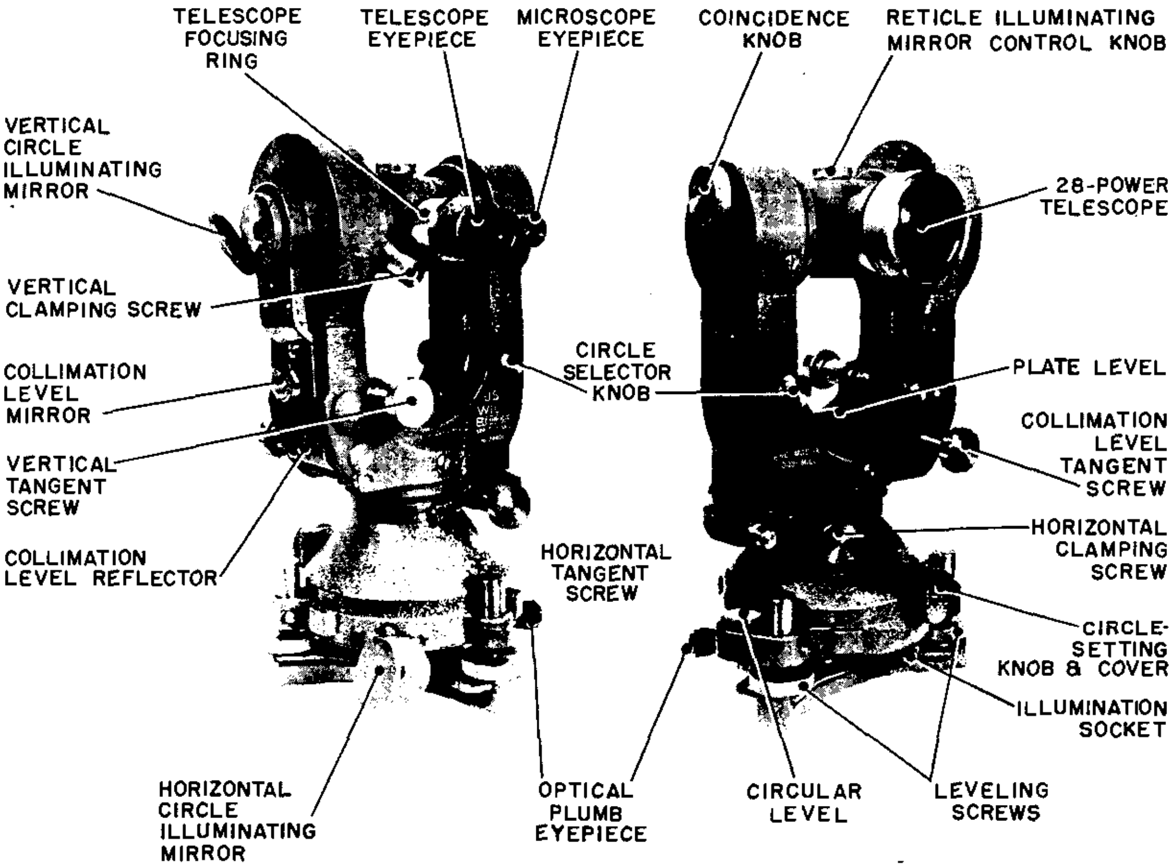



*Figure 38. The T2 theodolite.*

illuminating and reading the horizontal circle, contacts and connections for electric illumination, and three spike feet for securing the theodolite to the tribrach. The following items are located on the horizontal circle housing:

(1) *Circle-setting knob and cover.* The circle-setting knob, which is located on the side of the horizontal circle housing, is used to rotate the horizontal circle to any desired position. The cover of the circle-setting knob is provided to prevent the operator from disturbing the orientation of the horizontal circle by an accidental touch. The cover should be closed at all times except when the horizontal circle is being oriented.

(2) *Illumination mirror.* A hinged, tilting mirror to illuminate the horizontal circle is located on the lower portion of the horizontal circle housing. The intensity of the light on the horizontal circle can be adjusted by rotating and tilting the mirror until the circle is properly lighted. For artificial illumination, this mirror is removed and replaced by a plug-in lamp.

(3) *Instrument support lugs.* Three rectangular-shaped instrument support lugs are uniformly spaced around the base of the horizontal circle housing. These lugs are used to secure the theodolite to the base of the carrying case. The plug-in socket which receives

the battery box cable for artificial illumination is located immediately above one of the lugs.

c. *Alidade.* The alidade is the upper (rotating) part of the theodolite. It includes the telescope and microscope assemblies and the two standards that support them, the vertical circle assembly, and the horizontal clamp assembly. Located on the alidade are the following:

(1) *U-standard assembly.* The U-standard forms the support for all the components making up the upper part of the instrument and includes the horizontal circle axle and flange, the circle selector knob and prism, and the horizontal axis prism.

(2) *Levels.* The theodolite has a plate level and a vertical circle level (split bubble) in addition to the circular level on the tribrach. The plate level is located at the bottom of the opening between the standards and is graduated to aid the operator in the precise leveling of the instrument. The vertical circle level is completely built in and is located adjacent to the vertical circle.

(3) *Collimation level tangent screw.* The collimation level tangent screw is located below the vertical circle and on the same standard. This control is used for precise leveling of the vertical circle level (split bubble) by bringing the images of the ends of the bubble into coincidence. A prism on the side of the standard is provided for viewing the position of the bubble. Below the prism, a hinged reflector is rotated outward to provide illumination of the vertical circle level.

(4) *Telescope.* The 28-power telescope of the T2 theodolite can be rotated vertically about the horizontal axis of the theodolite. Objects appear inverted when viewed through the telescope. The reticle of the telescope is etched on glass and consists of horizontal and vertical crosslines and stadia lines. The reticle crosslines are focused by rotating the eyepiece; the image, by rotating the knurled focusing ring. Three adjusting screws are provided for correcting the horizontal collimation error. A knob located on top of the telescope controls a small mirror inside the telescope for illuminating the reticle when electric illumination is used.

(5) *Circle selector knob.* The circle selector knob is located immediately above the trademark inscription "Wild." The knob is inscribed with a heavy black line which indicates whether the image of the horizontal or the vertical circle is visible in the circle-reading microscope. When the line is horizontal, the horizontal circle may be viewed; when the line is vertical, the vertical circle may be viewed.

(6) *Circle-reading microscope.* Attached to the telescope is a microscope for viewing the horizontal and vertical circles. The circle to be viewed is selected by turning the circle selector knob to either the horizontal or the vertical position. The field of view of the microscope appears to contain two small windows. The upper window contains images of two diametrically opposite portions of the horizontal or vertical circle. One of the images of the circle is inverted and appears above the other image. The lower window contains the image of a portion of the micrometer scale. The image of the scale is brought into focus by rotating the knurled microscope eyepiece.

(7) *Coincidence knob.* The coincidence knob on the side of the right standard is used to obtain readings for either the horizontal or vertical circle in conjunction with the micrometer scale. It operates the micrometer scale to bring the vertical or horizontal circle graduations into coincidence.

(8) *Illumination mirror.* A tilting mirror for illuminating the vertical circle is

located on the side of the standard at the center of the vertical circle. This mirror is identical with the mirror on the horizontal circle in construction and use.

(9) *Horizontal clamping screw.* The horizontal clamping screw is located on the right front portion of the instrument immediately above the horizontal circle housing. This control is used to lock the alidade in any desired position on its vertical axis.

(10) *Horizontal tangent screw.* The horizontal tangent screw is located on the right rear portion of the instrument immediately above the horizontal circle housing. This control enables precision adjustment in the horizontal positioning of the telescope.

(11) *Vertical clamping screw.* The vertical clamping screw is located adjacent to the vertical circle. This control permits the telescope to be rotated vertically about its axis or to be locked in a fixed vertical position.

(12) *Vertical tangent screw.* The vertical tangent screw is immediately below the vertical clamping screw. This control permits precision adjustment in the vertical positioning of the telescope.

*d. Carrying Case.* The carrying case for the T2 theodolite consists of a base plate and steel dome-shaped hood. When the theodolite is placed on the base plate, it rests on three supports and is secured to the supports by three clamps. A padded wooden box is also furnished for transporting the theodolite in its carrying case.

*e. Electric Illumination Device.* The T2 theodolite contains a built-in wiring system for illuminating the circles, the micrometer scale, and the telescope reticle. Two bulb holders are in the base of the carrying case or in the accessory case. Each of the circle-illuminating mirrors can be replaced by pulling a mirror off the instrument and inserting a bulb holder in its place. A battery case is attached to one of the tripod legs, and the wiring from this case leads to an electric illumination plug located in the tribrach. A second wire from the battery case leads to a hand lamp that is used for general illumination around the instrument. A rheostat is provided on the battery case for adjusting the intensity of light. Telescope reticle illumination is adjusted by turning the reticle illumination knob on top of the telescope to rotate a small mirror located at the horizontal axis in the telescope.

*f. Tripod.* The universal tripod is issued with the theodolite. This tripod has extension legs and accessory case. The overall length of the closed tripod is 3 feet; the extended length is 5.2 feet. The accessory case is made of leather and is mounted on the tripod. The case contains a plumb bob with a plug-in sleeve and a wrench for the tripod legs. The head of the tripod is covered with a screw-on protector cap.

## 177. Setting Up the Theodolite

*a. Setting Up the Tripod.* The tripod used with the T2 theodolite is similar to that used with the aiming circle. The procedure for setting up this tripod is the same as that for the aiming circle M2 (para 148*a*).

*b. Removing the Theodolite From Its Case.* The T2 theodolite is removed from its case in the same manner as the T16 theodolite (para 159*b*), except that it is fastened to the base by three supports with locking devices.

*c. Plumbing and Leveling the Theodolite.* The procedure for plumbing and leveling the T2 theodolite is the same as that for the T16 theodolite (para 159*c*).

*d. Focusing the Telescope to Eliminate Parallax.* The telescope of the T2 theodolite is the same as the telescope of the T16 theodolite and it is focused to eliminate parallax in the same manner (para 162).

*e. Taking Down the Theodolite.* The T2 theodolite is taken down and placed in its carrying case in the same manner as the T16 theodolite (para 160).

## 178. Circle Readings

*a.* A system of lenses and prisms permits the observer to see small sections of diametrically opposite sides of either the horizontal circle or the vertical circle (fig. 39). The circles are

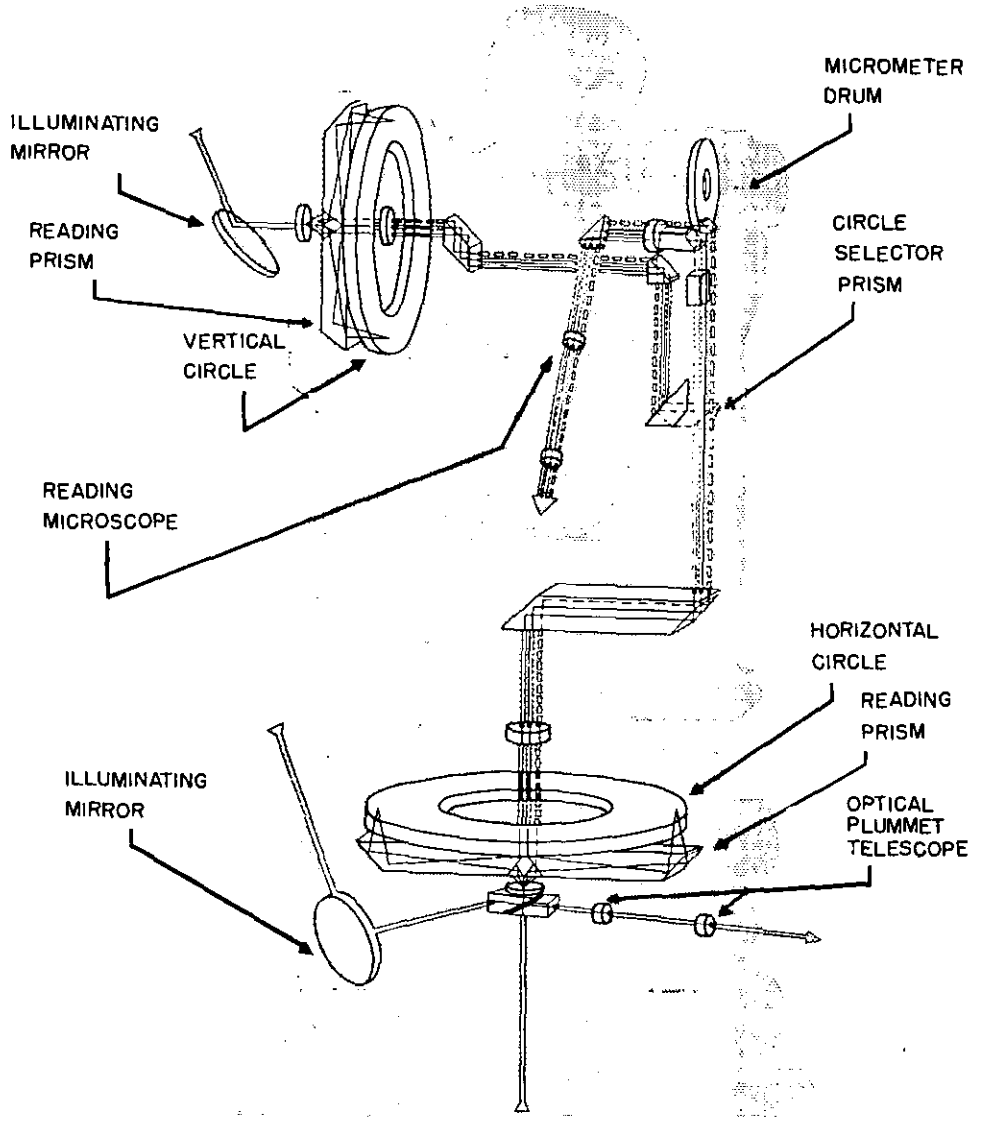



*Figure 39. Circle-reading optical system of the T2 theodolite.*

viewed through the circle-reading microscope located alongside the telescope. The circle to be viewed is selected by turning the circle selector knob on the right standard. The field of view of the circle-reading microscope contains two small windows (fig. 40). The upper window shows images of two diametrically opposite portions of the circle (horizontal or vertical). One image of the circle is inverted and apears above the other image. The lower window shows an image of a portion of the micrometer scale.

*b.* The coincidence knob on the side of the right standard is used to obtain readings for either of the circles in conjunction with the micrometer scale. Optical coincidence is obtained between diametrically opposite graduations of the circle by turning the coincidence knob. When this knob is turned, the images of the opposite sides of the circle appear to move in opposite directions across the upper window in the circle-reading microscope. The image of the micrometer scale in the lower window also

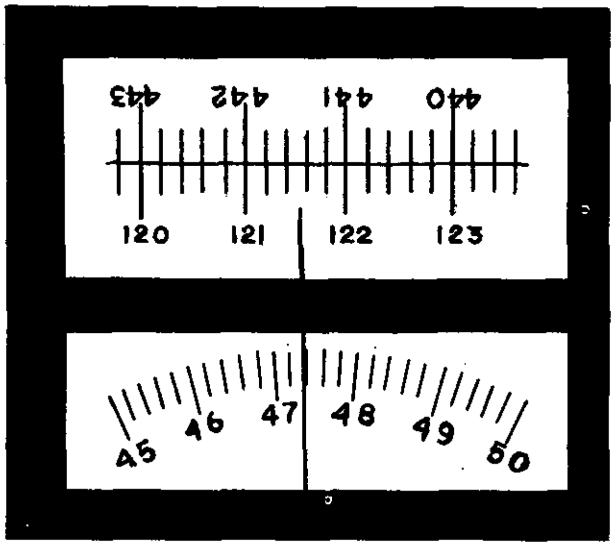



*Figure 40. T2 scales (mil-graduated) viewed through the circle-reading microscope.*

moves. The graduations of the circle (upper window) are brought into coincidence so that they appear to form continuous lines across the dividing line. The center of the field of view in the upper window is marked by a fixed vertical index line. The final coincidence adjustment should be made between circle graduations in the vicinity of this index line. The line is not used in reading the circle.

## 179. Horizontal Circle Readings

To determine a reading on the horizontal circle—

*a.* Rotate the circle selector knob until the black line on the face of the knob is horizontal.

*b.* Adjust the illuminating mirror so that both windows in the circle reading microscope are uniformly lighted.

*c.* Focus the microscope eyepiece so that the graduations of the circle and micrometer scale are sharply defined.

*d.* Observe the images in the microscope. Bring the circle graduations into coincidence at the center of the upper window by turning the coincidence knob. The final motion of the coincidence knob must be clockwise.

*e.* Read the horizontal circle and micrometer scale.

## 180. Steps in Circle Reading (Mil)

On the mil-graduated T2 theodolite, the main scale (upper window) is graduated in 2-mil increments (fig. 40). Each fifth graduation is numbered, omitting the unit digits; e.g., 10 mils appear as 1; 250 mils as 25; and 3,510 mils as 351. The micrometer scale (lower window) is graduated from 0.000 mil to 1.000 mil. Each 0.002 mil is marked with a graduation, and each fifth graduation is numbered (hundredth of a mil). The scale may be read to 0.001 mil by interpolation. The steps in reading the circles are as follows:

*a.* Bring the circles into coincidence (para 179) and determine the first erect numbered graduation to the left of the index line that marks the center of the upper window. This numbered graduation indicates the value of the circle reading in tens of mils. In figure 40, this value is 121.

*b.* Locate on the inverted scale the graduation for the number diametrically opposite 121 (the number +320). In figure 40 this number is 441 (viewed 441 ). The inverted number is always to the right of the index line which marks the center of the field of view. When the unit mils of the circle reading is zero, coincidence is obtained with the circle reading and its diametrically opposite number in coincidence with each other in the immediate vicinity of the index line. Both values always end in the same number—in this case, the number 1.

*c.* Count the number of spaces between graduations from 121 to the inverted 441. There are five spaces, representing 5 mils. Each of these spaces represents 1 mil.

*d.* Convert 121, which is tens of mils, to 1,210 mils and, to this value, add the unit mils determined in *c* above (1,210 + 5 = 1,215 mils, the angular value obtained from the main scale).

*e.* On the micrometer scale (lower window), the index line that marks the center of the field of view also indicates the value to be read from the micrometer scale. In figure 40, this value is 0.474 mil.

*f.* Add the values determined in *d* and *e* above (1,215 + 0.474) = 1,215.474 mils, the angular value displayed in figure 40).

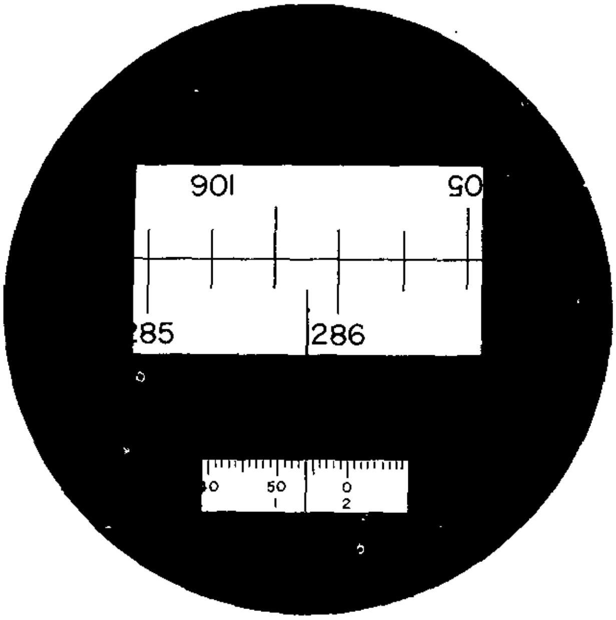



*Figure 41. T2 scales (sexagesimal) viewed through the circle-reading microscope.*

## 181. Steps in Circle Reading (Sexagesimal)

On the sexagesimal T2 theodolite, the main scale (upper window) is graduated at 20-minute intervals, and every third graduation is numbered to indicate a degree. The micrometer scale (lower window) is graduated in minutes and seconds from 0 to second to 10 minutes. The scale may be read to 1 second. The steps in reading the circles are as follows (fig. 41):

*a.* Bring the circles into coincidence (para 178*b*) and determine the first erect numbered graduation to the left of the index line that marks the center of the upper window. This numbered graduation indicates the value of the circle reading in degrees. In figure 41, this value is 285°.

*b.* Locate the inverted graduation which differs from 285° by 180°; this value is 105° (viewed 901). The inverted number is always to the right of the index line which marks the center of the field of view. (When the tens of minutes of the circle reading is zero, coincidence is obtained with the circle reading and its diametrically opposite number in coincidence with each other in the immediate vicinity of the index line.) Both values always end in the same number—in this case, the number 5.

*c.* Count the number of spaces between the graduations from 285 to the inverted 105. Each space represents 10 minutes. In figure 41, there are five spaces, representing 50 minutes.

*d.* The angular value obtained from the main scale (upper window) is 285° 50′ (285° + 50′ = 285° 50′).

*e.* The index line which marks the center of the field of view in the lower window indicates the value to be read on the micrometer scale. This scale has two rows of numbers below the graduations, the bottom row being the unit minutes and the top row seconds. In figure 41, the unit minutes and seconds are read as 1′54″.

*f.* Add the angular values determined in *d* and *e* above (285° 50′ + 1′54″ = 285° 51′54″, the angular value).

## 182. Vertical Circle Readings

The circle selector knob is rotated until the black line on the face of the knob is vertical. The vertical circle may now be viewed in the circle-reading microscope. A reading on the vertical circle is made in the same manner as a reading on the horizontal circle.

## 183. Setting the Horizontal Circle

There are two situations in which it is necessary to set the horizontal circle.

*a.* In the first instance, the horizontal circle is to be set to read a given value with the telescope pointed at a target. The initial circle setting of 0.150 ($\pm$0.100 mil) is used as an example.

(1) Point the instrument at the target.

(2) Using the coincidence knob, place a reading of 0.150 on the micrometer scale.

(3) Using the circle-setting knob, zero the main scale as accurately as possible, insuring that the numbered lines, which are 3,200 mils apart (the erect 0 graduation and the inverted 320 graduation), are touching each other.

(4) With the coincidence knob, bring the main scale graduations into a more precise coincidence.

(5) Read the horizontal circle. The read-

ing should be 0.150 (within ±0.100 mil). With care, a circle may be set to an accuracy of 0.010 mil.

*b*. In the second instance, it is desired to orient the instrument on a line of known direction from a reference direction (or lay off a predetermined angle).

(1) Point the instrument on the line for which the reference direction is provided and read the circle.

(2) Add the angular difference between the reference direction and the desired direction (or the predetermined angle) to the circle reading. The result is the circle reading for the instrument when it is pointed in the desired direction.

(3) Using the coincidence knob, set the micrometer scale to read the fractional portion of the desired circle reading to the thousandth of a mil.

(4) Using the horizontal clamping screw and the horizontal tangent screw, rotate the alidade to obtain coincidence on the main scale at the mils value corresponding to the reading obtained in (2) above. When coincidence is obtained, the instrument is pointing in the desired direction.

## 184. Measuring Horizontal Angles

*a*. Since the T2 theodolite is a direction-type instrument, the values of horizontal angles are determined by differences in circle readings rather than by direct measurement. The procedure for measuring and determining horizontal angles is (fig. 42) as follows:

(1) With the telescope in the direct (D) position, point to station A and record the initial circle setting (0.166 mil).

(2) With the telescope in the direct (D) position, point to station B and record the circle reading (1,215.475 mils).

(3) Plunge the telescope to the reverse (R) position, point to station B, and record the circle reading (4,415.503 mils).

(4) With the telescope in the reverse (R) position, point to station A and record the circle reading (3,200.200 mils).

(5) Subtract 3,200 mils from the reverse pointing on station A and mean the remainder with the direct pointing on station A (0.183 mil).

(6) Subtract 3,200 mils from the reverse pointing on station B and mean the remainder with the direct pointing on station B (1,215.489 mils).

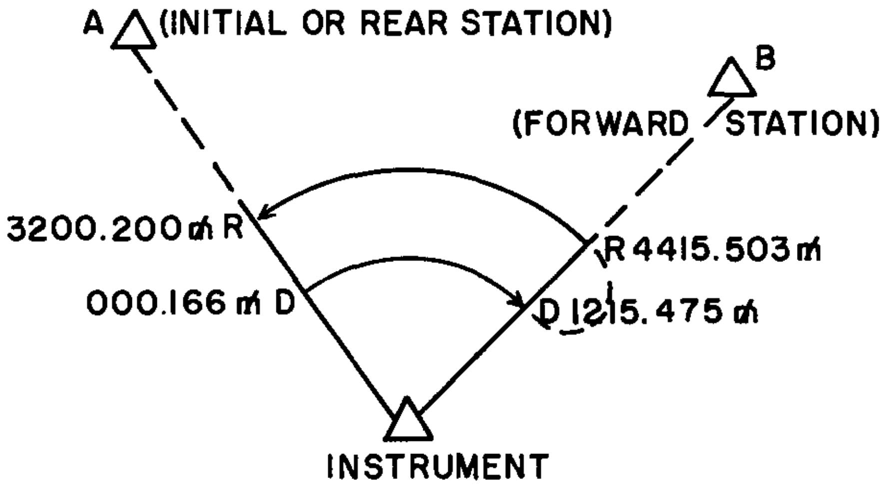
(7) Subtract the mean pointing on station A from the mean pointing on station B to determine the horizontal angle from station A to station B (1,215.489 −0.183 = 1,215.306 mils).

*Note.* Steps in (1) through (7) above constitute one direct and one reverse pointing on each station, which is referred to as *one position*.

*b*. When it is necessary to measure the angle to more than one station, a pointing is made on the initial station with the telescope in the direct position and then on each station around the horizon in a clockwise direction. After a reading is obtained on the last station with the telescope direct, the telescope is reversed and a pointing is made on each station in a counterclockwise direction, ending with the initial station. One set of direct and reverse pointings on all of the observed stations constitutes one position.

*c*. The direct and reverse pointing on each station should differ by 3,200 mils (or 180°), plus or minus the amount of the horizontal spread (twice the error in horizontal collimation) in the instrument. No value can be specified as the maximum allowable spread for an instrument; however, it should be small (0.150 mil or less) for convenience in meaning the pointings. The amount of the spread should be constant; otherwise, there are inconsistencies in operating the instrument. If the mean spread of an instrument exceeds 0.150 mil (or 30″), it should be adjusted at the first opportunity.

*d*. In artillery survey, one position is normally observed for traverse and two positions are observed for triangulation. However, if the primary requirement of a traverse is to establish an accurate direction (FA missile battalion), then two positions are observed.



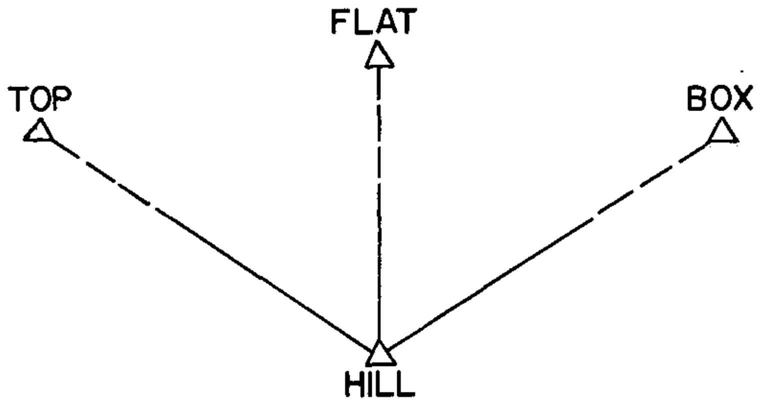

| STATION | T | HORIZONTAL ∡ MILS | MEAN | VERTICAL READING | VERTICAL ∡ MILS |
|---|---|---|---|---|---|
| A | D | 0000.166 | | | |
| | R | 3200.200 | 0000.183 | | |
| INST | | | | | |
| | MN | 1215.306 | | | +28.624 |
| | | | | | |
| B | D | 1215.475 | | 1571.384 | +28.616 |
| | R | 4415.503 | 1215.489 | 4828.631 | +28.631 |
| | | | | | |

*Figure 42. Extract from field notebook and sketch of pointings in measuring horizontal angles.*

*e.* When it is necessary, as in triangulation, to measure two positions, the second position is measured in the same manner as the first position, except that the second position normally is measured with the telescope in the reverse position for the initial pointing on each station. The initial circle settings should be as follows: first position, direct: 0.150 (±0.100) mils (or 00°00′30″ ± 20″); second position, reverse: 4,800.150 (±0.100) mils (or 270°00′30″ ± 20″).

*f.* The angle between two observed stations is determined by measuring the mean horizontal circle reading to each station and computing the difference between the mean circle readings. When two positions are taken, the value of the angle is determined by taking the mean of the values of the angle as determined from each of the two positions. Figure 43 illustrates the method of recording horizontal circle readings and determining the horizontal angles between three stations, with two positions observed.

*g.* When two positions are observed, if the two observed values for any angle differ by more than 0.050 mil (10″), these observed values should be rejected. If the observed values are rejected, the angle(s) must be remeasured, using approximately the same initial circle setting that was used to obtain the rejected value(s).




| STATION | T | HORIZONTAL ∡ MILS | MEAN | VERTICAL READING | VERTICAL ∡ MILS |
|---|---|---|---|---|---|
| TOP | D | 0000.112 | | | |
| | R | 3200.134 | 0000.123 | | |
| HILL ∡ | | 814.236 | | | -10.320 |
| | | | | | |
| FLAT | D | 0814.338 | | 1610.314 | -10.314 |
| | R | 4014.380 | 0814.359 | 4789.673 | -10.327 |
| HILL ∡ | | 896.669 | | | +31.051 |
| | | | | | |
| BOX | D | 1711.010 | | 1568.990 | +31.060 |
| | R | 4911.046 | 1711.028 | 4831.042 | +31.042 |
| | | | | | |
| | | | | MEAN HORIZ. ∡ | |
| TOP | R | 4800.176 | | 814.236 | ANGLE FROM FIRST POSITION |
| | D | 1600.166 | 4800.171 | 814.202 | ANGLE FROM SECOND POSITION |
| HILL ∡ | | 814.202 | | 814.219 | MEAN ANGLE AT HILL FROM TOP TO FLAT |
| | | | | | |
| FLAT | R | 5614.389 | | 896.669 | |
| | D | 2414.357 | 5614.373 | 896.627 | |
| HILL ∡ | | 896.627 | | 896.648 | MEAN ANGLE AT HILL FROM FLAT TO BOX |
| | | | | | |
| BOX | R | 0111.016 | | | |
| | D | 3310.984 | 0111.000 | | |

*Figure 43. Field notes for recording measurements of two angles, two positions with the mil-graduated T2 theodolite.*

### 185. Measuring Vertical Angles

*a.* The procedure for measuring vertical angles with the T2 theodolite is the same as that for the T16 theodolite (para 164*a*).

*b.* After sighting on the observed station, the bubble of the collimation level (split bubble) is centered in its vial by rotating the collimation level tangent screw until the images of the ends of the bubble coincide. Then, with the black line on the circle selector knob in the vertical position, the vertical circle reading is then made in the same manner as a horizontal circle reading. Figure 43 illustrates the method of recording vertical circle readings and determining the vertical angles.

### 186. Care and Cleaning of the Theodolite

The same procedures and precautions that apply to the care and cleaning of the T16 theodolite (para 166 and 167) also apply to the care and cleaning of the T2 theodolite.

### 187. Repair of the Theodolite

Adjustment (except as explained in paragraphs 189 through 194) and repair of the T2 theodolite must be performed by qualified instrument repair personnel. Theodolites in need of adjustment or repair should be turned in to the engineer unit responsible for providing maintenance service. TM 5–6675–205–15 outlines the categories of maintenance.

### 188. Adjustment of the Theodolite

*a.* The T2 theodolite must be kept in correct adjustment if accurate results are to be obtained. There are five tests and adjustments of the theodolite that should be made periodically. These tests should be performed in the sequence in which they are discussed in paragraphs 189 through 193. When a test indicates that an adjustment is necessary, this adjustment should be made and the instrument tested for accuracy before the next test is performed.

*b.* The five tests and adjustments of the theodolite are made with the instrument mounted on its tripod and accurately leveled. For these tests and adjustments, the instrument should be set up in the shade on firm ground with the head of the tripod as nearly level as possible. The theodolite should also be protected from the wind.

### 189. Plate Level Adjustment

*a. Purpose.* The purpose of the plate level adjustment is to make the vertical axis of the theodolite truly vertical when the bubble of the plate level is centered in its vial.

*b. Test.* To test the adjustment of the plate level, place the axis of the plate level parallel to two of the three leveling screws. With these two leveling screws center the bubble of the plate level. Rotate the instrument 1,600 mils and again center the bubble, using the third leveling screw. Repeat these steps until the bubble remains centered in both positions. Carefully center the bubble in the first position and then rotate the instrument 3,200 mils. If the bubble does not remain centered, adjustment is required; the discrepancy noted in the position of the bubble is the apparent error, or twice the actual error, of the plate level.

*c. Adjustment.* To adjust the plate level, remove one-half of the apparent error (the actual error) by turning the capstan adjusting screw located below the collimation level illuminator. The adjusting pin is used to turn the capstan adjusting screw. Repeat the test to detect any error remaining in the adjustment of the plate level and adjust, if necessary.

### 190. Optical Plumb Adjustment

*a. Purpose.* The purpose of the optical plumb adjustment is to make the vertical axis of the theodolite pass through the station mark when the theodolite is properly leveled and the station mark is centered in the reticle of the optical plumb.

*b. Test.* To test the optical plumb, suspend the plumb bob from the leveled instrument and mark a point on the ground exactly under the point of the plumb bob. Remove the plumb bob from the instrument and check to insure that the instrument is accurately leveled (i.e., the vertical axis is truly vertical). Look into the eyepiece of the optical plumb. If it is in correct adjustment, the mark on the ground will be centered in the reticle.

*c. Adjustment.* If the point on the ground is not centered in the optical plumb reticle, center the point by means of the three capstan adjusting screws located near the optical plumb eyepiece. Two of the these adjusting screws are located on opposite sides of the eyepiece, and the third adjusting screw is located below the eyepiece opposite a spring-loaded plunger. The bottom adjusting screw is locked in place by a capstan retaining nut, which is located immediately above the head of the adjusting screw. With an adjusting pin, loosen the retaining nut and raise or lower the reticle by turning the bottom adjusting screw to move the reticle image along the axis of the optical plumb in the same direction that the screw travels. The two side adjusting screws are used to move the image of the reticle in the opposite direction from their travel. If it is necessary to use these screws, they should be rotated an equal amount in opposite directions. It is usually necessary to loosen the screw below the eyepiece slightly to adjust the screws on the side and vice versa. To make the adjustment, loosen one of the two opposed screws and the retaining nut slightly. The spring-opposed adjusting screw should be used for necessary adjustments, and the opposed adjusting screws should be used to complete these adjustments. When the adjustment is complete, the two opposed adjusting screws must be fairly tight. Lock the bottom adjusting screw in place by tightening the retaining nut.

## 191. Verticality Adjustment

*a. Purpose.* The purpose of the verticality adjustment is to make the vertical crossline of the reticle lie in a plane perpendicular to the horizontal axis of the telescope.

*b. Test.* To test the verticality of the vertical crossline, select a well-defined distant point as near as possible to the horizontal plane of the instrument and center the vertical crossline on the selected point. With the vertical tangent screw, elevate and depress the telescope. If the vertical crossline continuously bisects the point, the adjustment is correct.

*c. Adjustment.* There are three adjusting screws on the telescope—a horizontal screw on the left side and two slant screws on the right side. If the vertical line does not continuously bisect the sighted point, turn the two slant screws an equal amount in opposite directions to rotate the reticle until the vertical crossline does bisect the point throughout the elevation and depression of the telescope.

## 192. Horizontal Collimation Adjustment

*a. Purpose.* The purpose of the horizontal collimation adjustment is to make the line of sight perpendicular to the horizontal axis of the telescope.

*b. Test.* To test the horizontal collimation, select a well-defined point at least 100 meters from the instrument and at approximately the same relative height. With the telescope in the direct position, center the vertical crossline on the selected point. Set the horizontal circle to any reading less than 3,200 mils, close the cover on the circle-setting knob, and record the reading. Plunge the telescope to the reverse position and take a second reading on the same point. The instrument operator should repeat both readings to insure that no error was made in reading the instrument. These two readings should differ by 3,200 mils. Assuming no error in the pointings or readings, any discrepancy between actual difference in the two readings and 3,200 mils is the apparent error, or twice the horizontal collimation error. If this discrepancy exceeds plus or minus 0.150 mil (30″), the horizontal collimation adjustment should be performed.

*c. Adjustment.* For the purpose of illustration, assume that the horizontal circle reading in the direct position is 0000.200 mil and in the reverse position is 3,200.800 mils. With the telescope in the direct position, use the coincidence knob to set the mean value (0.500) on the micrometer scale. Using the horizontal tangent screw, bring the main scale into coincidence with a value of 0 mil on the scale. In doing this, the vertical crossline is moved off the point by the amount of the horizontal collimation error. The vertical crossline is then alined on the selected point by lateral movement of the reticle within the telescope. To move the reticle, loosen (tighten) the two adjusting screws in the slant position on the right side of the telescope equally, and tighten (loosen) the single adjusting screw on the left side of the telescope. For moving the reticle, the adjusting screw(s) should be loosened before the screw(s) on the opposite side of the telescope is tightened. Repeat the test and adjustment procedure until the difference between the direct and reverse points is less than 0.050 mil (10″). When this adjustment is completed, repeat the verticality test to insure that the vertical crossline is still perpendicular to the horizontal axis of the telescope.

*Note.* This adjustment can also be made with the telescope in the reverse position, using the mean value for the reverse pointing i.e., 3,200.500.

### 193. Vertical Collimation Adjustment

*a. Purpose.* The purpose of the vertical collimation adjustment is to make the line of sight horizontal when the vertical circle reads 1,600 mils with the telescope in the direct position (4,800 mils with the telescope in the reverse position) and the ends of the collimation level bubble are in alinement.

*b. Test.* To test the vertical collimation, select a well-defined point at least 100 meters from the instrument. With the telescope in the direct position, take a vertical circle reading on the point, making sure that the collimation level bubble is precisely alined. Plunge the telescope to the reverse position and again take a vertical circle reading to the same point. The collimation level bubble must be precisely alined before, and checked after, each vertical circle reading. Repeat these two measurements to insure that no error was made. The sum of the two readings should equal 6,400 mils. Assuming no error in the pointings or readings, any difference between the sum of the two readings and 6,400 mils is the apparent (index) error, or twice the collimation level error. If the difference exceeds plus or minus 0.150 mil (30″), the vertical collimation level should be adjusted.

*c. Adjustment.* To adjust the vertical level, compute the correct vertical circle reading by applying one-half of the index error of the vertical circle to the direct reading. If the sum of the two readings is greater than 6,400 mils, subtract one-half the index error from the direct reading; if the sum is less than 6,400 mils, add one-half the index error to the direct reading. Place the instrument in the direct position and accurately sight on the point. Using the coincidence knob, set the fractional part of the correct vertical circle reading on the micrometer scale, and then obtain coincidence on the main scale at the correct vertical circle reading by using the collimation level tangent screw. With the telescope sighted on the point and the correct reading on the vertical circle, the ends of the collimation level bubble will not be alined. Aline the images of the ends of the collimation level bubble by using the two capstan adjusting screws located immediately below the collimation level. When adjusting the bubble, rotate both screws the same amount in opposite directions. After making the adjustment, tighten the screws by rotating the screws slightly in opposite directions, being careful not to change the alinement of the ends of the bubble. Repeat the test and adjustment procedure until the collimation level error is less than 0.050 mil (10″).

*Example:*

| | |
|---|---|
| Vertical circle reading for direct pointing | 1,544.400 |
| Vertical circle reading for reverse pointing | 4,856.098 |
| Sum | 6,400.498 |

Apparent (index) error =
6,400.498 − 6,400 = 0.498 mil

Collimation error = 0.498 ÷ 2 = 0.249 mil

Correct vertical circle reading (direct) =
1,544.400 − 0.249 = 1,544.151

With the telescope in the direct position, accurately sight on the point. Set the fractional portion of the correct scale reading on the micrometer scale by using the coincidence knob, and then obtain coincidence on the main scale at the correct vertical circle reading (1,544.151) by using the collimation level tangent screw. Bring the split bubble into coincidence by turning its adjusting screws.

*Note.* This adjustment can also be made with the telescope in the reverse position, using the mean value for the reverse pointing; i.e., 4,856.098 − 0.249 = *4,855.849 mils.*

### 194. Other Adjustments

Other adjustments to the T2 theodolite that may be required periodically are as follows:

*a. Leveling Screws.* The three leveling screws must turn smoothly and with moderate ease and without any shake or backlash. To tighten or loosen the movement of the leveling screw, use the capstan adjusting screw located immediately above each leveling screw.

*b. Tangent Screws.* The tangent screws must turn easily and smoothly, without backlash, throughout their travel. A capstan adjusting ring is located immediately behind each tangent screw. To adjust the tangent screws, rotate the adjusting ring with an adjusting pin.

*c. Circle-Setting Knob.* To adjust the circle-setting knob, turn the knob until three screws can be seen through the three holes in the face of the knob. Carefully loosen these screws enough to press the knob upward or downward to loosen or tighten the movement.

*d. Tripod.* There should be no play at the junction of the wood and metal parts of the tripod. If play exists, tighten the hexagon nuts on the foot plates and on the extensions of the tripod head. The legs, when released from the horizontal position, should fall to an angle of about 45° and remain there. Check the movement of the legs and, if necessary, tighten the clamping screws under the head of the tripod.

# CHAPTER 8

# TRAVERSE

## Section I. GENERAL

### 195. General

A traverse is a series of straight lines, called traverse legs, connecting a series of selected points, called traverse stations (fig. 44). In a traverse, distance and angle measurements are made and are used to compute the relative positions of the traverse stations on some system of coordinates, usually the UTM grid.

### 196. Starting Control

Since the purpose of a traverse is to locate points relative to each other on a common grid, certain elements of starting data are necessary. The coordinates and height of a starting point and an azimuth to an azimuth mark are required. There are several ways in which the starting data can be obtained, and the best data available should be used to begin a traverse. The different variations in starting control can be grouped into the following general categories:

*a. Known Control Available.* Survey control may be available in the form of existing stations with the station data published in a trig list, or higher headquarters may establish the station and provide the station data. The azimuth to an azimuth mark (starting direction) may be obtained by reference to a trig list, by computation from known coordinates, by astronomic observations, or by use of the azimuth gyro.

*b. Maps Available.* When survey control is not available in the area, the coordinates and height of the starting station can be assumed. The assumed data should approximate the correct coordinates and height as closely as possible to facilitate operations. When a map of the area is available, the approximate coordinates and height of the starting station can be scaled from the map. (For survey purposes, starting data scaled from a map is considered to be assumed data.) Starting direction can be determined by astronomic observations or by use of the azimuth gyro. If starting direction cannot be obtained by either of these methods, it should be assumed by using a declinated aiming circle or by scaling from the map.

*c. No Maps Available.* When neither survey control nor maps are available, the coordinates

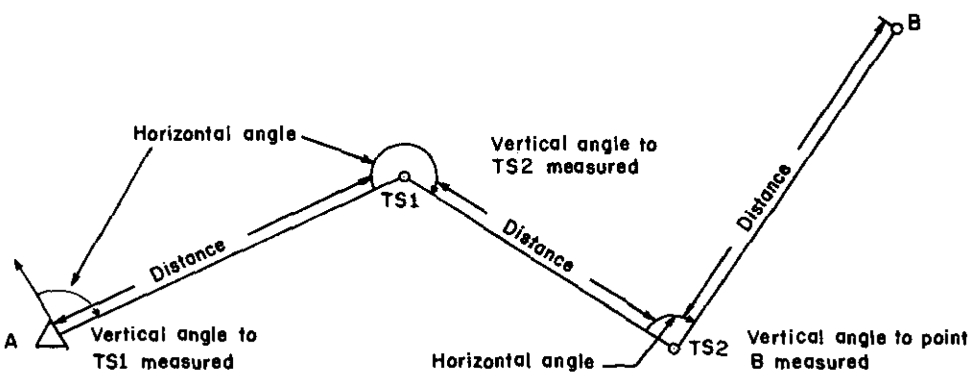



*Figure 44. A traverse.*

and height of the starting point must be assumed. Starting direction can be determined by the most accurate means available, as discussed in *a* and *b* above.

## 197. Types of Traverse

Three basic types of traverse are used in artillery survey. These are open traverse, closed traverse, and directional traverse.

*a. Open Traverse.* An open traverse originates at a starting station, proceeds to its destination, and ends at a station the relative position of which is not previously known. The open traverse is the least desirable type of traverse because it provides no check on fieldwork or starting data. For this reason, the planning of a traverse in the artillery should always provide for closure of the traverse. Traverses should be closed in all cases when time permits.

*b. Closed Traverse.* A closed traverse starts at a point and ends at the same point or at a point the relative position of which is known. The measurements can be adjusted by computations to minimize the effect of accidental errors made in the measurements. Large errors can be detected and corrected.

(1) *Traverse closed on starting point.* A traverse closed on the starting point is a traverse which originates at a starting station, moves to its destination, and returns to and terminates at the starting point. This type of traverse is considered the second best for artillery purposes and is used extensively at battalion level where limited control and time available for survey are important considerations. A traverse closed on the starting point provides a check on the fieldwork and computations and provides a basis for comparison to determine the accuracy of the work. However, this type of traverse does not provide a check on starting data or insure detection of systematic errors. For example, if digits of the starting coordinates are transposed or erroneous, no check is provided. If the tape used for distance measurements is longer than its labeled length, all of the recorded distances will be proportionally too short but will cause no change in the computed error of closure for the traverse.

(2) *Traverse closed on second known point.* A traverse closed on a second known point begins at a point of known coordinates, moves through the required point(s), and terminates at a second point of known coordinates. This type of traverse is the preferred type for artillery use because it provides a check on the fieldwork, computations, and starting data. It also provides a basis for comparison to determine the overall accuracy of the work.

*c. Directional Traverse.* A directional traverse is a traverse in which only the horizontal angles are measured. It is used to extend direction, or azimuth, only. This type of traverse can be either open or closed. It can be closed on the starting direction, on a second line of known direction established to an equal or a higher order of accuracy, or by astronomic or gyroscopic observations. Since direction is the most important element of artillery survey, it is sometimes necessary at lower echelons to map-spot battery locations and extend direction only.

## 198. Fieldwork

In a traverse, three stations are considered to be of immediate significance. These stations are referred to as the *rear station*, the *occupied station*, and the *forward station*. The rear station is the station from which the persons performing the traverse have just moved or a point to which the azimuth is known. The occupied station is the station at which the party is located and over which the instrument is set. The forward station is the next station in succession and is the immediate destination of the party. Fieldwork for a traverse is accomplished as follows:

*a. Horizontal Angles.* Horizontal angles are always measured at the occupied station by sighting the instrument at the rear station and measuring the clockwise angle to the forward station. To measure horizontal angles, instrument pointings are always made to the lowest visible point of the range pole which marks the rear and forward stations.

*b. Vertical Angles.* Vertical angles are always measured at the occupied station to the height of instrument (HI) on the range pole at the forward station. When the distance between two successive stations in a traverse exceeds 1,000 meters, the vertical angle is measured reciprocally; i.e., the vertical angle is measured in both directions for that particular leg. Measuring reciprocally eliminates errors caused by curvature and refraction.

*c. Distance.* The distance is measured in a straight line between the occupied station and the forward station. Horizontal taping procedures or electronic distance-measuring equipment are used.

## 199. Traverse Stations

*a. Selection of Stations.* In artillery survey, sites for traverse stations are normally selected as the traverse progresses. The stations must be located so that at any one station both the rear and forward stations are visible. If the distance is to be measured with a tape, the line between stations must be free of obstacles for the taping team. The number of stations in a traverse should be kept to a minimum to reduce the accumulation of instrumental errors and the amount of computing required. Short traverse legs require the establishment and use of a greater number of stations and may cause excessive errors in azimuth because small errors in centering the instrument, and station marking equipment and in instrument pointings will be magnified and absorbed in the azimuth closure as errors in angle measurement.

*b. Station Markers.* Traverse station markers are usually 1-inch by 1-inch wooden stakes, 6 inches or more in length. These stakes, called *hubs*, are driven flush with the ground. The center of the top of the hub is marked with a surveyor's tack or with an X to designate the exact point of reference for angular and linear measurements. To assist in recovering the station, a reference (witness) stake is driven into the ground so that it slopes toward the station (fig. 45). The identification of the station is written on the reference stake with a lumber crayon or a china marking pencil or on a tag

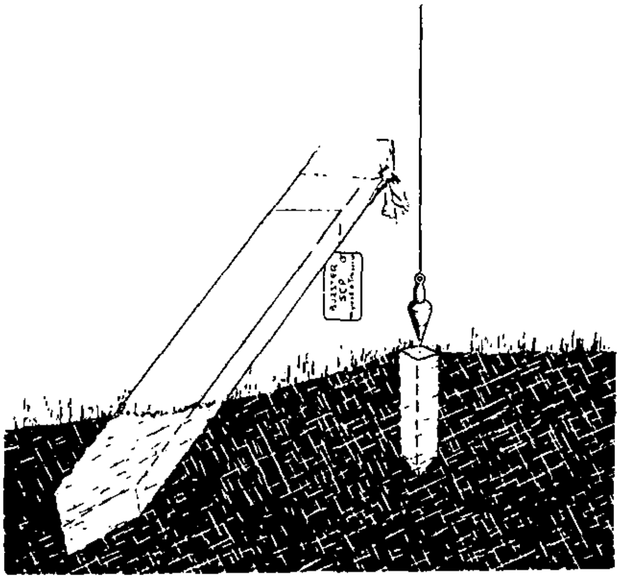


*Figure 45. A survey station marked with a reference stake.*

attached to the stake. Signal cloth may also be tied to the reference stake to further assist in identifying or recovering the station.

*c. Station Signals.* Signals must be erected over survey stations to provide a sighting point for the instrument operator and to serve as a reference for tape alinement by the taping team. Permanent tripods or similar signals have been erected over some primary survey control stations so that the stations can be occupied without disturbing the signal. In artillery survey, in which the stations sites are selected and marked as the fieldwork progresses, temporary signals must be erected at the stations as they are needed. The equipment used for station signals in artillery survey includes:

(1) *Range poles.* The range pole is constructed of tubular steel and consists of two interlocking sections. The length of the assembled pole is 6½ feet, and one end is tapered to a point. The pole is painted in 1-foot sections with alternate colors of red and white. For storage, the pole is disassembled

and placed in a canvas case. In use, the tapered point of the range pole is placed in the ground on the station mark, and a rod level is used to make the pole vertical for observations. The angular portion of the level is placed against the pole, with the circular level vial up. The top of the pole is then moved until the bubble in the vial is centered. The verticality of the range pole should be checked by verifying that the bubble remains centered at other points on the range pole. The range pole is maintained in a vertical position throughout the observing period either by use of a range pole tripod or by a man holding the pole. To prevent the measurement of angles to the wrong point, the range pole should be placed in a vertical position only when it is being used to mark a survey station.

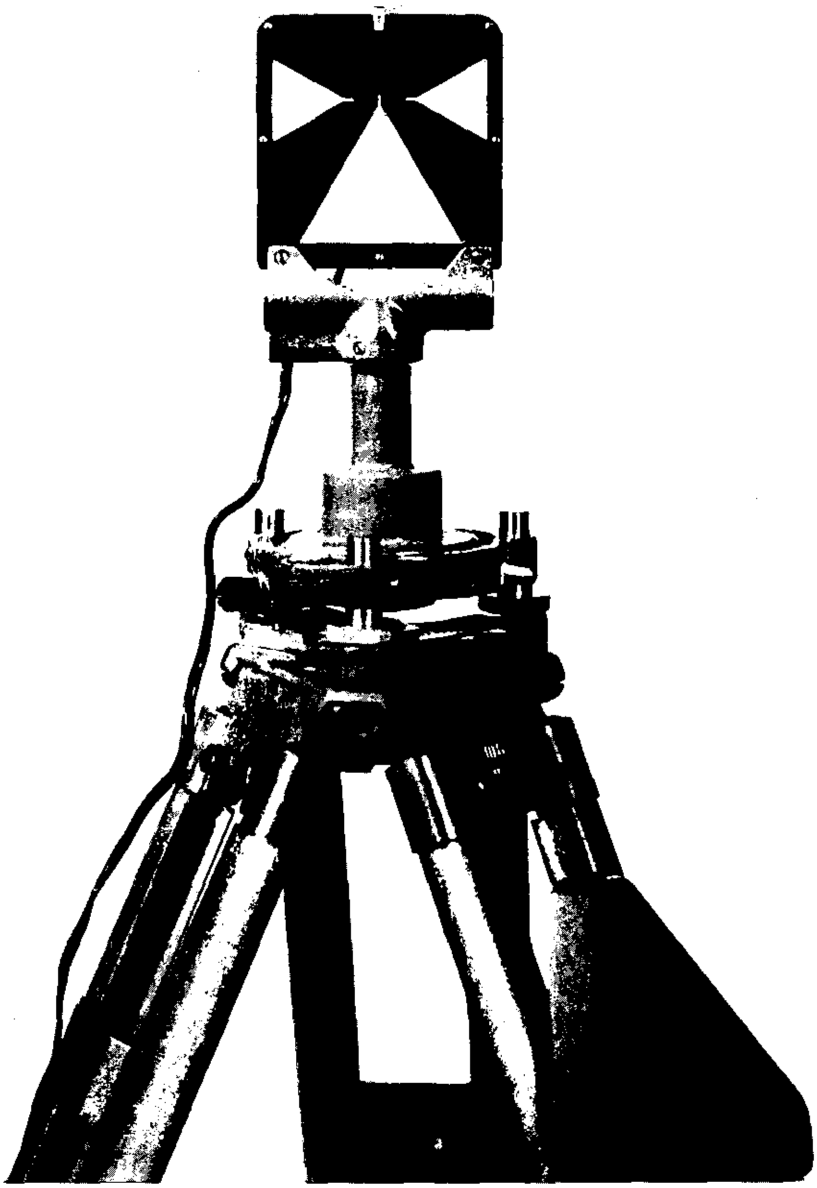


*Figure 46. Tripod-mounted target.*

(2) *Target set, surveying.* The target set (fig. 46) is used to mark the end of the orienting line by artillery missile batteries that have special accuracy requirements for the azimuth of the orienting line. The target set may also be issued to artillery survey elements that are required to perform survey to fourth-order accuracy. The target is mounted on the same tripod that is used with the T2 and T16 theodolites. The tripod is set up, leveled, and plumbed in the same manner as for the theodolites. After setup, the target is oriented so that it can be seen directly by the instrument which is sighting on it. The target can be illuminated for night use. Greater accuracy is obtained on short traverse legs by using the target rather than range poles. The cross-hairs in the telescope should bisect the triangles of the target when sighting on it. Flexibility can be obtained by interchanging and leap-frogging theodolites and targets on the tripods, thus reducing setup time. The longitudinal level and optical plummet must be adjusted in the same manner as for the T2 theodolite.

## 200. Organization of Traverse Parties

The number of personnel available to perform survey will depend on the unit's table of organization and equipment (TOE). The organization of these persons into a traverse party and the duties assigned to each member will depend on the unit's standing operating procedure (SOP). The organization and duties of traverse party members are based on the functional requirements of a traverse. See appendix III for a detailed description of duties of individuals.

*a. Fifth-Order Traverse Party.*

(1) *Chief of party.* The chief of party selects and marks the locations for the traverse stations and supervises the work of the other members of the party. He also assists the survey officer in the reconnaissance and planning of the survey.

(2) *Instrument operator.* The instrument operator measures the horizontal and vertical angles at each traverse station. He also operates the azimuth gyro and the DME, when the DME is authorized by the TOE.

(3) *Recorder.* The recorder keeps the field notes for the party in a field notebook. He records the angles measured by the instrument operator, the distance measured by the tapeman, and all other data pertaining to the survey. The recorder is normally the party member designated to check the taped distances by pacing between traverse stations.

(4) *Computer.* Two computers compute the grid coordinates and height of each traverse station as the traverse progresses. The computers work independently and check their results with each other.

(5) *Tapeman.* Two tapemen measure the distance from one traverse station to the next. Each tapeman keeps a record of the distances taped. The tapemen compare their recorded distances before reporting the measured distances to the recorder.

(6) *Rodman.* The rodman assists the chief of party in marking the traverse stations, removes the range pole from the rear station when signaled by the instrument operator, and moves the range pole forward to the next traverse station. Some TOE's do not provide for this position. In such cases, another member of the party is designated by the party chief to perform these tasks.

*b. Fourth-Order Traverse Party.* The fourth-order traverse party consists of 10 men. There are two types of fourth-order traverse parties, as follows:

(1) *Ten-man traverse party.* The 10-man traverse party is basically the same as the fifth-order traverse party with two additional tapemen who form a second taping team.

(2) *DME traverse party.* The DME traverse party is equipped with three T2 theodolites and three DME units, containing three instruments per unit. The personnel are organized as follows: One chief of party, three instrument operators, three recorders, two computers, and one rodman.

*c. Reduced Strength Party.* Often the authorized number of men are not available to perform the traverse. Under such circumstances, members of the survey party may be required to perform more than one function. Shortages in personnel will seldom affect the jobs of the instrument operator or the tapemen, since these two functions must be performed if a traverse is to be conducted. If the party is short the rodman, the chief of party may perform the duties of the rodman, in addition to his own duties. If the party is short a computer, the recorder may perform the duties of a computer. If there is no recorder, the instrument operator may act as his own recorder. If three or more men are absent from the party, the fieldwork is completed and the computations are performed later by designated personnel. The organization of a reduced strength party is not bound by strict rules; however, for a party to function when personnel shortages exist, the party members must be trained to operate interchangeably.

## 201. Night Traverse

Many times the artillery surveyor will be forced to survey at night to accomplish his mission. Daytime traverse techniques and organization can be used at night with certain modification. Night traverses require more

DESIGNATION Position Area Survey DATE 15 Jul 1960

| Station | R | Horizontal ∡ mils | Vertical ∡ mils | Corrected Vertical | Distance Meters |
|---|---|---|---|---|---|
| Az Mk | 1 | 1675.0 | + 5.0 | + 8.0 | |
| Bn SCP | 2 | 3350.5 | + 5.5 | + 8.5 | |
| TS-1 | Mn ∡ | 1675.2 | | + 8.2 | 158.52 |
| | | | | | |
| Bn SCP | 1 | 4703.0 ~~4730.0~~ | - 9.0 | - 6.0 | |
| TS-1 | 2 | 3006.5 | - 9.5 | - 6.5 | |
| OS "A" | Mn ∡ | 4703.2 | | - 6.2 | 97.40 |
| | | | | | |
| TS-1 | 1 | 3001.5 | + 7.5 | + 10.5 | |
| OS "A" | 2 | 6002.5 | + 7.5 | + 10.5 | |
| "A" Cen | Mn ∡ | 3001.2 | | + 10.5 | 92.46 |
| | | | | | |
| TS-1 | 1 | 4791.0 | + 1.5 | 4.5 | |
| OS-"A" | 2 | 3182.0 | + 2.0 | + 5.0 | |
| TS-2 | Mn ∡ | 4791.0 | | + 4.8 | 115.32 |
| | | | | | |
| OS "A" | 1 | 4435.5 | - 8.5 | - 5.5 | |
| TS-2 | 2 | 2471.5 | - 9.5 | - 6.5 | |
| Bn SCP | Mn ∡ | 4435.8 | | - 6.0 | 118.78 |
| | | | | | |
| TS-2 | 1 | 3594.0 | | | |
| Bn SCP | 2 | 788.0 | | | |
| Az Mk | Mn ∡ | 3594.0 | | | |

Chief of Party: Sgt Brown
Weather: Clear - Hot Observer: Sgt Jones Tape: Pfc Benton
Pfc Kunnke
Instrument Nr: M2 # 1789 Recorder: Cpl Smith

REMARKS

Vertical Angle correction is + 3.0 mils
Bn SCP is located 14 M N of ℄ of Blue Beaver Rd, 68 M W of SW corner of Little Axe School
Bn SCP is tack in center of 2" x 2" wooden Hub Flush with ground. Az Mk is Flag Pole, 450 M SW of Bn SCP

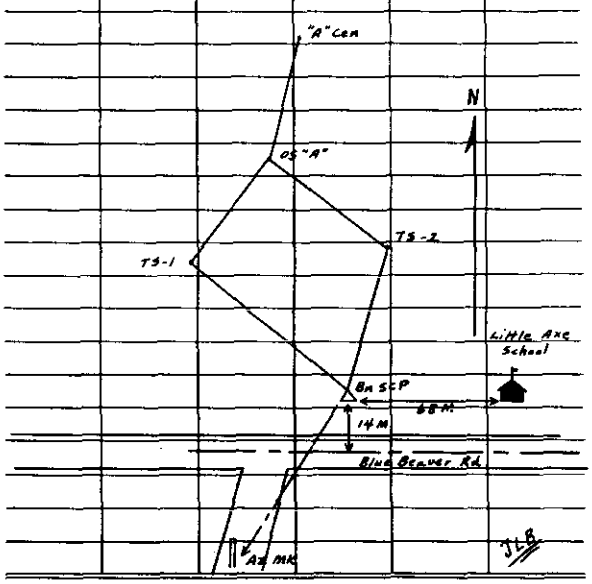



*Figure 47. Recorder's notes for 1:500 (aiming circle) traverse.*

work, more training, more personnel, and more coordination.

*a. Equipment.* The equipment used in a daytime traverse is used in a night traverse with the addition of the necessary lighting equipment. Included in this lighting equipment are flashlights for all personnel and two aiming post lights for each range pole. If aiming post lights are not available, two flashlights for each range pole will suffice. All lighting devices should be equipped with a filter of some type to insure greater light security and to prevent undue glare in the telescope of the observing instrument when it is pointed at a station. The observing instrument should be equipped with its organic lighting equipment.

*b. Personnel.* The standard traverse party must be supplemented with additional personnel to enable it to function properly at night. Three additional men act as light holders and accompany and assist the tapemen. When possible, a fourth man assists the rodman.

*c. Angle Measuring.* The procedure used in measuring angles in daylight is used at night except that the instrument must be equipped with a night lighting device. The instrument operator should coordinate with the rodman to insure that the lights on the range poles are placed and pointed properly and are moved to the next station when the observation is completed.

*d. Recording.* The recording procedures used during daylight are used at night except that the recorder must be supplied with a flashlight so that he can see to record. He should record in the remarks section of the field notes anything which may have an effect on the survey,

DESIGNATION POSITION AREA SURVEY DATE 17 JUL 19 60

| Station | T | Horizontal ∢ Mils | Mean | Vertical Reading | Vertical ∢ Mils |
|---|---|---|---|---|---|
| Az Mk | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| Bn SCP | Mn ∢ | 942.2 | | | +11.5 |
| | | | | | |
| OS "B" | D | 943.1 | | 1588.5 | +11.5 |
| | R | 4143.2 | 943.2 | 4811.5 | +11.5 |
| | | | | | |
| Bn SCP | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| OS "B" | Mn ∢ | 1585.1 | | | −11.5 |
| | | | | | |
| "B" Cen | D | 1586.1 | | 1611.4 | −11.4 |
| | R | 4786.1 | 1586.1 | 4788.4 | −11.6 ~~11.4~~ |
| OS "B" | Mn ∢ | 1820.5 | | | +14.1 |
| | | | | | |
| Sta Mac | D | 3406.5 | | 1585.9 | +14.1 |
| | R | 206.7 | 3406.6 | 4814.1 | +14.1 |
| | | | | | |
| OS "B" | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| Sta Mac | Mn ∢ | 1492.2 | | | |
| | | | | | |
| Az Mk | D | 1493.1 | | | |
| | R | 4693.2 | 1493.2 | | |

Chief of Party: Sgt Brown
Weather: Windy-Cool Observer: Sgt Jones Tape: Pfc Benton
Pfc Kunnke
Instrument Nr: T16 #5459 Recorder: Cpl Smith

| Distance Meters | REMARKS |
|---|---|
| | Bn SCP is located 3.2 miles |
| | W of BM 189 and is 21 M |
| 485.73 | N of ℄ West Rd Bn SCP is |
| | tack in 2" x 2" wooden hub |
| | flush with ground and is marked |
| | with witness stake. Azimuth |
| | Mark is station ZEB, located on |
| | ZEB ridge and marked with a |
| | Quad Marker. |
| 89.34 | |
| | |
| | |
| 365.01 | |

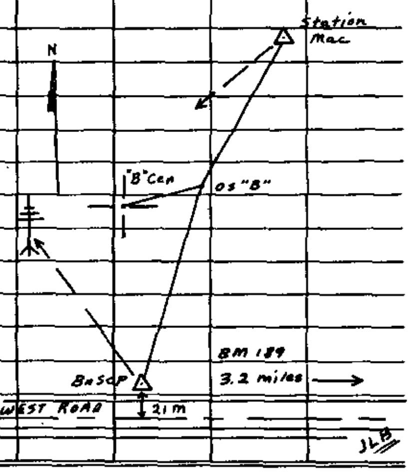



*Figure 48. Recorder's notes for fifth-order (T76 theodolite) traverse.*

CHIEF OF PARTY: SGT KASS

WEATHER: CLEAR-COOL OBSERVER: SP/4 HUNT TAPE: PFC BROWN

INSTRUMENT NO. T2 #1881 RECORDER: SP/4 KEUTHAN PFC MYERS

DESIGNATION TRAVERSE DATE 24 JUL 19 60

| STATION | T | HORIZONTAL ∡ MILS | MEAN | VERTICAL READING | VERTICAL ∡ MILS | DISTANCE METERS |
|---|---|---|---|---|---|---|
| KIOWA | D | 0000.155 | | | | |
| | R | 3200.162 | 0000.158 | | | |
| DODGE | MN ∡ | 3185.176 | | | +20.571 | 672.10 |
| TS-1 | D | 3185.327 | 3185.334 | 1579.419 | +20.581 | 672.12 |
| | R | 6385.342 | | 4820.561 | +20.561 | 672.08 |
| DODGE | D | 0000.214 | | | | |
| | R | 3200.222 | 0000.218 | | | |
| TS 1 | MN ∡ | 2943.340 | | | -18.938 | 537.92 |
| TS-2 | D | 2943.551 | 2943.558 | 1618.902 | -18.902 | 537.88 |
| | R | 6143.564 | | 4781.026 | -18.975 | 537.97 |

REMARKS

STATION DODGE IS LOCATED IN NORTH ARBUCKLE AREA, FT SILL MILITARY RESERVATION 0.8 MILES W. OF BALD RIDGE RANGE CENTRAL ON HIGHEST POINT OF GRASSY HILL. STATION IS 4 METERS W ℄ N-SRD, 5 METERS N OF ℄ E-WRD, MARKED BY 1" PIPE IN CONCRETE FLUSH WITH GROUND AND 15' WHITE WOODEN QUAD MARKER. AZ MK IS QUAD MARKER ON KIOWA HILL 2200M SW OF STATION DODGE.

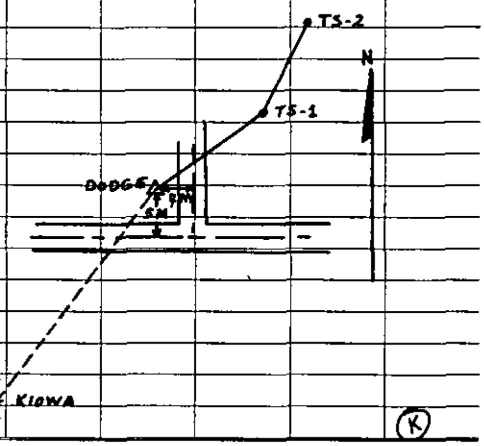



*Figure 49. Recorder's notes for fourth-order (T2 theodolite) traverse.*

such as burned out lights, only one light on the forward station, etc.

*e. Taping.* For information on taping at night, see paragraph 92.

*f. Communications.* Communication during a night traverse should be conducted by radio. However, radio is not always convenient or available and at times the survey party must resort to light signals. These light signals should be prearranged and simple. For example, the instrument operator may have to signal the rodman to raise or lower the bottom light on a range pole or inform the rodman to move to the next station, etc. In arranging signals, the survey party should avoid waving the lights, since a waving light may easily attract the enemy's attention. Every precaution should be taken in sending light signals to avoid detection by the enemy.

## 202. Traverse Field Notes

For examples of field notes on traverse, see figures 47 through 49.

# Section II. COMPUTATIONS

## 203. Azimuth Computation

In order for a traverse to be computed, an azimuth must be determined for each leg of the traverse. The azimuth is determined for each succeeding leg of the traverse by adding the value of the measured angle at the occupied station to the azimuth from the occupied station to the rear station. The example which follows illustrates this procedure. It should be noted that on occupation of each successive station the first step is to compute the back-azimuth of the preceding traverse leg; i.e., the azimuth from the occupied station to the rear station.

*a. Example Problem.*

(1) *Given:*

| | |
|---|---|
| Azimuth from station A to az mk | 5592.6 mils |
| Angle az mk–A–TS1 | 2134.0 mils |
| Angle A–TS1–TS2 | 3820.5 mils |
| Angle TS1–TS2–B | 1756.5 mils |

(2) *Required:*
Azimuth from station TS2 to B.

*b. Solution.*

(1) At station A—

| | |
|---|---|
| Azimuth from A to az mk | = 5592.6 mils |
| (+) angle az mk–A–TS1 | = 2134.0 mils |
| Sum | = 7726.6 mils |
| (−) a full circle | = 6400.0 mils |
| Azimuth A to TS1 | = 1326.6 mils |

(2) At station TS1—

| | |
|---|---|
| Azimuth from station A to TS1 | = 1326.6 mils |
| (+) a half circle | = 3200.0 mils |
| Azimuth from TS1 to A | = 4526.6 mils |
| (+) angle A–TS1–TS2 | = 3820.5 mils |
| Sum | = 8347.1 mils |
| (−) a full circle | = 6400.0 mils |
| Azimuth TS1 to TS2 | = 1947.1 mils |

(3) At station TS2—

| | |
|---|---|
| Azimuth from TS1 to TS2 | = 1947.1 mils |
| (+) a half circle | = 3200.0 mils |
| Azimuth from TS2 to TS1 | = 5147.1 mils |
| (+) angle TS1–TS2–B | = 1756.5 mils |
| Sum | = 6903.6 mils |
| (−) a full circle | = 6400.0 mils |
| Azimuth TS2 to B | = 503.6 mils |

## 204. Azimuth-Bearing Angle Relationship

*a.* An azimuth is required in traverse to permit the determination of a bearing angle. The bearing angle of a traverse leg, not the azimuth, is the element used in computations. The azimuth of a line is defined as the horizontal clockwise angle from a base direction to the line. The base direction used in artillery survey is grid north. The bearing angle of a line is the acute angle formed by the intersection of that line with a grid north-south line. Figure 50 illustrates the relationship between the azimuth of a line and its bearing.

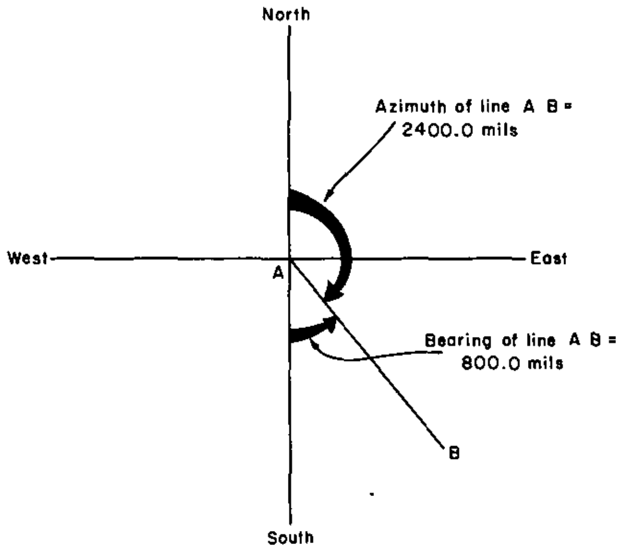



*Figure 50. Relationship of azimuth and bearing.*

*b.* The manner in which bearing angles are computed from a given azimuth depends on the quadrant in which that azimuth lies (fig. 51). When the azimuth is in the first quadrant, 0 to 1,600 mils, the bearing is equal to the azimuth. When the azimuth is in the second quadrant, 1,600 to 3,200 mils, the bearing is equal to 3,200 mils minus the azimuth. When the azimuth is in the third quadrant, 3,200 to 4,800 mils, the bearing is equal to the azimuth minus 3,200 mils. When the azimuth is in the fourth quadrant, 4,800 to 6,400 mils, the bearing is equal to 6,400 mils minus the azimuth.

## 205. Coordinate Computations

*a.* If the coordinates of a point are known and the azimuth and distance from that point to a second point are known, the coordinates of the second point can be determined. In figure 52, the coordinates of station A are known and the coordinates of TS1 are to be deter-

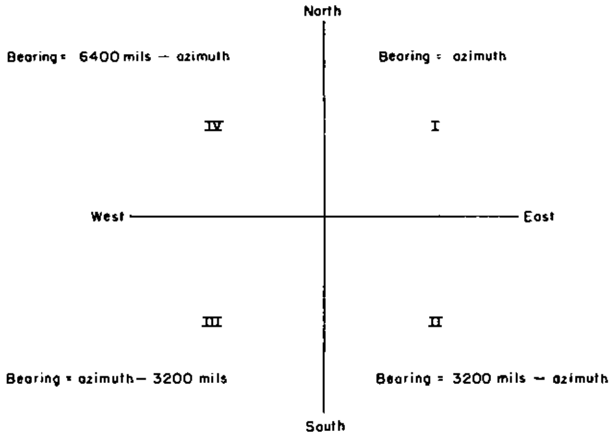



*Figure 51. Determination of bearing angle.*

mined. The azimuth and distance from station A to TS1 have been determined by measuring the horizontal angle az mk–A–TS1 and by taping the distance from station A to TS1. The grid easting and grid northing lines through both of the points are shown. The coordinates of TS1, are determined by applying the difference in easting (dE) to the easting coordinates of station A and the difference in northing (dN) to the northing coordinates of station A.

*b.* In figure 52, the traverse leg appears in the first quadrant. It is for this reason that dE and dN must be added to the easting and northing coordinates of station A. If the traverse leg were to appear in one of the other quadrants, the signs of dE and dN would change The signs of dE and dN are determined by the quadrant in which the traverse leg lies (fig. 53).

## 206. Determination of dE and dN

The determination of the values of dE and dN between two points when the azimuth and distance between those points are known requires the solution of a right triangle. In figure 52, side A–TS1 is known because the distance between A and TS1 is a taped distance. The bearing angle at station A is also known, since it was readily determined from the azimuth of station A to TS1. Since the intersection of the north-south line through station A and the east-west line through TS1 forms a right angle (1,600 mils), a right triangle is created with the hypotenuse (side A–TS1) known.

*To determine dE:*

$$\text{Sine of bearing angle} = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{\text{dE}}{\text{distance}}$$

or,

$$\text{dE} = \text{sine of bearing angle} \times \text{distance.}$$

*To determine dN:*

$$\text{Cosine of bearing angle} = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{\text{dN}}{\text{distance}}$$

or,

$$\text{dN} = \text{cosine of bearing angle} \times \text{distance.}$$

## 207. Scale Factor

The log of the scale factor is applied to the dE and dN computations of all surveys executed to fourth-order accuracy. The purpose of the log scale factor is to convert ground distance to map distance when the UTM grid is used. This factor is not used in surveys performed to accuracies of less than fourth-order. The scale factor value varies with the distance of the occupied station from the central meridian of the UTM grid zone. The scale factors are given for every 10,000 meters east and west of the central meridian and are shown in tabulated form on the back of DA Form 6–2 (fig. 56). The values of the scale factor are extracted by entering the table with the approximate easting value of the occupied station to the nearest 10,000 meters.

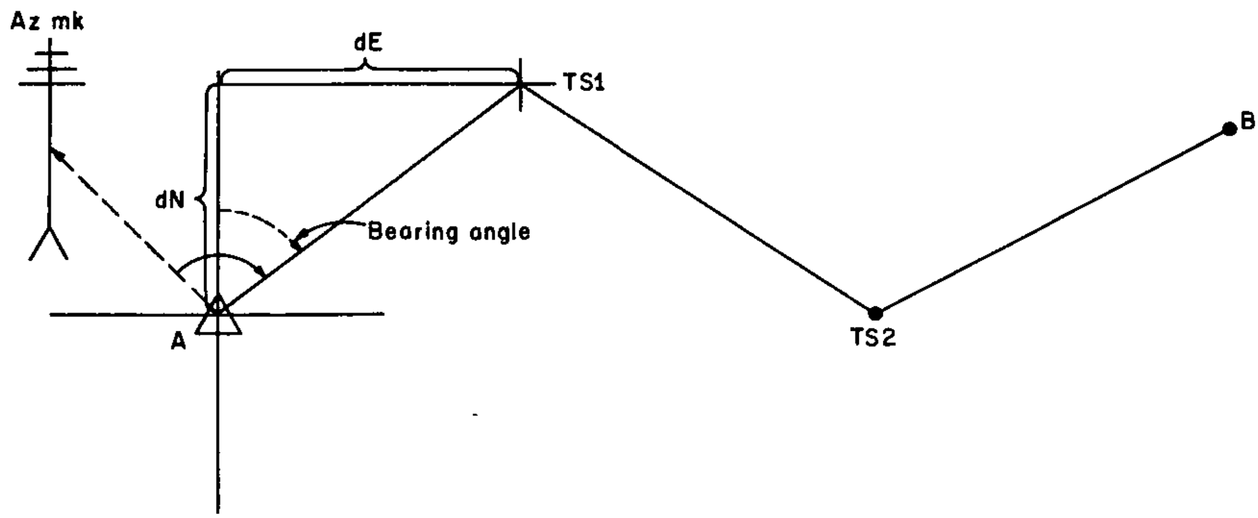



*Figure 52. Requirements for dE and dN.*

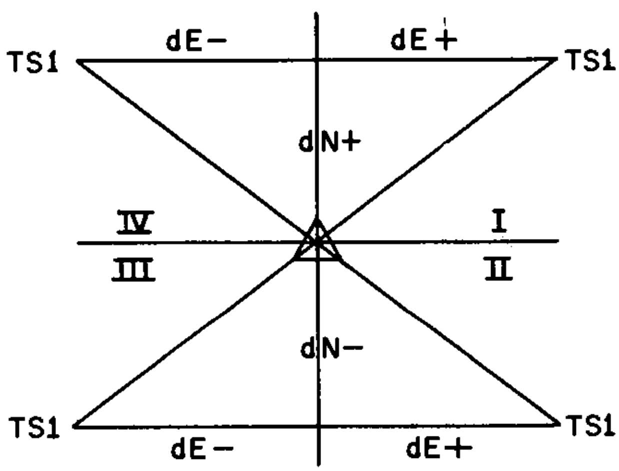



*Figure 53. Relationship of quadrant and sign.*

## 208. Determination of dH

In a traverse, the height of each traverse station must be determined. This is accomplished by determining the difference in height (dH) between the occupied and the forward station. The vertical angle at the occupied station and the horizontal distance from the occupied station to the forward station are used to determine the difference in height between the two by solution of a right triangle. In figure 54, the distance is the horizontal taped distance from station A to TS1. The vertical angle at station A is the vertical angle measured to HI at station TS1. The difference in height between the two stations is the side of the right triangle which requires solving.

*To determine dH:*

$$\text{Tangent of vertical angle} = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{\text{dH}}{\text{distance}}$$

or,

$$\text{dH} = \text{tangent of vertical angle} \times \text{distance.}$$

## 209. DA Form 6–2

*a.* DA Form 6–2 (figs. 55, 56, and 57) is used to determine coordinates and height from azimuth, distance, and vertical angle.

*b.* Entries on the form are shown in figures 55 and 57.

*c.* Formulas to be used are shown on the back of DA Form 6–2 (fig. 56).

## 210. Determination of Azimuth and Distance From Coordinates

*a.* In survey operations, it is often necessary to determine the azimuth and distance between two stations of known coordinates. Some examples of such a requirement are computation of a starting azimuth when the coordinates of two intervisible points are known, computation of azimuth and length of a target area base

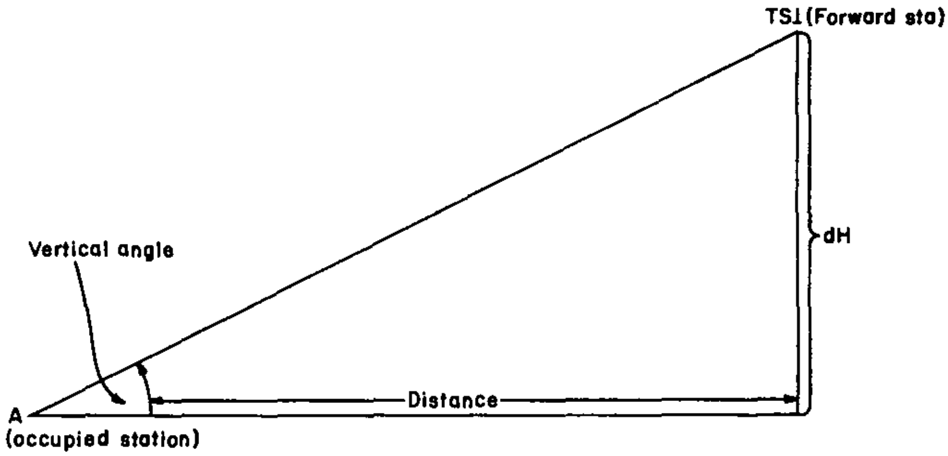



*Figure 54. Right triangle for determination of dH.*

or the base of a triangulation scheme, and computation of azimuth and distance between critical surveyed points when swinging and sliding the grid is necessary. The standard form for this computation is DA Form 6–1. Figure 58 illustrates the computation of azimuth and distance from the coordinates of two points. dE and dN are determined by finding the difference between the two easting and northing coordinates. The signs (±) of dE and dN, as determined on the form, are used for finding the quadrant in which the azimuth is located. As in paragraph 208, the right triangle formed by dE, dN, and the grid distance is used to determine the bearing angle of the desired azimuth as follows:

$$\text{Tangent of bearing angle} = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{dE}{dN}$$

Logarithms are used to solve for the bearing angle on the form. Once the bearing angle is known, the azimuth can be readily determined from the block in the upper right corner in which dE and dN were plotted.

*b.* The bearing angle and dE or dN, whichever is larger, are the factors needed to compute the distance between the two points.

$$\text{Sine of bearing} = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{dE}{\text{grid distance}}$$

$$\text{Cosine of bearing} = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{dN}{\text{grid distance}}$$

or,

$$\text{Grid distance} = \frac{dE}{\text{sin of bearing}} \text{ or } \frac{dN}{\text{cos of bearing}}$$

Logarithms are also used to solve for the grid distance. The larger side is used, since it is opposite the stronger angle in the right triangle (para 228), thus enabling the determination of a more accurate distance.

## 211. Reciprocal Measurement of Vertical Angles

The effects of curvature and refraction on lines of sight must be considered for traverse legs in excess of 1,000 meters. These effects can be compensated for by reciprocal measurements of the vertical angle at each end of such a leg. *When vertical angles are measured reciprocally, the vertical angle at each end of the leg should be measured to the same height above the station (normally HI).* If this cannot be done, DA Form 6–2b, Computation—Trig-

## COMPUTATION · COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE AND VERTICAL ANGLE
(FM 6-120)

Date: 11 Mar 60 — Area: Foxtrot — Notebook reference: A-2-60

Rear station: Dog

| Azimuth | | Distance and bearing to forward station | |
|---|---|---|---|
| Az to rear station | 52 47 5 | | |
| + Station angle | 14 03 0 | Az to bearing | 2 50 5 |
| Sum | 66 50 0 | | |
| − 360°/6400 mil | 64 00 0 | Bearing | |
| Az to fwd station | 2 50 5 | | 2 50 5 |
| (±) 180°/3200 mil | 32 00 0 | Distance | 113.61 m |
| Az to rear station | 34 50 5 | | |
| + Station angle | 26 10 8 | Az to bearing | |
| Sum | 60 61 3 | | 64 00 0 |
| − 360°/6400 mil | | | 60 61 3 |
| Az to fwd station | 60 61 3 | Bearing | 3 38 7 |
| (±) 180°/3200 mil | 32 00 0 | Distance | 71.40 m |
| Az to rear station | 28 61 3 | | |
| + Station angle | 51 77 5 | Az to bearing | |
| Sum | 80 38 8 | | 32 00 0 |
| − 360°/6400 mil | 64 00 0 | | 16 38 8 |
| Az to fwd station | 16 38 8 | Bearing | 15 61 2 |
| (±) 180°/3200 mil | 32 00 0 | Distance | 117.66 m |
| Az to rear station | 48 38 8 | | |
| + Station angle | | Az to bearing | |
| Sum | | | |
| − 360°/6400 mil | | Bearing | |
| Az to fwd station | | | |
| (±) 180°/3200 mil | | Distance | m |
| Az to rear station | | | |

| Station | Item | Easting | Item | Northing | Item | Height |
|---|---|---|---|---|---|---|
| Pet | Log conv ft to meters | 9.484 0158 | Log conv ft to meters | 9.484 0158 | Vertical angle | + 18 1 |
| | Log scale factor | | Log scale factor | | Log conv factor | |
| | Log sin bearing | 9.386 421 | Log cos bearing | 9.986 732 | Log tan vert angle | 8.249 725 |
| | Log distance | 2.055 417 | Log distance | 2.055 417 | Log distance | 2.055 417 |
| | Sum = log ΔE | 1.441 838 | Sum = log ΔN | 2.042 149 | Sum = log ΔH | 0.305 142 |
| T51 | Log conv ft to meters | 9.484 0158 | Log conv ft to meters | 9.484 0158 | Vertical angle | − 0 3 |
| | Log scale factor | | Log scale factor | | Log conv factor | |
| | Log sin bearing | 9.513 782 | Log cos bearing | 9.975 534 | Log tan vert angle | 6.469 121 |
| | Log distance | 1.853 698 | Log distance | 1.853 698 | Log distance | 1.853 698 |
| | Sum = log ΔE | 1.367 480 | Sum = log ΔN | 1.829 232 | Sum = log ΔH | 8.322 819 |
| T52 | Log conv ft to meters | 9.484 0158 | Log conv ft to meters | 9.484 0158 | Vertical angle | − 16 6 |
| | Log scale factor | | Log scale factor | | Log conv factor | |
| | Log sin bearing | 9.999 685 | Log cos bearing | 8.580 726 | Log tan vert angle | 8.212 147 |
| | Log distance | 2.070 629 | Log distance | 2.070 629 | Log distance | 2.070 629 |
| | Sum = log ΔE | 2.070 314 | Sum = log ΔN | 0.651 355 | Sum = log ΔH | 0.282 776 |
| T53 | Log conv ft to meters | 9.484 0158 | Log conv ft to meters | 9.484 0158 | Vertical angle | ± |
| | Log scale factor | | Log scale factor | | Log conv factor | |
| | Log sin bearing | | Log cos bearing | | Log tan vert angle | |
| | Log distance | | Log distance | | Log distance | |
| | Sum = log ΔE | | Sum = log ΔN | | Sum = log ΔH | |

| Station | E | N | H |
|---|---|---|---|
| Pet | 554 187.6 | 3 835 928.4 | 132.7 |
| ± | +27.7 | +110.2 | +2.0 |
| T51 | 554 215.3 | 3 836 038.6 | 134.7 |
| ± | −23.3 | +67.5 | 0.0 |
| T52 | 554 192.0 | 3 836 106.1 | 134.7 |
| ± | +117.6 | −4.5 | −1.9 |
| T53 | 554 309.6 | 3 836 101.6 | 132.8 |

To convert azimuth to bearing: Bearing = 360°/6400 mil − Az; Bearing = Az − 180°/3200 mil; Bearing = Azimuth; Bearing = 180°/3200 mil − Az

Log conversion factors: Feet to meters; Feet to yards; Meters to feet; Meters to yards

Station — Computer — Checked — Sheet of sheets

DA FORM 1 AUG 55 6-2 EDITION OF 1 OCT 52 IS OBSOLETE.

*Figure 55. Sample computation of fifth-order traverse.*

TABLE-UTM GRID SCALE FACTORS FOR ARTILLERY

Add log scale factor to log ground distance to obtain log UTM grid distance. The easting value used to determine log UTM scale factor is easting of the known station to nearest 10,000 meters.

| EASTING OF STARTING STATION | | LOG SCALE FACTOR | |
|---|---|---|---|
| 500,000 | 500,000 | 9.9998300 | |
| 490,000 | 510,000 | 9.9998300 | |
| 480,000 | 520,000 | 9.9998300 | |
| 470,000 | 530,000 | 9.9998300 | |
| 460,000 | 540,000 | 9.9998300 | |
| Easting 450,000 | $\boxed{550,000}$ | $\boxed{9.9998400}$ | Log Scale Factor |
| 440,000 | 560,000 | 9.9998400 | |
| 430,000 | 570,000 | 9.9998500 | |
| 420,000 | 580,000 | 9.9998600 | |
| 410,000 | 590,000 | 9.9998700 | |
| 400,000 | 600,000 | 9.9998800 | |
| 390,000 | 610,000 | 9.9998900 | |
| 380,000 | 620,000 | 9.9999000 | |
| 370,000 | 630,000 | 9.9999200 | |
| 360,000 | 640,000 | 9.9999300 | |
| 350,000 | 650,000 | 9.9999500 | |
| 340,000 | 660,000 | 9.9999700 | |
| 330,000 | 670,000 | 9.9999800 | |
| 320,000 | 680,000 | 0.0000000 | |
| 310,000 | 690,000 | 0.0000200 | |
| 300,000 | 700,000 | 0.0000400 | |
| 290,000 | 710,000 | 0.0000600 | |
| 280,000 | 720,000 | 0.0000900 | |
| 270,000 | 730,000 | 0.0001100 | |
| 260,000 | 740,000 | 0.0001300 | |
| 250,000 | 750,000 | 0.0001600 | |
| 240,000 | 760,000 | 0.0001900 | |
| 230,000 | 770,000 | 0.0002200 | |
| 220,000 | 780,000 | 0.0002500 | |
| 210,000 | 790,000 | 0.0002800 | |
| 200,000 | 800,000 | 0.0003100 | |
| 190,000 | 810,000 | 0.0003400 | |
| 180,000 | 820,000 | 0.0003700 | |
| 170,000 | 830,000 | 0.0004100 | |
| 160,000 | 840,000 | 0.0004500 | |
| 150,000 | 850,000 | 0.0004800 | |
| 140,000 | 860,000 | 0.0005200 | |
| 130,000 | 870,000 | 0.0005600 | |
| 120,000 | 880,000 | 0.0006000 | |
| 110,000 | 890,000 | 0.0006400 | |
| 100,000 | 900,000 | 0.0006900 | |

GIVEN:
Coordinates and Height of occupied station.
Azimuth STATION to REAR STATION.

FIELD DATA:
Observe horizontal angles and vertical angles.
Tape horizontal ground distance between occupied station and forward station.

GUIDE:
Enter field data in blocks marked.
Sign of dH; (+) when elevation angle, (-) when depression angle.

LIMITATIONS:
This form should not be used for vertical control when horizontal distance exceeds 1,000 meters unless reciprocal vertical angles are observed and meaned.
This computation requires that HI at occupied station and height of target at forward station be equal.
When distance exceeds 1,000 meters or when HI and height of target are unequal use DA Form 6-2b for more accurate vertical control.

RESULTS:
Coordinates and height of forward station.

FORMULA:
dE = dist. x Sin Bearing dN = dist. x Cos Bearing dH = dist. x tan vertical angle.

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*Figure 56. Back of DA Form 6-2.*

## COMPUTATION - COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE AND VERTICAL ANGLE
(FM 6-2 and FM 6-122)

Rear station: MIKE

**Station: JOE** — Coordinates: E 550 448.13, N 3 837 623.35; Height 418.3

| Azimuth | | Distance and bearing to forward station | | Log | | Log | | Log | |
|---|---|---|---|---|---|---|---|---|---|
| Az to rear station | 49 48 072 | Az to bearing | 32 00 000 | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Vertical angle | − 14 67 |
| + Station angle | 38 54 081 | | 24 02 151 | Log scale factor | 9.999 8400 | Log scale factor | 9.999 8400 | Log conv factor | |
| Sum | 88 02 151 | Bearing | 7 97 85 | Log sin bearing | 9.848 5664 | Log cos bearing | 9.850 3998 | Log tan vert angle | 8.158 4600 |
| − 180°/3200 mils | 64 00 000 | Distance | 817.39 ft | Log distance | 2.912 4293 | Log distance | 2.912 4293 | Log distance | 2.912 4293 |
| Az to fwd station | 24 02 151 | | | Sum 1 log dE | 2.760 8357 | Sum 2 log dN | 2.762 6691 | Sum 3 log dh | 1.070 8893 |
| (±) 180°/3200 mils | 32 00 000 | | | | | | | | |
| Az to rear station | 56 02 151 | | | | | | | | |

dE + 576.55; dN − 578.99; dh − 11.8

**Station: TS-1** — Coordinates: E 551 024.68, N 3 837 044.36; Height 406.5

| Azimuth | | Distance and bearing to forward station | | Log | | Log | | Log | |
|---|---|---|---|---|---|---|---|---|---|
| + Station angle | 36 84 992 | Az to bearing | 32 00 000 | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Vertical angle | − 1 48 |
| Sum | 92 87 143 | | 28 87 143 | Log scale factor | 9.999 8400 | Log scale factor | 9.999 8400 | Log conv factor | |
| − 180°/3200 mils | 64 00 000 | Bearing | 3 12 86 | Log sin bearing | 9.480 4997 | Log cos bearing | 9.979 1837 | Log tan vert angle | 7.162 2619 |
| Az to fwd station | 28 87 143 | Distance | 943.57 ft | Log distance | 2.974 7741 | Log distance | 2.974 7741 | Log distance | 2.974 7741 |
| (±) 180°/3200 mils | 32 00 000 | | | Sum 1 log dE | 2.455 1138 | Sum 2 log dN | 2.953 7978 | Sum 3 log dh | 0.137 0360 |
| Az to rear station | 60 87 143 | | | | | | | | |

dE + 285.18; dN − 899.09; dh − 1.4

**Station: TS-2** — Coordinates: E 551 309.86, N 3 836 145.27; Height 405.1

| Azimuth | | Distance and bearing to forward station | | Log | | Log | | Log | |
|---|---|---|---|---|---|---|---|---|---|
| + Station angle | 20 51 311 | Az to bearing | 32 00 000 | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Vertical angle | + 10 82 |
| Sum | 81 38 454 | | 17 38 454 | Log scale factor | 9.999 8400 | Log scale factor | 9.999 8400 | Log conv factor | |
| − 180°/3200 mils | 64 00 000 | Bearing | 14 61 55 | Log sin bearing | 9.995 9758 | Log cos bearing | 9.131 9548 | Log tan vert angle | 8.026 2435 |
| Az to fwd station | 17 38 454 | Distance | 1,050.22 ft | Log distance | 3.021 2803 | Log distance | 3.021 2803 | Log distance | 3.021 2803 |
| (±) 180°/3200 mils | 32 00 000 | | | Sum 1 log dE | 3.017 0961 | Sum 2 log dN | 2.153 0751 | Sum 3 log dh | 1.047 5238 |
| Az to rear station | 49 38 454 | | | | | | | | |

dE + 1 040.15; dN − 142.26; dh + 11.2

**Station: BN SCP** — Coordinates: E 552 350.01, N 3 836 003.01; Height 416.3

| Azimuth | | Distance and bearing to forward station | | Log | | Log | | Log | |
|---|---|---|---|---|---|---|---|---|---|
| + Station angle | 41 55 774 | Az to bearing | 32 00 000 | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Log conv ft to meters | ~~9 4 8 4 0 1 5 8~~ | Vertical angle | + 2 07 |
| Sum | 90 94 228 | | 26 94 228 | Log scale factor | 9.999 8400 | Log scale factor | 9.999 8400 | Log conv factor | |
| − 180°/3200 mils | 64 00 000 | Bearing | 5 05 77 | Log sin bearing | 9.677 9580 | Log cos bearing | 9.944 1059 | Log tan vert angle | 7.307 9708 |
| Az to fwd station | 26 94 228 | Distance | 1,136.94 ft | Log distance | 3.055 7376 | Log distance | 3.055 7376 | Log distance | 3.055 7376 |
| (±) 180°/3200 mils | 32 00 000 | | | Sum 1 log dE | 2.733 5356 | Sum 2 log dN | 2.999 6835 | Sum 3 log dh | 0.363 7084 |
| Az to rear station | 58 94 228 | | | | | | | | |

dE + 541.42; dN − 999.27; dh + 2.3

**Station: TS-3** — Coordinates: E 552 891.43, N 3 835 003.74; Height 418.6

To convert azimuth to bearing — Log conversion factors: Feet to meters; Feet to yards; Meters to feet; Meters to yards

Computer: KEUTHAN — Checker: BLOXOM — Sheet of sheets

DA FORM 6-2, 1 AUG 55. EDITION OF 1 OCT 52 IS OBSOLETE.

*Figure 57. Sample computation of fourth-order traverse.*

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# COMPUTATION - AZIMUTH AND DISTANCE FROM COORDINATES
(FM 6-120)

| STATION | | E COORDINATE | | N COORDINATE | |
|---|---|---|---|---|---|
| FROM: Pet | A | 554 187.61 | A | 3 835 928.41 | AZ. = 360° − Bearing (6400 mil) dE − dN + ; AZ. = Bearing dE + dN + |
| TO: Dog | B | 553 864.21 | B | 3 836 080.39 | |
| IF A IS LESS THAN B, REPEAT A | AA | | AA | 3 835 928.41 | dE − dN − ; dE + dN − |
| IF AA IS BLANK, USE A-B, SIGN (−) / IF AA IS FILLED, USE B-AA, SIGN (+) | dE | +/(−) 323.40 | dN | (+)/− 151.98 | AZ. = 180° (3200 mil) + Bearing ; AZ. = 180° (3200 mil) − Bearing |

| | | | |
|---|---|---|---|
| LOG dE | 2.509 740 | ANGLE HAVING LOG TAN BEARING A TO B | 11 52 5 |
| LOG dN | 2.181 786 | DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AND USING SKETCH AS GUIDE | 64 00 0 |
| | | | 11 52 5 |
| LOG dE − LOG dN = LOG TAN BEARING A TO B | 0.327 954 | AZIMUTH A TO B | 52 47 5 |

| IF dE IS MORE THAN dN | | IF dE IS LESS THAN dN | |
|---|---|---|---|
| REPEAT LOG dE | 2.509 740 | REPEAT LOG dN | |
| LOG SIN BEARING | 9.956 666 | LOG COS BEARING | |
| LOG dE − LOG SIN BEARING = LOG GRID DISTANCE A TO B IN METERS | 2.553 074 | LOG dN − LOG COS BEARING = LOG GRID DISTANCE A TO B IN METERS | |
| LOG CONVERSION FACTOR METERS TO YARDS | ~~0.038 8629~~ | LOG CONVERSION FACTOR METERS TO YARDS | 0.038 8629 |
| LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS | | LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS | |
| | 357.3 (M) YDS | | M YDS |

| STATION | | E COORDINATE | | N COORDINATE | |
|---|---|---|---|---|---|
| FROM: | A | | A | | AZ. = 360° − Bearing (6400 mil) dE − dN + ; AZ. = Bearing dE + dN + |
| TO: | B | | B | | |
| IF A IS LESS THAN B, REPEAT A | AA | | AA | | dE − dN − ; dE + dN − |
| IF AA IS BLANK, USE A-B, SIGN (−) / IF AA IS FILLED, USE B-AA, SIGN (+) | dE | + − | dN | + − | AZ. = 180° (3200 mil) + Bearing ; AZ. = 180° (3200 mil) − Bearing |

| | | | |
|---|---|---|---|
| LOG dE | | ANGLE HAVING LOG TAN BEARING A TO B | |
| LOG dN | | DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AND USING SKETCH AS GUIDE | |
| LOG dE − LOG dN = LOG TAN BEARING A TO B | | AZIMUTH A TO B | |

| IF dE IS MORE THAN dN | | IF dE IS LESS THAN dN | |
|---|---|---|---|
| REPEAT LOG dE | | REPEAT LOG dN | |
| LOG SIN BEARING | | LOG COS BEARING | |
| LOG dE − LOG SIN BEARING = LOG GRID DISTANCE A TO B IN METERS | | LOG dN − LOG COS BEARING = LOG GRID DISTANCE A TO B IN METERS | |
| LOG CONVERSION FACTOR METERS TO YARDS | 0.038 8629 | LOG CONVERSION FACTOR METERS TO YARDS | 0.038 8629 |
| LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS | | LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS | |
| | M YDS | | M YDS |

FORMULAS: TAN BEARING $= \frac{dE}{dN}$ GRID DISTANCE $= \frac{dE}{\text{SIN BEARING}} = \frac{dN}{\text{COS BEARING}}$

| | | |
|---|---|---|
| COMPUTER | CHECKER | SHEET OF SHEETS |
| NOTEBOOK REFERENCE | AREA | DATE |

DA FORM 6-1, 1 AUG 55 — REPLACES EDITION OF 1 NOV 53, WHICH WILL BE USED UNTIL EXHAUSTED.

*Figure 58. Computation of azimuth and distance, fifth-order survey.*

# COMPUTATION—TRIGONOMETERIC HEIGHTS

| Block | No. | Item | | | | |
|---|---|---|---|---|---|---|
| | | OCCUPIED STATION | SCP 2 | SCP 3 | | |
| | | FORWARD STATION | SCP 3 | SCP 4 | | |
| | | HORIZONTAL DISTANCE BETWEEN STATIONS — GROUND ☐ UTM GRID ☒ | 8 693.82 | 3 426.39 | | |
| BLOCK I | 1 | HEIGHT OF INSTRUMENT AT OCCUPIED STATION | + 1.6 | + 1.6 | + | + |
| BLOCK I | 2 | HEIGHT OF TARGET AT FORWARD STATION | − 1.6 | − 1.6 | − | − |
| BLOCK I | 3 | ALGEBRAIC SUM (1) AND (2) | ± 0.0 | ± 0.0 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 4 | HEIGHT OF INSTRUMENT AT FORWARD STATION | − 1.6 | − 1.6 | − | − |
| RECIPROCAL ANGLES ONLY BLOCK II | 5 | ALGEBRAIC SUM (3) AND (4) | − 1.6 | − 1.6 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 6 | HEIGHT OF TARGET AT OCCUPIED STATION | + 1.6 | + 1.6 | + | + |
| RECIPROCAL ANGLES ONLY BLOCK II | 7 | ALGEBRAIC SUM (5) AND (6) | ± 0.0 | ± 0.0 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 8 | 1/2 OF (7) | ± 0.0 | ± 0.0 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 9 | VERTICAL ANGLE OCCUPIED STATION TO FORWARD STATION | + 18 90 | − 10 30 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 10 | VERTICAL ANGLE FORWARD STATION TO OCCUPIED STATION WITH SIGN REVERSED | + 18 93 | − 10 34 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 11 | ALGEBRAIC SUM (9) AND (10) | + 37 83 | − 20 64 | ± | ± |
| RECIPROCAL ANGLES ONLY BLOCK II | 12 | 1/2 OF (11) | + 18 92 | − 10 32 | ± | ± |
| BLOCK III | | NON-RECIPROCAL ANGLES ONLY | | | | |
| BLOCK III | 12 | VERTICAL ANGLE OCCUPIED STATION TO FORWARD STATION | ± | ± | ± | ± |
| BLOCK IV | 13 | LOG OF HORIZONTAL DISTANCE BETWEEN STATIONS | 3.939 2106 | 3.534 8368 | | |
| BLOCK IV | 14 | LOG TAN (12) | 8.268 9710 | 8.005 6945 | | |
| BLOCK IV | 15 | (13) + (14) | 2.208 1816 | 1.540 5313 | | |
| BLOCK IV | 16 | IF HORIZONTAL DISTANCE IS: GRID, USE LOG SCALE FACTOR FROM REVERSE; GROUND, LEAVE BLANK | 9.999 8400 | 9.999 8400 | | |
| BLOCK IV | 17 | (15) − (16) | 2.208 3416 | 1.540 6913 | | |
| BLOCK IV | 18 | NUMBER HAVING LOG (17) USE SIGN OF (12) | + 161.6 | − 34.7 | ± | ± |
| BLOCK IV | 19 | IF BLOCK II IS BLANK REPEAT (3) IF BLOCK II IS FILLED REPEAT (8) | ± 0.0 | ± 0.0 | ± | ± |
| BLOCK IV | 20 | ALGEBRAIC SUM (18) AND (19) | + 161.6 | − 34.7 | ± | ± |
| BLOCK IV | 21 | NON-RECIPROCAL ANGLES ONLY: CURVATURE AND REFRACTION CORRECTION FROM REVERSE | + | + | + | + |
| BLOCK IV | 22 | ALGEBRAIC SUM (20) AND (21) | + 161.6 | − 34.7 | ± | ± |
| BLOCK IV | 23 | HEIGHT OF ☒ OCCUPIED ☐ FORWARD STATION | + 371.6 | + 533.2 | + | + |
| BLOCK IV | 24 | IF (23) IS HEIGHT OF OCCUPIED STATION REPEAT (22); IF (23) IS HEIGHT OF FORWARD STATION REPEAT (22) WITH OPPOSITE SIGN | + 161.6 | − 34.7 | ± | ± |
| BLOCK IV | 25 | ALGEBRAIC SUM (23) AND (24) = HEIGHT OF ☐ OCCUPIED ☒ FORWARD STATION | 533.2 | 498.5 | | |

| | | | |
|---|---|---|---|
| COMPUTER BRAUN | CHECKER HOFELDT | SHEET OF SHEETS | |
| NOTEBOOK REFERENCE 1-16 | AREA FOXTROT | DATE 16 JAN | |

DA FORM 1 MAY 56 6-2b REPLACES DA FORM 6-2b, 1 OCT 52, WHICH IS OBSOLETE.

*Figure 59. Computation of height, fourth-order survey.*

TABLE - CORRECTION FOR CURVATURE AND REFRACTION
(No interpolation necessary for Artillery Survey)
Use only when dH is computed using non-reciprocal vertical angles.
SIGN ALWAYS PLUS
Enter in (21)

| Log Dist (M) | Corr (M) |
|---|---|
| 3.079 | .1 |
| 3.230 | .2 |
| 3.322 | .3 |
| 3.386 | .4 |
| 3.435 | .5 |
| 3.473 | .6 |
| 3.508 | .7 |
| 3.537 | .8 |
| 3.562 | .9 |
| 3.584 | 1.0 |
| 3.625 | 1.2 |
| 3.658 | 1.4 |
| 3.687 | 1.6 |
| 3.712 | 1.8 |
| 3.736 | 2.0 |
| 3.784 | 2.5 |
| 3.824 | 3.0 |
| 3.857 | 3.5 |
| 3.886 | 4.0 |
| 3.912 | 4.5 |
| 3.934 | 5.0 |
| 3.955 | 5.5 |
| 3.974 | 6.0 |
| 3.992 | 6.5 |
| 4.007 | 7.0 |

TABLE-UTM GRID SCALE FACTORS FOR ARTILLERY

| EASTING OF STARTING STATION | | LOG SCALE FACTOR |
|---|---|---|
| 500,000 | 500,000 | 9.9998300 |
| 490,000 | 510,000 | 9.9998300 |
| 480,000 | 520,000 | 9.9998300 |
| 470,000 | 530,000 | 9.9998300 |
| 460,000 | 540,000 | 9.9998300 |
| 450,000 | 550,000 | 9.9998400 |
| 440,000 | 560,000 | 9.9998400 |
| 430,000 | 570,000 | 9.9998500 |
| 420,000 | 580,000 | 9.9998600 |
| 410,000 | 590,000 | 9.9998700 |
| 400,000 | 600,000 | 9.9998800 |
| 390,000 | 610,000 | 9.9998900 |
| 380,000 | 620,000 | 9.9999000 |
| 370,000 | 630,000 | 9.9999200 |
| 360,000 | 640,000 | 9.9999300 |
| 350,000 | 650,000 | 9.9999500 |
| 340,000 | 660,000 | 9.9999700 |
| 330,000 | 670,000 | 9.9999800 |
| 320,000 | 680,000 | 0.0000000 |
| 310,000 | 690,000 | 0.0000200 |
| 300,000 | 700,000 | 0.0000400 |
| 290,000 | 710,000 | 0.0000600 |
| 280,000 | 720,000 | 0.0000900 |
| 270,000 | 730,000 | 0.0001100 |
| 260,000 | 740,000 | 0.0001300 |
| 250,000 | 750,000 | 0.0001600 |
| 240,000 | 760,000 | 0.0001900 |
| 230,000 | 770,000 | 0.0002200 |
| 220,000 | 780,000 | 0.0002500 |
| 210,000 | 790,000 | 0.0002800 |
| 200,000 | 800,000 | 0.0003100 |
| 190,000 | 810,000 | 0.0003400 |
| 180,000 | 820,000 | 0.0003700 |
| 170,000 | 830,000 | 0.0004100 |
| 160,000 | 840,000 | 0.0004500 |
| 150,000 | 850,000 | 0.0004800 |
| 140,000 | 860,000 | 0.0005200 |
| 130,000 | 870,000 | 0.0005600 |
| 120,000 | 880,000 | 0.0006000 |
| 110,000 | 890,000 | 0.0006400 |
| 100,000 | 900,000 | 0.0006900 |

Given:
UTM grid distance or horizontal ground distance in meters between stations.
Height of one station in meters.

Field data:
Observe vertical angle between instrument at one station and target at other station.
Height of instrument.
Height of target.

Guide:
Enter field data in blocks marked $\boxed{\phantom{xxxxxx}}$.
When vertical angles are observed in two directions, either station may be designated as the occupied station. Use Blocks I, II, and IV.
When vertical angle is observed in one direction, use Blocks I, III, and IV. Use curvature and refraction correction from table above.
Elevation of occupied station need not be known.
In (16), obtain approximate easting coordinate of occupied station from other computations or from map. Use this value to obtain scale factor from table above.
If height of either station in (23) is below sea level (-), add 1,000 meters algebraically to (23); proceed with computation as indicated. Subtract 1,000 meters algebraically from (25) to obtain height of station.
If height of occupied station is used in (23), then height of forward station is obtained in (25).
All angular units used in computation must be the same (mils or degrees).

Limitation:
This computation does not provide for reduction of ground distance to sea level distance.

Results:
Height of the unknown station in meters.

. GOVERNMENT PRINTING OFFICE: 1956 O—385533

*Figure 60. Back of DA Form 6–2b.*

onometric Heights (fig. 59), must be used in computing the height of the forward station.

### 212. DA Form 6–2b

*a.* DA Form 6–2b (figs. 59 and 60) is used to determine the height of the forward station when the vertical angles are measured reciprocally or nonreciprocally to different heights above the station.

*b.* Entries required are the vertical angles measured, height of station, height of instrument, and height of target.

*c.* The formula to be used is shown on the back of the form.

### 213. Accuracies, Specifications and Techniques

The overall accuracy of a traverse depends on the equipment and methods used in the measurements, the accuracy achieved, and the accuracy of the starting and closing data. In artillery survey, three minimum accuracies serve as standards for survey personnel to meet in both fieldwork and computations. These accuracies are fourth-order (1:3,000), fifth-order (1:1,000), and 1:500 survey. Fourth-order surveys are normally performed by division artillery and the corps artillery target acquisition battalion to extend survey control. Field artillery battalions normally perform fifth-order surveys to establish survey control for the required elements of the battalion. Survey to an accuracy of 1:500 normally is performed only by artillery elements that have a limited survey capability (e.g. radar sections) and use the aiming circle to measure angles. The specifications and techniques to achieve the accuracies required in artillery survey are tabulated in appendix II and are discussed in *a* through *c* below.

*a. Fourth-Order Accuracy.* A fourth-order traverse starting from existing survey control must start and close on stations established to an accuracy of fourth-order or higher. If survey control of the required accuracy is not available, the fieldwork and computations can be completed and the traverse evaluated for accuracy by using assumed starting data, provided the traverse is terminated at the starting station. The T2 theodolite is used to measure the angles. Horizontal angles are measured one position; vertical angles are measured once with the telescope in the direct position and once with the telescope in the reverse position (1D/R). Distances are double-taped to a comparative accuracy of 1:5,000 with the 30-meter steel tape or measured with electronic distance-measuring equipment, using the procedures discussed in chapter 6.

(1) *Position accuracy.*

(*a*) The maximum allowable error in position closure for a fourth-order traverse is generally expressed as 1:3,000, or 1 meter of radial error for each 3,000 meters of traverse. The radial error of closure is the linear distance between the correct coordinates of the closing station and the coordinates of that station as determined from the traverse. The radial error of closure is determined by comparing the correct coordinates of the closing point with the traverse coordinates of that point. The difference between the two is the radial error of closure.

| | |
|---|---|
| Correct coordinates of closing point: | 560068.0—3838037.0 |
| Traverse coordinates of closing point: | 560064.0—3838040.0 |
| | eE = 4.0    eN = 3.0 |

The difference between the two eastings of the closing point, error in easting (eE), forms one side of the right triangle in figure 61; the difference between the two northings, error in northing (eN), forms a second side. The hypotenuse of the right triangle is the radial error of closure.

(*b*) The radial error may be determined by computation on DA Form 6–1, by using the Pythagorean theorem, or by plotting eE and eN to scale and measuring the hypotenuse. The most commonly used of these sys-

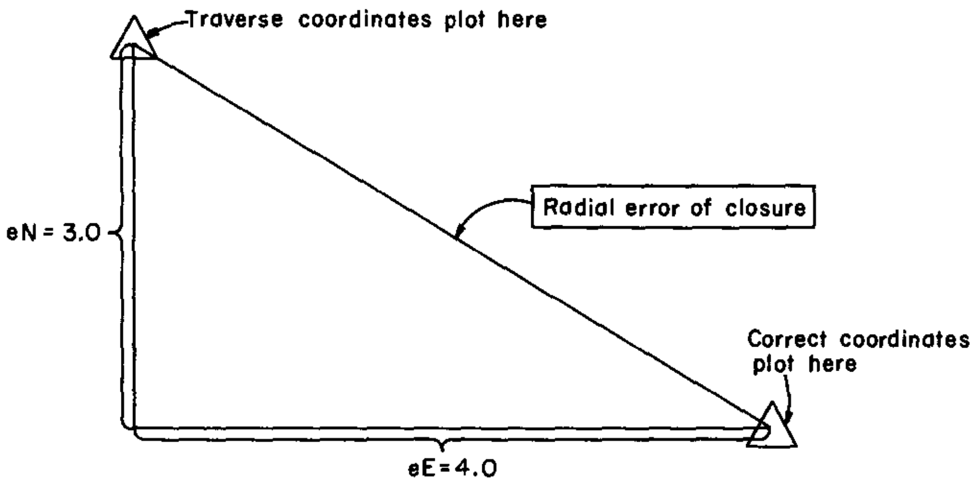



*Figure 61. Radial error of closure.*

tems is the Pythagorean theorem. By use of this theorem and the data in figure 61, the radial error would be computed as follows:

$$\begin{aligned} \text{Radial error} &= \sqrt{(eE)^2 + (eN)^2} \\ &= \sqrt{4.0^2 + 3.0^2} \\ &= \sqrt{16.0 + 9.0} \\ &= \sqrt{25.0} \\ &= 5.0 \text{ meters} \end{aligned}$$

When the radial error of closure has been determined, one other factor is required to complete the computation of the accuracy ratio. This factor is the total length of the traverse which is determined by adding the distances of all traverse legs (excluding distances to offset stations) in the traverse. Assuming that for the radial error computed above the total length of the traverse is 5,555 meters, the accuracy would be determined as follows:

$$\begin{aligned} \text{Accuracy ratio} &= \frac{1}{\text{total length of traverse} \div \text{radial error}} \\ &= \frac{1}{5555 \div 5.0} \\ &= \frac{1}{1111} \quad \text{or, rounded down,} \\ &= \frac{1}{1100} \end{aligned}$$

(*c*) This accuracy ratio is suitable for evaluating a traverse in most cases; however, when the traverse is long, the accuracy achieved may be within tolerance and yet the radial error will be excessive. For this reason, when the length of the traverse exceeds 9 kilometers, the allowable radial error (AE) in meters is computed by the formula AE $= \sqrt{K}$, where K is the total length of the traverse to the nearest one-tenth kilometer. For example, the allowable error for a traverse 14.8 kilometers in length would be AE = $\sqrt{14.8}$, or 3.85 meters, rather than 4.93 meters if computed by the 1:3,000 accuracy ratio.

(2) *Height accuracy.* The allowable error in meters for the height closure of a fourth-order traverse of any length is also computed by the formula AE = $\sqrt{K}$. By this formula, the allowable height error for a traverse of less than 9 kilometers will be slightly greater than the allowable position error, whereas the allowable error for height and position will be the same for traverses 9 kilometers or greater in length.

(3) *Azimuth closure.* The allowable error in azimuth closure for a fourth-order traverse depends on the number of main-scheme angles used in carrying the azimuth through the traverse. The allowable azimuth error in mils for a traverse that has no more than six main-scheme angles is computed by the formula AE = 0.04$\cancel{m}$ × N, where N is the number of main-scheme angles. If there are more than six main scheme angles in the traverse, the allowable azimuth error is computed by the formula

$$AE = 0.1\cancel{m} \sqrt{N}.$$

*b. Fifth-Order Accuracy.* A fifth-order traverse starting from existing control must start and close on stations established to an accuracy of fifth-order or higher. When survey control of the required accuracy is not available, the fieldwork and computations can be completed and the traverse evaluated for accuracy by using assumed starting data, provided the traverse is closed on the starting station. The T16 theodolite is used to measure the angles. Horizontal angles are measured one position; vertical angles are measured once with the telescope in the direct position and once with the telescope in the reverse position (1D/R). Distances are single-taped with the 30-meter steel tape and checked for gross errors by pacing or are measured with electronic distance-measuring equipment if it is available.

(1) *Position accuracy.* The maximum allowable error in position closure for a fifth-order traverse is expressed by the accuracy ratio of 1:1,000 or 1 meter of radial error for each 1,000 meters of traverse. (See *a*(1)(*a*) above for determination of radial error.)

(2) *Height accuracy.* The maximum allowable error in height closure for a fifth-order traverse is ±2 meters.

(3) *Azimuth closure.* The allowable error in azimuth closure for a fifth-order traverse is computed by the formula AE = 0.1$\cancel{m}$ × N, where N is the number of main-scheme angles in the traverse.

*c. 1:500 Survey.* The specifications and techniques that apply to the fieldwork and computations of a fifth-order traverse apply to a traverse performed to an accuracy of 1:500 with the following exceptions:

(1) *Position.* The allowable error in position closure is 1:500.

(2) *Height.* Vertical angles are measured twice with the aiming circle. The mean value should be within ±0.5 mil of the first reading. The allowable error in height closure is ±2 meters.

(3) *Azimuth.* Horizontal angles are measured two repetitions with the aiming circle. The accumulated value is divided by 2 to determine the mean value, which should be within ±0.5 mil of the first reading. The allowable error in azimuth closure is computed by the formula AE = 0.5$\cancel{m}$ × N, where N is the number of angles in the traverse.

## Section III. TRAVERSE ADJUSTMENT

### 214. General

Establishing a common grid throughout an entire corps or division artillery sector is not as simple as it may at first appear. When a party is extending survey control over long distances by traverse, the traverse may well be within the prescribed accuracy and still be considerably in error. This problem is magnified when several traverse parties are employed to extend control and attempt to tie their work together. Seldom, if ever, will these parties coincide on their linkage, but, by adjusting the traverse throughout, some compensation will be made for those errors which have accumulated. A traverse executed to a prescribed accuracy of fourth-order must always be closed and adjusted. An adjusted traverse is one in which the errors have been distributed systematically so that the closing data as determined by the traverse coincides with the correct closing data. There is, of course, no possible means of determining the true magnitude of the errors in angle and distance measuring which occur throughout a traverse. Traverse adjustment is based on the assumption that the errors have gradually accumulated, and the corrections are made accordingly. Three adjustments must be made in adjusting a traverse—azimuth, coordinates, and height. These adjustments eliminate the effects of systematic errors on the assumption that they have been constant and equal in their effect upon each traverse leg. Blunders, such as dropped tape lengths or misread angles, cannot be compensated for in traverse adjustment. Additionally, a traverse which does not meet the prescribed standard of accuracy is not adjusted but is checked for error. *If the error cannot be found, the traverse must be performed again from the start.*

## 215. Sources of Errors

The errors that are compensated for by traverse adjustment are not those errors commonly known as mistakes or blunders but are errors that fall into one of the following classes:

*a.* Instrumental errors—errors that arise from imperfections in, or faulty adjustment of, the instruments with which the measurements are taken. For example, a tape may be too long or too short or a plate level may be out of adjustment.

*b.* Personnel errors—errors that arise from the limitations of the human senses of sight and touch. For example, an error may be made in estimating the tension applied to a steel tape.

*c.* Natural errors—errors that arise from variations in the phenomena of nature, such as temperature, humidity, wind, gravity, refraction, and magnetic declination. For example, the length of a tape will vary directly with the temperature; i.e., it will become longer as the temperature increases and shorter as the temperature decreases.

## 216. Azimuth Adjustment

*a. Determining Azimuth Correction.* Since the computation of position is in part dependent on azimuth, the first step in adjusting a traverse is to determine the azimuth error and adjust the azimuth. The azimuth error is obtained by determining the difference between the azimuth established by traverse (computed) and the known azimuth at the closing point. The azimuth correction is the azimuth error with a sign affixed which will cause the computed azimuth, with the correction applied, to equal the known azimuth. For example, the azimuth from a point to an azimuth mark is known to be 2,571.624 mils. The closing azimuth of a traverse to the same azimuth mark is determined to be 2571.554 mils. The azimuth correction is determined as follows:

Azimuth error = known azimuth − azimuth established by traverse
= 2,571.624 mils − 2,571.554 mils
= 0.070 mil

Azimuth correction = +0.070 mil.

*b. Application of Azimuth Correction.* Since traverse adjustment is based on the assumption that errors present have accumulated gradually and systematically throughout the traverse, the azimuth correction is applied accordingly. The correction is distributed equally among the angles of the traverse with any remainder distributed to the larger angles. For example, assume that the traverse, for which the azimuth correction was determined, consisted of three traverse legs and four angles as follows:

| *Station* | *Measured angle* |
|---|---|
| SCP | 2410.716 mils |
| TS1 | 2759.630 mils |
| TS2 | 3765.876 mils |
| SCP (closing) | 2886.617 mils |

The azimuth correction is divided by the total number of angles. In this case, +0.070 mil ÷ 4 = 0.017 mil per angle with a remainder of 0.002 mil. Each of the four angles will be adjusted by 0.017 mil and the two largest angles will be adjusted by an additional 0.001 mil each to compensate for the remaining 0.002 mil.

| *Station* | *Measured angle* | *Azimuth correction* | *Adjusted angle* |
|---|---|---|---|
| SCP | 2410.716 | +0.017 | 2410.733 |
| TS1 | 2759.630 | +0.017 | 2759.647 |
| TS2 | 3765.876 | +0.018 | 3765.894 |
| SCP | 2886.617 | +0.018 | 2886.635 |

*c. Action After Adjustment.* After the angles have been adjusted, the adjusted azimuth of each leg of the traverse should be computed by using the starting azimuth and the adjusted angles at each traverse station. These computations should be performed on fresh sheets of DA Form 6–2, not on the sheets used in the original computations. The adjusted azimuth should be computed throughout the entire traverse and checked against the correct azimuth to the closing azimuth mark before any of the coordinate adjustments are begun.

## 217. Coordinate Adjustment

After the azimuth of each traverse leg has been adjusted, the coordinates of the stations in the traverse must be adjusted. The first step in adjusting the coordinates is to recompute the coordinates of all stations in the traverse, using the adjusted azimuths to obtain new bearing angles.

*a. Determining Easting and Northing Corrections.* The easting and northing corrections for the traverse are determined by subtracting the coordinates of the closing station (as recomputed with the adjusted azimuth) from the known coordinates of the closing station.

For example,

Correction = known coordinates − coordinates established by traverse

= 550554.50—3835829.35 (correct coordinates)

$$\begin{array}{rr} -550550.50 & -3835835.35 \\ \hline = \quad +4.00 & -6.00 \end{array}$$

(traverse coordinates)

*b. Application of Easting and Northing Corrections.* The corrections determined in *a* above are for the entire traverse. The assumption is made that these corrections are based on errors proportionately accumulated throughout the traverse. Therefore, the corrections must be distributed proportionately. The amount of easting or northing correction to be applied to the coordinates of each station is computed by multiplying the total correction (easting or northing) by the total length of all the traverse legs up to that station and dividing it by the total length of all of the legs in the traverse. For example, using the total easting and northing corrections previously determined, assume that the total length of the traverse is 22,216.89 meters and that the total length of the traverse legs up to TS4 is 3,846.35 meters.

$$\text{Easting correction at TS4} = \frac{\text{total easting correction} \times \text{traverse length to TS4}}{\text{total traverse length}}$$

$$= \frac{+4.00 \times 3{,}846.35}{22{,}216.89}$$

$$= \frac{+15{,}385.40}{22{,}216.89}$$

$$= +0.69 \text{ meter}$$

$$\text{Northing correction at TS4} = \frac{\text{total northing correction} \times \text{traverse length to TS4}}{\text{total traverse length}}$$

$$= \frac{-6.00 \times 3{,}846.35}{22{,}216.89}$$

$$= \frac{-22{,}478.10}{22{,}216.89}$$

$$= -1.04 \text{ meters}$$

### 218. Height Adjustment

Like azimuth adjustment, the height adjustment is based on the assumption that the error of closure is accumulated throughout the traverse in equal amounts at each traverse station.

*a. Determining Height Correction.* The height correction is determined by comparing the height of the closing point as established by the traverse with the known height of the closing point and applying a sign which will cause the established height, with the correction applied algebraically, to equal the known height. For example:

$$\begin{aligned}\text{Height correction} &= \text{known height} - \text{height established by traverse}\\ &= 478.3 \text{ meters} - 477.5 \text{ meters}\\ &= +0.8 \text{ meter}\end{aligned}$$

*b. Application of Height Correction.* The height correction is distributed evenly throughout all stations of the traverse with any remainder distributed to those stations computed from the longest legs. The height correction is not applied to the traverse height of each station but is applied to the difference in height (dH) between each traverse station.

| *Station* | *Traverse height* | *dH* | *Correction* | *Adjusted height* |
|---|---|---|---|---|
| SCP | 478.3 | | | 478.3 |
| TS1 | 486.7 | +8.4 | +0.2 | 486.9 |
| TS2 | 495.9 | +9.2 | +0.3 | 496.4 |
| SCP | 477.5 | −18.4 | +0.3 | 478.3 |

## Section IV. LOCATION OF TRAVERSE ERRORS

### 219. Analysis of Traverse for Errors

A good survey plan executed by a well-trained party provides numerous checks in both computations and fieldwork. However, these checks do not always eliminate errors. On the contrary, errors are made both in the fieldwork and in computations and are often not discovered until the survey has been completed. The surveyor should be able to isolate these errors and determine their causes. Often an analysis of the fieldwork and the computations of a survey in error will save hours of repetitious labor and computations. To assist in this analysis, the chief of survey party should maintain in the field a sketch, drawn to scale, of each survey as it is being performed. If available, a reliable map can also be used to advantage. If an error is apparent upon completion of the survey, the procedures in paragraphs 220 and 221 should be followed to isolate the error. An assumption must be made that only one error exists. If more than one error exists, it will not be possible to isolate the errors.

### 220. Isolation of Distance Error

*a. Indication of Distance Error.* The azimuth for the traverse closes within the allowable tolerance; however, the coordinate closure is in error beyond the limits allowed for the prescribed accuracy.

*b. Isolation of Distance Error.* Compare the known coordinates of the closing point with the computed coordinates of that point. From this comparison, determine the error in easting and the error in northing. Compute the distance (radial error) and azimuth from the known coordinates to the computed coordinates. If a distance error has been made, the traverse leg containing the distance error will have the same azimuth (or back-azimuth) as the radial error (fig. 62), and the distance error will be approximately the same length as the radial error. Remeasure the suspected traverse leg to verify the location of the error. Under some circumstances, several legs with azimuths approximating the azimuth of the radial error may be suspected of containing the error. In this case, check the computations for each suspected leg. If there is no error in the computations, remeasure each suspected leg until the leg containing the error is found.

### 221. Isolation of Azimuth Error

*a. Indication of Azimuth Error.* The azimuth closure and the coordinate closure are in error

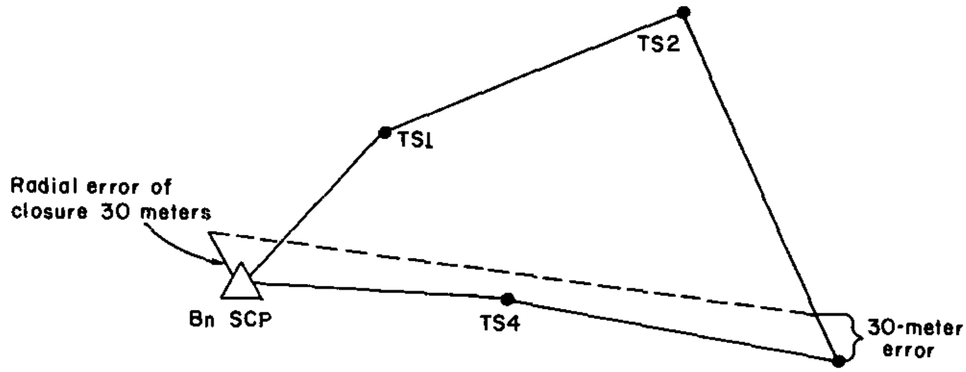



*Figure 62. Distance error.*

beyond the limits allowed for the prescribed accuracy.

*b. Isolation of Azimuth Error.* Compare the computed azimuth with the known azimuth of the closing point, and determine the azimuth error. Determine the azimuth and distance of the radial error. Construct a scaled sketch of the traverse. Draw in the radial error, and then construct a line perpendicular to, and at the midpoint of, the radial error. Extend this line through the area in the sketch showing the fieldwork. The station at which the angular error was made will be on or very near this extended line. Check the computations and the field notes for that station. If no error can be found, remeasure the angle. If the remeasured angle compares favorably with the original angle, a multiple error exists and the survey must be rerun.

*c. Alternate Solution.* When a graphical plot cannot be made, an azimuth error can be isolated by determining the approximate distance of the station in error from the closing station. To determine the distance, use the mil relation formula ($m = w \div r$), the distance of the radial error, and the azimuth error of closure. Substitute the radial error for the width and the azimuth error of closure for the mils in the formula. For example, Range (in thousands) to suspected stations = radial error ÷ azimuth error of closure or

$$
\begin{aligned}
r &= w \div m \\
&= 100 \text{ meters} \div 10 \text{ mils} \\
&= 10 \text{ (range in thousands)} \\
&= 10{,}000 \text{ meters}
\end{aligned}
$$

This procedure may be used to determine one or more suspect stations. By trial and error and systematic elimination, the station in error may be located. To locate the station in error, compare the known coordinates of the closing station with the coordinates of a suspect station and compute the azimuth and distance between the two. Then compare the computed coordinates of the closing station with the coordinates of the suspect station and compute the azimuth and distance between the two. If the error is at that station, the azimuths should vary by the amount of the error of the azimuth closure of the traverse, and the distances will be approximately the same. If the error is not at that station, the azimuths will disagree but not by an amount equivalent to the azimuth closure error (fig. 63). Repeat the procedure for each of the suspect stations. When the suspect station has been isolated, check the computations and field notes for that station. If no error can be found, remeasure the angle at the station. If the remeasured angle compares favorably with the original angle, rerun the entire survey.

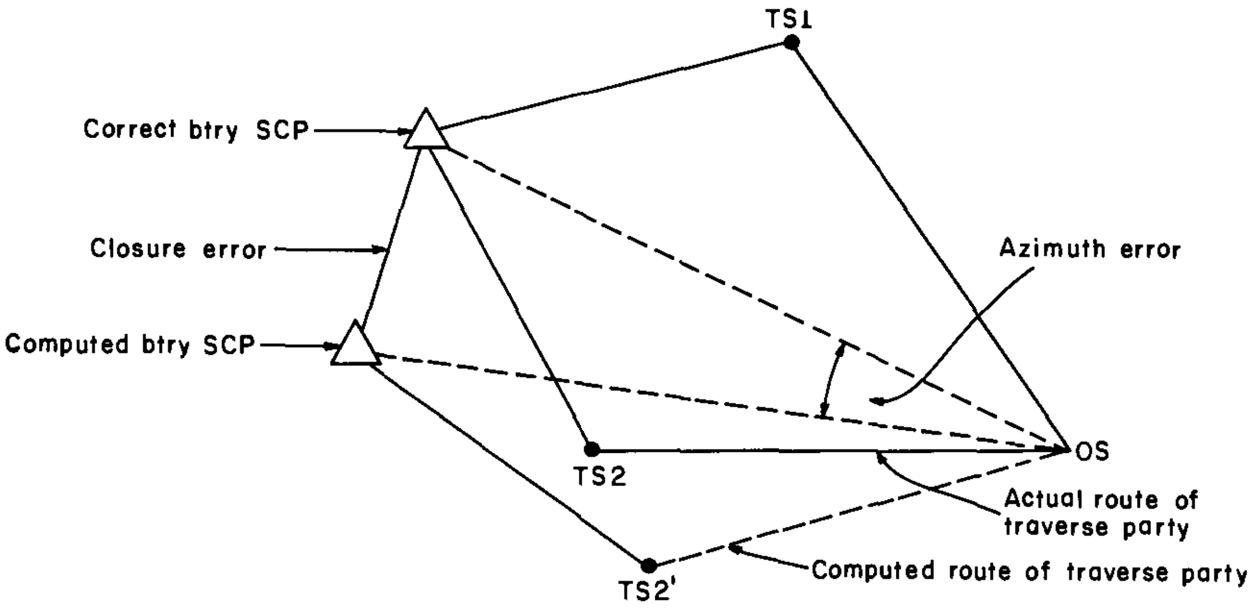



*Figure 63. Azimuth error.*

# CHAPTER 9

# TRIANGULATION

## Section I. GENERAL

### 222. Purpose of Triangulation in Artillery Surveys

*a.* Triangulation is a method of extending survey control through the use of triangular figures. Measured horizontal angles and one measured side of the triangle serve as the basis for determining the length of the remaining sides. A wide range of combinations of known data exists with which required data may be determined. These combinations range from the simple single triangle with a measured base and three measured angles to the solution of two adjacent triangles, from three known positions, with two measured angles in a three-point resection problem. Triangulation methods may be used at all levels of artillery survey to determine the position of control points. It is generally better to use triangulation in situations in which the distance involved or the terrain traverse difficult or impossible. More detailed planning and reconnaissance is required for triangulation than for other methods.

*b.* Direct support artillery units may find triangulation of value in the conduct of connection surveys between position areas and target areas. Triangulation is well suited to situations involving the extension of survey control over long distances (e.g., 10 to 20 kilometers per party), such as those required in division artillery and corps artillery survey. The issue of distance-measuring equipment, has, however, shifted the emphasis at these levels to the use of DME traverse. Although the DME traverse is a rapid and accurate means of providing the required control, it is wholly dependent on the successful operation of a delicate electronic device, the DME. When electronic countermeasures (ECM) are employed or during periods of electronic silence, the DME cannot be used. For this reason, artillery surveyors must maintain proficiency in triangulation.

### 223. Terminology Associated with Triangulation

*a. Accuracy ratio* is a ratio of linear precision, such as 1:3,000 (meaning that for every 3,000 units surveyed the error must not exceed one unit), computed in triangulation when the scheme closes on a known control point. The accuracy ratio is computed by dividing the radial error into the total distance surveyed. The radial error is determined as discussed in paragraph 213; the total distance is the sum of the lengths of the shortest triangle sides connecting the starting point and the closing point.

*b. Adjustment* is the distribution of angular and linear errors throughout a scheme and the subsequent recomputation of positions.

*c. Azimuth check* is the periodic determination of azimuth by astronomic or gyroscopic means for the purpose of checking the azimuth of triangle sides.

*d.* The *base* is a line the length and azimuth of which are known, as well as the coordinates and height of one or both ends. The base is used as one side of a triangle to determine the azimuth and length of the other sides. Base lengths can be computed between stations of known position, double-taped, or determined by electronic distance-measuring equipment. Base azimuths can be determined by computation from known positions, by astronomic observation, or by gyroscopic means.

*e.* A *chain* is a scheme of several of the same type of figures connected by common sides, as a chain of single triangles or a chain of quadrilaterals.

*f.* A *check base* is a side of one triangle in a chain or scheme designated as the place in the scheme where the computed length and azimuth of the side, as carried through the scheme, is compared to the observed length and azimuth of the same side. A triangle side in at least every fifth triangle is normally designated a check base.

*g.* The *closing error* is the amount by which data determined by the triangulation differs from known data. Closing errors in azimuth, height, position, and/or length are normally determined when triangulation closes.

*h. Closure* is a term used to describe the tie-in of triangulation to known control.

*i. Distance angles* are the angles in a triangle opposite a side used as a base in the solution of the triangle or opposite a side the length of which is to be computed. In a chain of single triangles, as the computation proceeds through the chain, two sides of each triangle are used—a known side and a side to be determined. The angles opposite these sides are the distance angles.

*j. Error in position* is the difference between the position of a point determined by triangulation and the position of known control. Error in position is usually expressed in terms of the radial error.

*k.* A *figure* is a term used to identify one triangle or one quadrilateral in a chain of triangles.

*l. Intersection* is a method of survey which employs one triangular figure in which only two angles are measured. The size of the third angle is computed from the values of the two measured angles.

*m.* A *scheme* is a broad term applied to planned triangulation. A scheme of triangulation may include single triangles, a chain of triangles, and/or a chain of quadrilaterals.

*n. Spherical excess*, although not normally a concern of artillery surveyors, is a measure of the amount by which the sum of the three interior angles of a triangle exceeds 3,200 mils due to curvature of the earth.

*o. Square root of K* ( $\sqrt{K}$ ) is used in the evaluation of fourth-order surveys to apply the principle that errors accrue as a function of the square root of opportunity for error. K represents distance in kilometers.

*p. Square root of N* ( $\sqrt{N}$ ) is used in the evaluation of fourth-order surveys to apply the principle that errors accrue as a function of the square root of the opportunity for error. N represents the number of stations.

*q. Strength of figure* is an expression of the comparative precision of computed lengths in a triangulation net as determined by the size of the angles. Conditions other than size of angles are considered in surveys of a higher order than those encountered in artillery survey.

*r. Summation R1* ($\Sigma R1$) is a term used to denote the sum of the strength factors for the stronger route in a triangulation net. (The Greek letter sigma is used as the abbreviation.)

*s. Triangle closure* is a term associated with the amount by which the sum of the three angles of a plane triangle fails to equal 3,200 mils.

## 224. Triangulation Figures

*a. Acceptable Triangulation Figures.* The nature of the operation, which dictates the time available and the accuracy required, is generally the factor which governs the selection of the type of triangulation figure to be employed. Acceptable figures for use in artillery survey are as follows:

(1) *Single triangle.* The single triangle (fig. 64) is an acceptable figure but should be used only when time does not permit the use of a quadrilateral. The single triangle does not provide a check on the computed value of the unknown side as is afforded by other figures. A survey operation completed by the use of one single triangle is not considered to be a closed survey. For such a survey operation to be a closed survey, the unknown point should be surveyed by use of a quadrilateral or the survey should be extended and tied to a known point. The single tri-

GENERAL

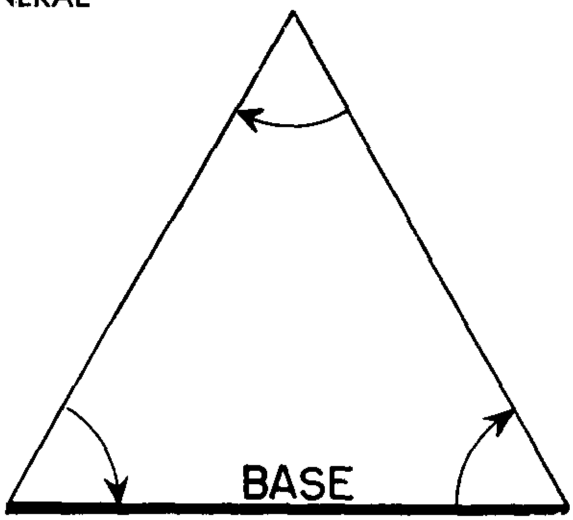



*Figure 64. A single triangle.*

angle can be used to advantage when an obtacle must be crossed in a taped traverse.

(2) *Quadrilateral.* One quadrilateral (fig. 65) can be used to extend survey control. Since the length of the required side can be computed through two pairs of triangles and a check made, a survey employing a quadrilateral is considered to be a closed survey.

(3) *Chain of single triangles.* In a chain of single triangles (fig. 66), as in a single triangle, the only check available is that afforded by the closure of each triangle to 3,200 mils. A survey operation completed by use of a chain of single triangles is not considered to be a closed survey unless a check base measurement is performed and the comparison results in a satisfactory check or unless the scheme is tied to existing control. When time permits, the added observations should be made to make the chain of single triangles a chain of quadrilaterals.

(4) *Chain of quadrilaterals.* Use of a chain of quadrilaterals (fig. 66) is favored for the extension of survey control since this figure has desirable check features. In practice, this figure is generally used when long distances over favorable terrain are to be covered. It is used primarily at division artillery and corps artillery levels. Its use in the field artillery battalion is generally limited to situations wherein time is not critical; which cause departure from established practice, e.g., BnSCP furnished 8 to 10 kilometers from battalion; or where it is desired to strengthen previously completed chains of single triangles.

(5) *Chain of polygons.* A polygon is a figure of three, four, five, or more sides. A network of these figures, with central points occupied, can be used effectively to extend control over a wide area and to tailor a survey scheme to the available terrain. The advantages of using a chain of polygons are similar to those of using the quadrilateral; i.e., side lengths can be computed through several different triangles.

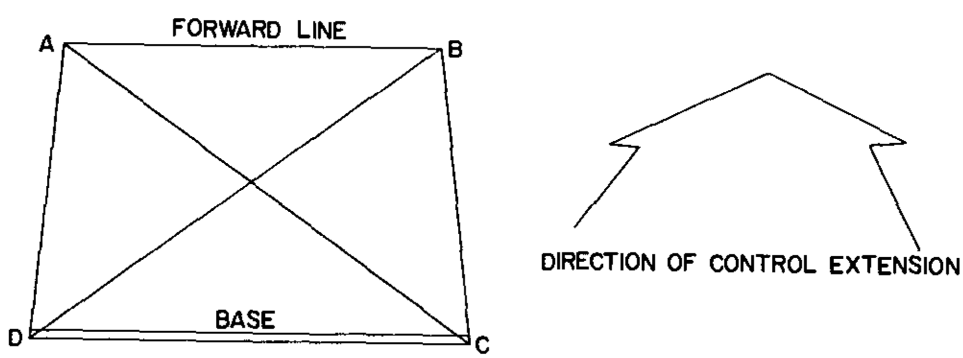
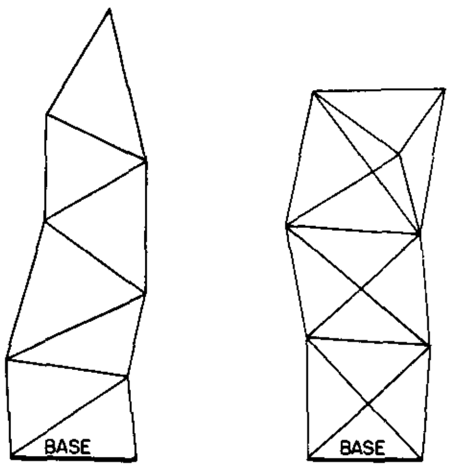



*Figure 65. A quadrilateral.*




CHAIN OF SINGLE TRIANGLES CHAIN OF QUADRILATERALS

*Figure 66. Triangulation schemes.*

*b. Strength of Triangulation Figures.* The sine function is used in the computation of triangle sides. Values computed from the sine of angles near 0 mil or 3,200 mils are subject to large ratios of error. For this reason, the distance angles in any triangulation figure must be greater than 400 mils.

## 225. Accuracy of Triangulation

Triangulation is performed in both artillery fifth- and fourth-order surveys. The relative merits of the triangulation method, as compared with other methods, e.g., traverse, are based only on the nature of the operation and the terrain and not on the degree of precision to be attained. The principal factors in the determination of the accuracy of triangulation are the average allowable triangle closure and the discrepancy between the measured length of a line and its length as computed through the scheme from a previously established base. These factors together with the adherence to prescribed specifications, define the order of accuracy of the triangulation. The complete specifications to achieve fifth- and fourth-order accuracies are shown in appendix II.

## 226. Reconnaissance and Planning

The reconnaissance consists of the selection of stations; the number and locations of the stations, in turn, determine the size and shape of the resulting triangles, the number of stations to be occupied, and the number of angles to be measured. During the reconnaissance, consideration is given to the intervisibility and accessibility of stations, the usefulness of the stations for other requirements, the strength of figure factors, the signals to be used at stations, and the suitability of the terrain for base line and check base measurements.

# Section II. SINGLE TRIANGLE

## 227. Fieldwork

*a.* The fieldwork for a single triangle is performed to determine the size of the interior horizontal angles, the size of the vertical angles, and the length and azimuth of a side. Figures 67 through 69 are samples of field notes taken during triangulation.

(1) *Horizontal angles.* At each of the three points forming the triangle, the horizontal angle between the other two points is measured. In triangles forming a part of a fifth-order survey, horizontal angles are measured one position with the T16 theodolite; for fourth-order survey, horizontal angles are measured two positions with the T2 theodolite with agreement between the positions held to 0.05 mil.

(2) *Vertical angles.* Vertical angles are measured once with the telescope in the direct position and once with the telescope in the reverse position for both fourth- and fifth-order surveys. Reciprocal vertical angles should be measured in order to cancel the effects of curvature and refraction.

(3) *Base length.* The length of the side of the triangle to be used as the base may be determined by computation from known coordinates, by double-taping, or by using electronic distance-measuring equipment.

DESIGNATION TRIANGULATION DATE 15 JUL 1959

WEATHER: CLEAR-HOT
INSTRUMENT NR.: M2 #1789

CHIEF OF PARTY: SGT. BROWN
OBSERVER: SGT JONES
RECORDER: CPL. SMITH
TAPE: PFC MILLER PFC OTTO

| STATION | R | HORIZONTAL ∡ (mil) | MEASURED VERT ∡ (mil) | CORRECTED VERT ∡ (mil) | DISTANCES METERS |
|---|---|---|---|---|---|
| AZ. MK. | 1 | 1358.0 | | | |
| BALL | 2 | 2715.5 | | | |
| RED | MN. ∡ | 1357.8 | | | |
| RED | 1 | 973.0 | +05.5 | +07.7 | 851.25 |
| BALL | 2 | 1946.0 | +05.0 | +07.2 | 851.37 |
| MET | MN. ∡ | 973.0 | +05.2 | +07.4 | 851.31 |
| MET | 1 | 1217.5 | -03.5 | -01.3 | |
| RED | 2 | 2434.5 | -04.0 | -01.8 | |
| BALL | MN. ∡ | 1217.2 | -03.8 | -01.6 | |
| BALL | 1 | 1009.0 | -01.0 | +1.2 | |
| MET | 2 | 2018.5 | -01.0 | +1.2 | |
| RED | MN ∡ | 1009.2 | -01.0 | +1.2 | |

REMARKS

VERTICAL ANGLE CORRECTION IS +2.2 MILS.
AZ. MK. IS WESTERNMOST OF TWO RADIO
TOWERS APRX 2 MILES NORTH OF STA. BALL
EXTREME TIP OF TOWER IS AZIMUTH MARK.

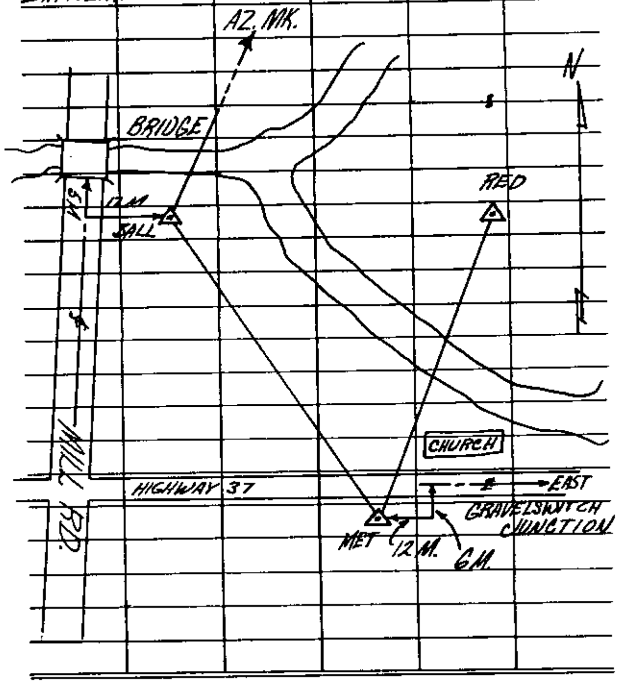



*Figure 67. Recorder's notes for aiming circle triangulation.*

(a) *Computation from known coordinates.* When both ends of the line selected as the base are known survey control points, the length of the base can be computed using DA Form 6–1. The stations selected must have been established as part of the same survey net and should be of an order higher than that of the survey being conducted.

(b) *Taping.* The base must be double-taped to a comparative accuracy of 1:7,000 for fourth-order survey and 1:3,000 for fifth-order survey.

(c) *Electronic distance measuring.* The length of the base of a triangle can be rapidly and accurately determined by using electronic distance-measuring equipment. Base length determination with the Tellurometer requires two coarse and four fine readings; with the DME, the line should be measured in both directions. These criteria apply to both fourth- and fifth-order surveys.

(4) *Base azimuth.* DA Form 6–1 may be used to determine the azimuth of the base when both ends of the base are known survey control points. When the base length is determined by taping or by using electronic distance-measuring instruments, the azimuth must be determined by astronomic means or, when celestial bodies are not usable, by gyroscopic means.

*b*. The complete specifications for fieldwork for fourth- and fifth-order surveys are shown in appendix II.

DESIGNATION TRIANGULATION DATE 24 JUL 19 60

| Station | T | Horizontal ∡ mils | mean | Vertical reading | Vertical ∡ mils |
|---|---|---|---|---|---|
| Dick | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| Tom | Mn ∡ | 733.8 | | | +15.6 |
| | | | | | |
| Harry | D | 734.8 | | 1584.4 | +15.6 |
| | R | 3934.8 | 734.8 | 4815.6 | +15.6 |
| | | | | | |
| Harry | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| Dick | Mn ∡ | 1091.5 | | | -19.5 |
| | | | | | |
| Tom | D | 1092.5 | | 1619.5 | -19.5 |
| | R | 4292.5 | 1092.5 | 4781.5 | -19.5 |
| | | | | | |
| Tom | D | 0001.0 | | | |
| | R | 3201.0 | 0001.0 | | |
| Harry | Mn ∡ | 1374.5 | | | +3.9 |
| | | | | | |
| Dick | D | 1375.5 | | 1596.1 | +3.9 |
| | R | 4575.5 | 1375.5 | 4803.9 | +3.9 |

Chief of Party: Sgt Jones
Weather: Clear-Warm Observer: Sgt Haines
Instrument Nr: T-16 #7439 Recorder: Cpl Matt

REMARKS

Tom is located 50M N of ℄ Merritt Rd and 75 M W of ℄ Adams Rd. Dick is located 35M E of ℄ Oak Rd and is located 45M S of SE edge of bridge. Harry is located 60M W of ℄ Adams Rd and 25M S of fence. All stations are 1" pipe in concrete flush with ground. Taped distance from Tom to Dick is 900.28 M Vertical angles are to HI.

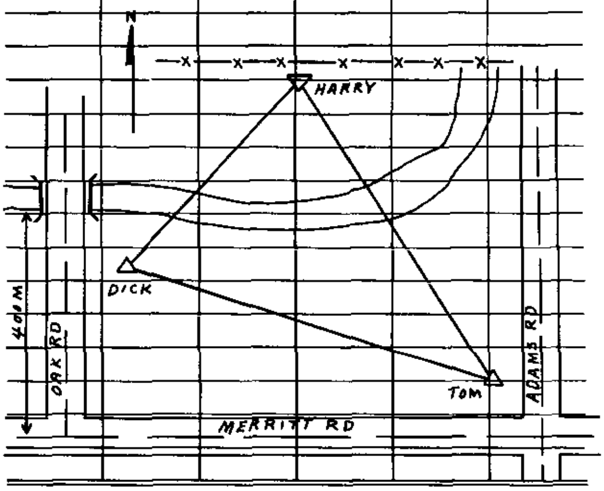



*Figure 68. Recorder's notes for fifth-order, T16 theodolite, triangulation.*

## 228. Computation of a Single Triangle

*a.* The purpose of triangulation computations is to determine the coordinates and height of an unknown point (fig. 70). The requirements for these computations are azimuth of the base, length of the base, value of the distance angles, and a vertical angle from one of the known points (A or B) to the unknown point.

*b.* The mathematical basis for determining the distance is the law of sines (fig. 71). The law of sines states that in a triangle the sides are proportional to the sines of the angles opposite them or, $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$.

The two parts of the formula that involve both known data and required data are selected, and the unknown element is isolated on one side of the equals sign. For example, if side BC is known and all the angles have been measured, the length of either side CA or BA can be computed.

To solve for side CA:

$$\frac{b}{\sin B} = \frac{a}{\sin A}$$

$$b \sin A = a \sin B$$

$$b = \frac{a \sin B}{\sin A}$$

To solve for side BA:

$$\frac{a}{\sin A} = \frac{c}{\sin C}$$

$$c \sin A = a \sin C$$

$$c = \frac{a \sin C}{\sin A}$$

*c.* After the length of the desired side is computed from the law of sines, the azimuth of the desired side is determined by applying the measured angle to the known base azimuth. The vertical angle is known from the fieldwork. The elements essential for the computation of easting, northing, and height are now known. The remainder of the computations is identical with the computations in a traverse problem.

CHIEF OF PARTY: SGT McDONALD

WEATHER: CLEAR-COOL OBSERVER: SGT KNOTT

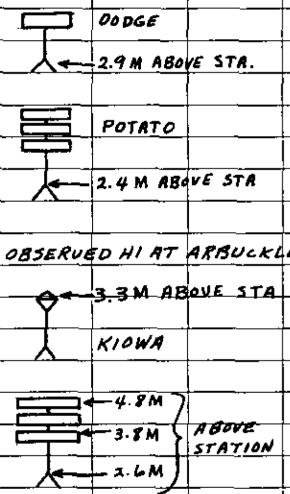
INSTRUMENT NO. T2 #1881 RECORDER: CPL THIEN

DESIGNATION TRIANGULATION DATE 25 JUL 19

| STATION | T | HORIZONTAL ∡ MILS | MEAN | VERTICAL READING | VERTICAL ∡ MILS |
|---|---|---|---|---|---|
| DODGE | D | 0000.105 | | 1567.146 | +32.854 |
| | R | 3200.121 | 0000.113 | 4832.888 | +32.888 |
| CADDO | MN | 1621.411 | | | +32.871 |
| POTATO | D | 1621.518 | 1621.524 | 1600.966 | -0.966 |
| | R | 4821.531 | | 4799.017 | -0.983 |
| CADDO | MN | 2360.443 | | | -0.974 |
| ARBUCKLE | D | 3981.966 | 3981.967 | 1551.792 | +48.208 |
| | R | 0781.968 | | 4848.169 | +48.169 |
| CADDO | MN | 1782.516 | | | +48.188 |
| KIOWA | D | 5764.475 | 5764.483 | 1621.390 | -21.390 |
| | R | 2564.491 | | 4778.832 | -21.168 |
| | | | | | -21.279 |

REMARKS

FIRST POSITIONS OF TWO POSITIONS. BASE LENGTH: CADDO-DODGE 3409.41 M (BT 1)




HEIGHT OF SIGNAL AT CADDO

HI = 1.5 M

RBM

*Figure 69. Recorder's notes for fourth-order, T2 theodolite, triangulation.*

These computations are fundamental to all triangulation operations from the simple single triangle to the most complex quadrilateral or central point figure.

*d.* The form provided to simplify and systematize the triangle solution is DA Form 6–8. The front side of DA Form 6–8 is designed for the solution of two single triangles. In figure 72, DA Form 6–8 is divided into four major parts labeled A through D. These parts are described in (1) through (4) below.

(1) *Part A.* Spaces are provided for entry of the three station names and are keyed to a triangle sketch. The base of the triangle is always the line CB. Angles from the field notebook are recorded in the OBSERVED ANGLES column. The sum of the observed angles is compared to 3,200 mils; if the difference is within the tolerable limits for the order of survey being conducted, the difference is divided by 3 and listed by each station under the CORRECTION column, preceded by the appropriate sign. When the difference is not evenly divisible by 3, the remainder is distributed to the larger angles. The results of applying the values in the correction column to the values in the observed angles column are listed in the CORRECTED ANGLES column, together with the total, 3,200 mils.

(2) *Part B.* Two determinations essential to solving the problem are made in part B. In the upper right corner of part B, spaces are provided for determining the logarithm of the UTM grid length of the base. The block to the left is used for the solution of the

DESIGNATION TRIANGULATION (CONT) DATE 25 JUL 19

| STATION | T | HORIZONTAL ∡ MILS | MEAN | MEAN HORIZONTAL ANGLE |
|---|---|---|---|---|
| DODGE | R | 4800.213 | | 1621.411 |
| | D | 1600.227 | 1600.220 | 1621.431 |
| CADDO | MN | 1621.431 | | 1621.421 |
| POTATO | R | 0031.629 | 3221.631 | 2360.443 |
| | D | 3221.633 | | 2360.446 |
| CADDO | MN | 2360.446 | | 2360.444 |
| ARBUCKLE | R | 2382.072 | 5582.077 | 1782.516 |
| | D | 5582.083 | | 1782.524 |
| CADDO | MN | 1782.524 | | 1782.520 |
| KIOWA | R | 4164.591 | 0964.601 | |
| | D | 0964.611 | | |

REMARKS

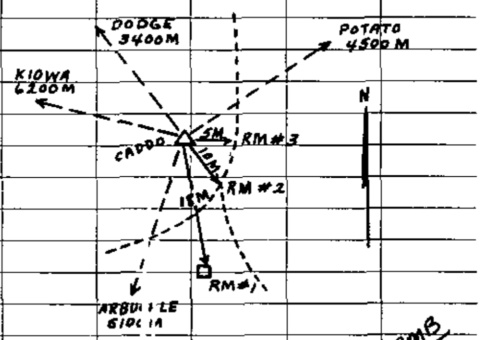
SECOND POSITION

STATION CADDO IS LOCATED IN THE SOUTH ARBUCKLE AREA OF FT SILL MILITARY RESERVATION, 1.6 MILES S. OF BALD RIDGE RANGE CENTRAL ON HIGHEST POINT OF GRASSY KNOLL W. OF RATTAN CREEK. STATION IS 1" BRONZE PLUG SET IN 10" X 10" CONCRETE BLOCK FLUSH WITH GROUND.

RM # 1 IS OLD TARGET TANK

RM # 2 IS FORK IN TRAIL

RM # 3 IS 2" PIPE STICKING 1' ABOVE GROUND ON W. SIDE OF TRAIL




RMB

*Figure 69*—Continued.

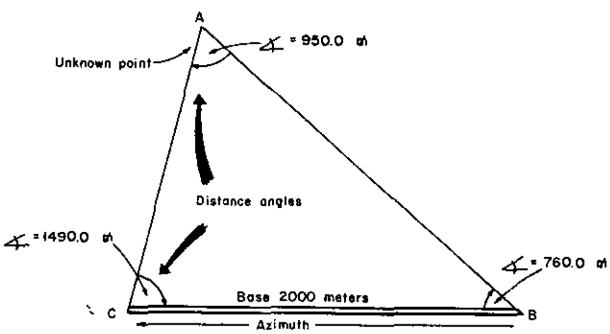
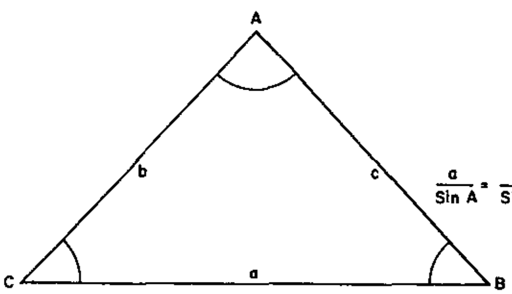



*Figure 70. Computation requirements.*




$$\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$$

*Figure 71. Law of sines.*

law of sines for either side CA or BA. Instructions relating to the side not being solved should be lined out.

(3) *Part C.* Part C provides spaces for determining the azimuth from B to A or from C to A. This azimuth must be determined before E and N can be computed. The base azimuth must be known and expressed as C to B, if coordinates are to be computed through side CA, or as B to C, if coordinates are to be computed through side BA. To the azimuth is added either the corrected angle at B or the corrected angle at C, subtracted from 6,400 mils. When the corrected angle at C is used, the auxiliary block TO FIND STATION ANGLE AT C is used. The sum is the azimuth from C to A or from B to A and will be used to determine the bearing angle.

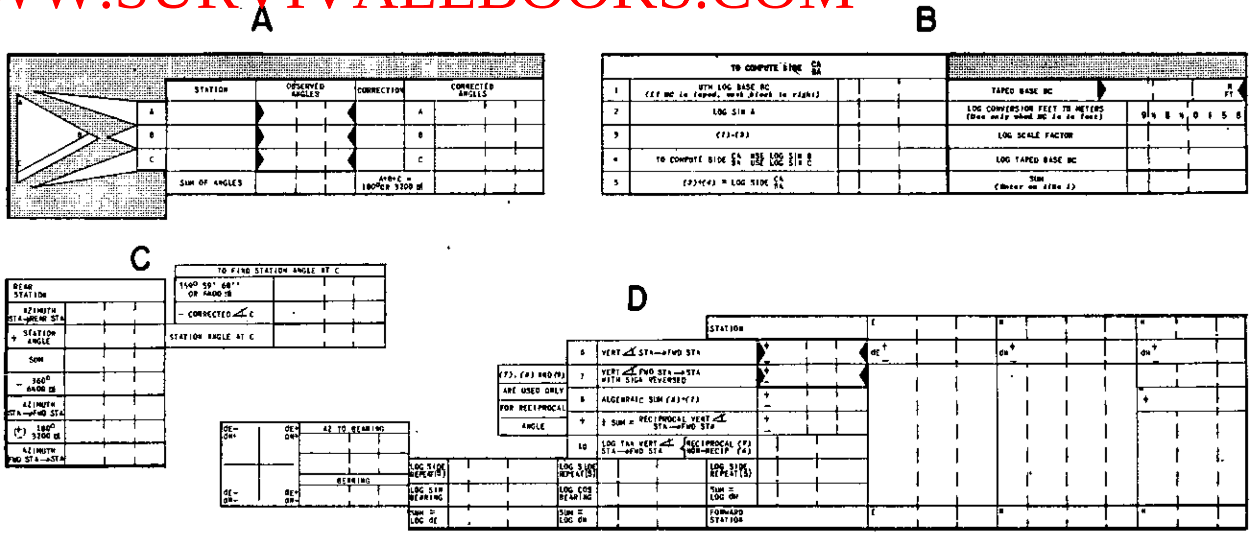



*Figure 72. Main parts of DA Form 6–8.*

(4) *Part D.* Part D is used to reduce the azimuth to a bearing and provides spaces for the computation of dE, dN, and dH and the application of these values to the E, N, and H of station B or C. Lines 6 through 10 are used to mean vertical angles which were observed in both directions (reciprocal). The computations are complete when the coordinates for E, N, and H of the forward station have been determined.

*e.* For height determination, the vertical angle is measured reciprocally to the height of instrument (HI) at each station or, if the distance is too great, the vertical angle is measured to the height of a target erected over the station. When the measurements are to HI, the heights of triangulation stations are computed on DA Form 6–8. If the length of the side is greater than 1,000 meters and if the vertical angle is not measured reciprocally, the table of curvature and refraction corrections on the back of DA Form 6–8 must be used. The log length of the side computed is used to enter the table. When the vertical angle is measured to a target erected over the station or to any point other than HI, the height of the unknown station is computed on DA Form 6–2b (fig. 59). Instructions for the use of DA Form 6–2b are on the back of the form (fig. 60). Height control is extended along the forward line of each triangle in the scheme; therefore, the computations for height control follow the same route (fig. 73) as those for coordinates.

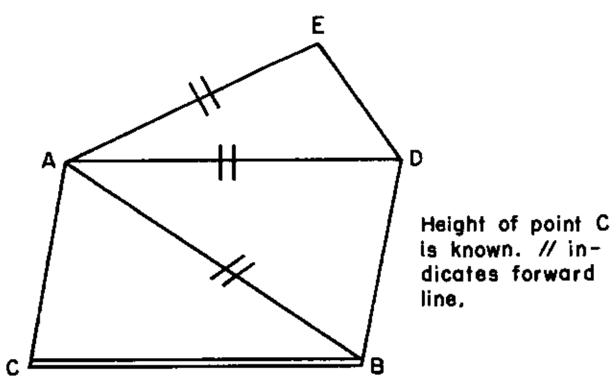



*Figure 73. Route of trigonometric height computations.*

*f.* The selection of side CA or side BA as the required side in a single triangle is governed by the strength of the angles at B and C. The side selected is the side opposite the stronger (nearer 1,600 mils) of the two angles. If the coordinates of only one end of the base are known, it may become necessary to use the opposite end of the base for the occupied station. Coordinates of that point are computed as in traverse. Figure 74 is a completed DA Form 6–8, showing the computations for a fifth-order triangulation scheme.

**COMPUTATION - PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES AND VERTICAL ANGLES**

| | STATION | OBSERVED ANGLES | CORRECTION | | CORRECTED ANGLES |
|---|---|---|---|---|---|
| A | STOP | 13 33 0 | +1 | A | 13 33 1 |
| B | LOOK | 9 78 9 | | B | 9 78 9 |
| C | LISTEN | 8 88 0 | | C | 8 88 0 |
| | SUM OF ANGLES | 31 99 9 | A+B+C = 180° OR 3200 mil | | 32 00 0 |

| TO COMPUTE SIDE CA/BA | | |
|---|---|---|
| 1 | UTM LOG BASE BC (If BC is taped, work block to right) | 3 075 729 |
| 2 | LOG SIN A | 9 984 917 |
| 3 | (1)-(2) | 3 090 812 |
| 4 | TO COMPUTE SIDE CA USE LOG SIN B; BA USE LOG SIN C | 9 913 699 |
| 5 | (3)+(4) = LOG SIDE CA/BA | 3 004 511 |

| | | FT |
|---|---|---|
| TAPED BASE BC | | |
| LOG CONVERSION FEET TO METERS (Use only when BC is in feet) | 9.484 0158 | |
| LOG SCALE FACTOR | | |
| LOG TAPED BASE BC | | |
| SUM (Enter on line 1) | | |

| REAR STATION | LOOK |
|---|---|
| AZIMUTH STA→REAR STA | 17 28 8 |
| + STATION ANGLE | 55 12 0 |
| SUM | 72 40 8 |
| - 360° 6400 mil | 64 00 0 |
| AZIMUTH STA→FWD STA | 8 40 8 |
| (±) 180° 3200 mil | 32 00 0 |
| AZIMUTH FWD STA→STA | 40 40 8 |

| TO FIND STATION ANGLE AT C | |
|---|---|
| 359° 59' 60" OR 6400 mil | 64 00 0 |
| - CORRECTED ∠ C | 8 88 0 |
| STATION ANGLE AT C | 55 12 0 |
| AZ TO BEARING | 8 40 8 |
| BEARING | 8 40 8 |

(7), (8) AND (9) ARE USED ONLY FOR RECIPROCAL ANGLE

| | | |
|---|---|---|
| 6 | VERT ∠ STA→FWD STA | + 25 7 |
| 7 | VERT ∠ FWD STA→STA WITH SIGN REVERSED | + 25 5 |
| 8 | ALGEBRAIC SUM (6)+(7) | + 51 2 |
| 9 | ½ SUM = RECIPROCAL VERT ∠ STA→FWD STA | + 25 6 |
| 10 | LOG TAN VERT ∠ STA→FWD STA {RECIPROCAL (9) / NON-RECIP (6)} | 8 400 332 |

| | | | | | |
|---|---|---|---|---|---|
| LOG SIDE REPEAT (5) | 3 004 511 | LOG SIDE REPEAT (5) | 3 004 511 | LOG SIDE REPEAT (5) | 3 004 511 |
| LOG SIN BEARING | 9 866 202 | LOG COS BEARING | 9 831 373 | SUM = LOG dH | 1 404 843 |
| SUM = LOG dE | 2.870 713 | SUM = LOG dN | 2.835 884 | FORWARD STATION | STOP |

| STATION | E | N | H |
|---|---|---|---|
| LISTEN | 552 820 9 | 3 834 018 6 | 387 4 |
| | dE + 742 5 | dN + 685 3 | dH + 25 4 |
| STOP | 553 563 4 | 3 834 703 9 | 412 8 |

| | STATION | OBSERVED ANGLES | CORRECTION | | CORRECTED ANGLES |
|---|---|---|---|---|---|
| A | | | | A | |
| B | | | | B | |
| C | | | | C | |
| | SUM OF ANGLES | | A+B+C = 180° OR 3200 mil | | |

| TO COMPUTE SIDE CA/BA | | |
|---|---|---|
| 1 | UTM LOG BASE BC (If BC is taped, work block to right) | |
| 2 | LOG SIN A | |
| 3 | (1)-(2) | |
| 4 | TO COMPUTE SIDE CA USE LOG SIN B; BA USE LOG SIN C | |
| 5 | (3)+(4) = LOG SIDE CA/BA | |

| | | M FT |
|---|---|---|
| TAPED BASE BC | | |
| LOG CONVERSION FEET TO METERS (Use only when BC is in feet) | 9.484 0158 | |
| LOG SCALE FACTOR | | |
| LOG TAPED BASE BC | | |
| SUM (Enter on line 1) | | |

| REAR STATION | |
|---|---|
| AZIMUTH STA→REAR STA | |
| + STATION ANGLE | |
| SUM | |
| - 360° 6400 mil | |
| AZIMUTH STA→FWD STA | |
| (±) 180° 3200 mil | |
| AZIMUTH FWD STA→STA | |

| TO FIND STATION ANGLE AT C | |
|---|---|
| 359° 59' 60" OR 6400 mil | |
| - CORRECTED ∠ C | |
| STATION ANGLE AT C | |
| AZ TO BEARING | |
| BEARING | |

(7), (8) AND (9) ARE USED ONLY FOR RECIPROCAL ANGLE

| | | |
|---|---|---|
| 6 | VERT ∠ STA→FWD STA | ± |
| 7 | VERT ∠ FWD STA→STA WITH SIGN REVERSED | ± |
| 8 | ALGEBRAIC SUM (6)+(7) | ± |
| 9 | ½ SUM = RECIPROCAL VERT ∠ STA→FWD STA | ± |
| 10 | LOG TAN VERT ∠ STA→FWD STA {RECIPROCAL (9) / NON-RECIP (6)} | |

| | | | | | |
|---|---|---|---|---|---|
| LOG SIDE REPEAT (5) | | LOG SIDE REPEAT (5) | | LOG SIDE REPEAT (5) | |
| LOG SIN BEARING | | LOG COS BEARING | | SUM = LOG dH | |
| SUM = LOG dE | | SUM = LOG dN | | FORWARD STATION | |

| STATION | E | N | H |
|---|---|---|---|
| | dE ± | dN ± | dH ± |
| | | | |

If dH is computed using the non-reciprocal vertical angle from STA to FWD STA; add correction for curvature and refraction when log side is more than 3.000

COMPUTER LECLAIR | CHECKER Hunt | SHEET ___ OF ___ SHEETS | DATE | AREA | NOTEBOOK REFERENCE

DA FORM 1 OCT 55 6-8 — REPLACES DA FORM 6-8, 1 NOV 53, WHICH WILL BE USED UNTIL EXHAUSTED.

*Figure 74. Completed DA Form 6–8 showing fifth order triangulation computations.*

## Section III. CHAINS OF TRIANGLES

### 229. Chain of Single Triangles

*a.* More distance can be covered and more survey control established by joining single triangles together with a common side. Triangles so connected are referred to as a chain of single triangles (fig. 75). In all the triangles except the final triangle of the scheme, the side common to two triangles is called the forward side and is the side whose length is determined in the computation. This side then becomes the base of the next triangle in the chain. Although the chain of single triangles offers but one route for the computation, strength of figure is a consideration in planning the chain.

*b.* The size of the distance angles in a triangle is used as the measure of relative strength. The strength factors of a triangle are determined by use of a strength of figure table (fig. 76). The distance angles of the triangle serve as arguments for entering the table—the small distance angle dictates the column; the larger distance angle, the row. The smaller the factor, the greater the relative strength of the triangle.

*c.* When the sum of the strength factors in a chain of single triangles exceeds 200 or at every fifth triangle, a check base should be measured. If the difference between the computed length and azimuth and the measured length and azimuth is within prescribed tolerances, the scheme may be continued, using the measured data. For fifth-order surveys, the computed length of the check base must agree with the measured length within 1:1,000 and the computed azimuth must agree with the astro or gyro azimuth within 0.1 mil times the number of angles used to carry the azimuth to the check base. For fourth-order surveys, the check comparisons are 1:3,000 and 0.1 mil $\times \sqrt{N}$ where N is the number of angles used to carry the azimuth to the check base.

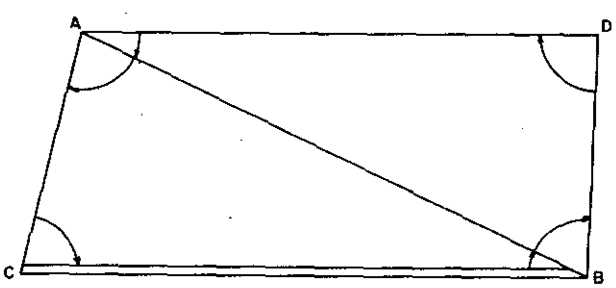



*Figure 75. Chain of single triangles.*

*d.* Computation of the chain of single triangles is performed on DA Form 6–8. The form is used as described in paragraph 228 except that the taped base block in the upper right corner is used only for the first triangle in the chain; for subsequent triangles, the log of the side to be used as the base is used from the preceding triangle.

*e.* A chain of single triangles does not provide sufficient internal checks to guard against survey blunders or a means of estimating the accuracy of the work. If convenient, the chain of triangles may be closed on a second known survey point and its accuracy may be computed by the traverse accuracy ratio formula. If this is done, the length of the survey used in the accuracy computation should be the sum of the lengths of the shortest triangle sides connecting the starting point with the closing point. The lengths can be determined from a map or computed by slide rule if they were not computed in the scheme. In general, a base check is simpler and provides an adequate check. The length of the terminal side of the final triangle is measured and compared with the length computed through the chain of triangles. The allowable closing error in position or the results of a base check are specified in appendix II for the order of survey being performed. In either case, if the chain of triangles consists of more than five triangles, the lengths of additional sides must be measured so that there are not more than five triangles between measured sides. The azimuth of the terminal leg should be determined by astronomic or gyroscopic observation at the earliest practicable time to guard against degrading the azimuth due to lack of refinements in the method of computations. Error in azimuth is determined by comparing the trig list azimuth or the astro or gyro azimuth with the azimuth from the scheme. The number of main scheme angles for the purpose of the check is equal to the number of triangles in the scheme. If the comparison of the measured values with the computed values agrees with the specifications

| Mils | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 150 | 605 | | | | | | | | | | | | | | | | | | | |
| 200 | 465 | 334 | | | | | | | | | | | | | | | | | | |
| 250 | 391 | 272 | 212 | | | | | | | | | | | | | | | | | |
| 300 | 347 | 233 | 176 | 143 | | | | | | | | | | | | | | | | |
| 350 | 320 | 210 | 155 | 123 | 104 | | | | | | | | | | | | | | | |
| 400 | 300 | 192 | 139 | 109 | 91 | 78 | | | | | | | | | | | | | | |
| 450 | 283 | 178 | 127 | 97 | 80 | 68 | 58 | | | | | | | | | | | | | |
| 500 | 272 | 169 | 119 | 90 | 73 | 61 | 52 | 46 | | | | | | | | | | | | |
| 550 | 264 | 162 | 112 | 84 | 68 | 56 | 47 | 41 | 37 | | | | | | | | | | | |
| 600 | 257 | 157 | 108 | 80 | 64 | 53 | 44 | 38 | 34 | 31 | | | | | | | | | | |
| 700 | 245 | 147 | 99 | 72 | 57 | 46 | 38 | 32 | 28 | 25 | 20 | | | | | | | | | |
| 800 | 236 | 139 | 93 | 67 | 52 | 41 | 33 | 28 | 24 | 21 | 17 | 13 | | | | | | | | |
| 900 | 229 | 133 | 88 | 62 | 48 | 38 | 30 | 25 | 21 | 19 | 14 | 11 | 9 | | | | | | | |
| 1000 | 223 | 129 | 84 | 59 | 45 | 35 | 27 | 23 | 19 | 17 | 12 | 9 | 7 | 6 | | | | | | |
| 1100 | 218 | 125 | 81 | 56 | 43 | 33 | 25 | 21 | 17 | 15 | 11 | 8 | 6 | 5 | 4 | | | | | |
| 1200 | 215 | 123 | 79 | 55 | 41 | 31 | 24 | 20 | 16 | 14 | 10 | 7 | 5 | 4 | 3 | 2 | | | | |
| 1300 | 211 | 119 | 76 | 52 | 39 | 29 | 22 | 18 | 15 | 13 | 9 | 6 | 4 | 3 | 2 | 2 | 1 | | | |
| 1400 | 207 | 117 | 74 | 51 | 37 | 28 | 21 | 17 | 14 | 12 | 8 | 5 | 4 | 3 | 2 | 1 | 1 | 0 | | |
| 1500 | 205 | 115 | 72 | 49 | 36 | 27 | 20 | 16 | 13 | 11 | 7 | 5 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | |
| 1600 | 202 | 112 | 71 | 48 | 35 | 26 | 19 | 15 | 12 | 10 | 7 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1700 | 199 | 110 | 69 | 46 | 34 | 25 | 19 | 14 | 12 | 10 | 6 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | |
| 1800 | 196 | 108 | 67 | 45 | 33 | 24 | 18 | 14 | 11 | 9 | 6 | 4 | 2 | 2 | 1 | 1 | 0 | 0 | | |
| 1900 | 193 | 106 | 66 | 44 | 32 | 23 | 17 | 13 | 11 | 9 | 6 | 4 | 2 | 1 | 1 | 1 | 0 | | | |
| 2000 | 190 | 104 | 64 | 42 | 30 | 22 | 16 | 13 | 10 | 8 | 5 | 3 | 2 | 2 | 1 | 1 | | | | |
| 2100 | 187 | 102 | 63 | 41 | 30 | 22 | 16 | 12 | 10 | 8 | 5 | 3 | 2 | 2 | 1 | | | | | |
| 2200 | 184 | 99 | 61 | 40 | 29 | 21 | 15 | 12 | 9 | 8 | 5 | 3 | 2 | 2 | | | | | | |
| 2300 | 180 | 97 | 59 | 39 | 28 | 20 | 15 | 11 | 9 | 8 | 5 | 4 | 3 | | | | | | | |
| 2400 | 176 | 95 | 57 | 38 | 27 | 20 | 15 | 11 | 9 | 8 | 6 | 4 | | | | | | | | |
| 2500 | 171 | 92 | 55 | 36 | 26 | 20 | 15 | 12 | 10 | 9 | 7 | | | | | | | | | |
| 2600 | 166 | 89 | 54 | 36 | 26 | 20 | 16 | 13 | 11 | 10 | | | | | | | | | | |
| 2650 | 164 | 88 | 53 | 36 | 26 | 20 | 16 | 14 | 12 | | | | | | | | | | | |
| 2700 | 161 | 86 | 53 | 36 | 27 | 21 | 17 | 15 | | | | | | | | | | | | |
| 2750 | 159 | 85 | 53 | 37 | 28 | 23 | 19 | | | | | | | | | | | | | |
| 2800 | 155 | 84 | 54 | 38 | 31 | 26 | | | | | | | | | | | | | | |
| 2850 | 153 | 85 | 56 | 42 | 35 | | | | | | | | | | | | | | | |
| 2900 | 151 | 87 | 60 | 48 | | | | | | | | | | | | | | | | |
| 2950 | 153 | 94 | 71 | | | | | | | | | | | | | | | | | |
| 3000 | 163 | 112 | | | | | | | | | | | | | | | | | | |
| 3050 | 202 | | | | | | | | | | | | | | | | | | | |

*Figure 76. Table for determining strength of figure factors (mils).*

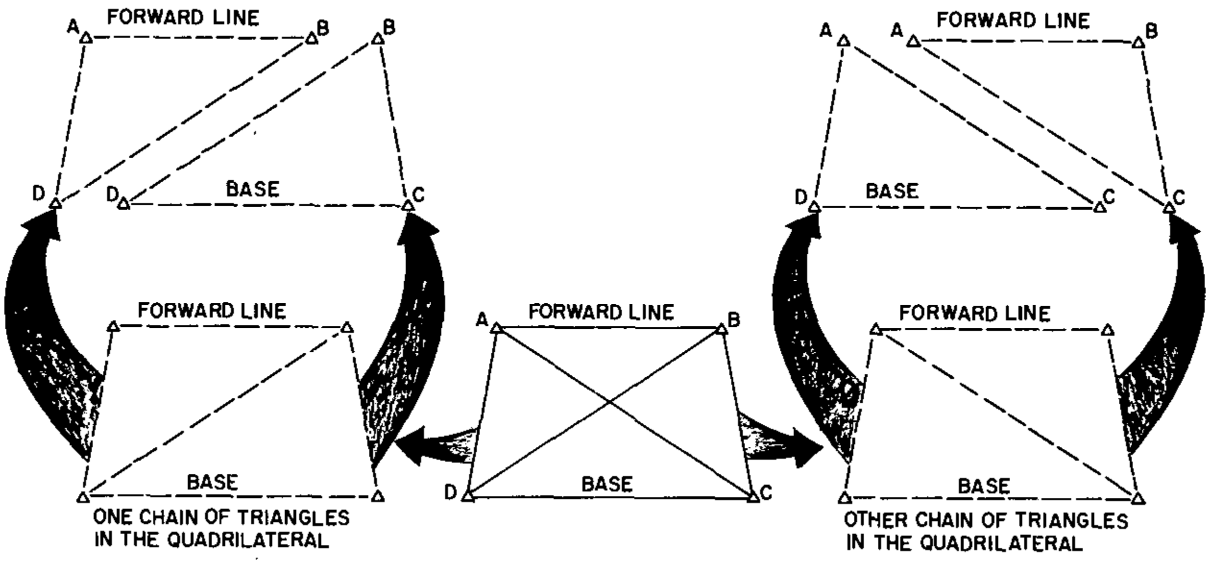



*Figure 77. A quadrilateral separated into two single chains of two triangles each.*

in appendix II, the scheme should be continued, using the measured data. Adjustment of computed values to measured values may be performed at the SIC using machine-programmed computers.

## 230. Chain of Quadrilaterials

*a.* A quadrilateral is a four-sided figure used for the extension of survey control. In artillery surveys, both diagonals of the figure must be observed. Each diagonal divides the figure into two triangles with the diagonal common to both triangles. Figure 77 shows a quadrilateral divided by its diagonals.

*b.* The requirements for the computation of a quadrilateral are the same as those for the computation of a single triangle; i.e., the length of the base, the azimuth of the base, and the

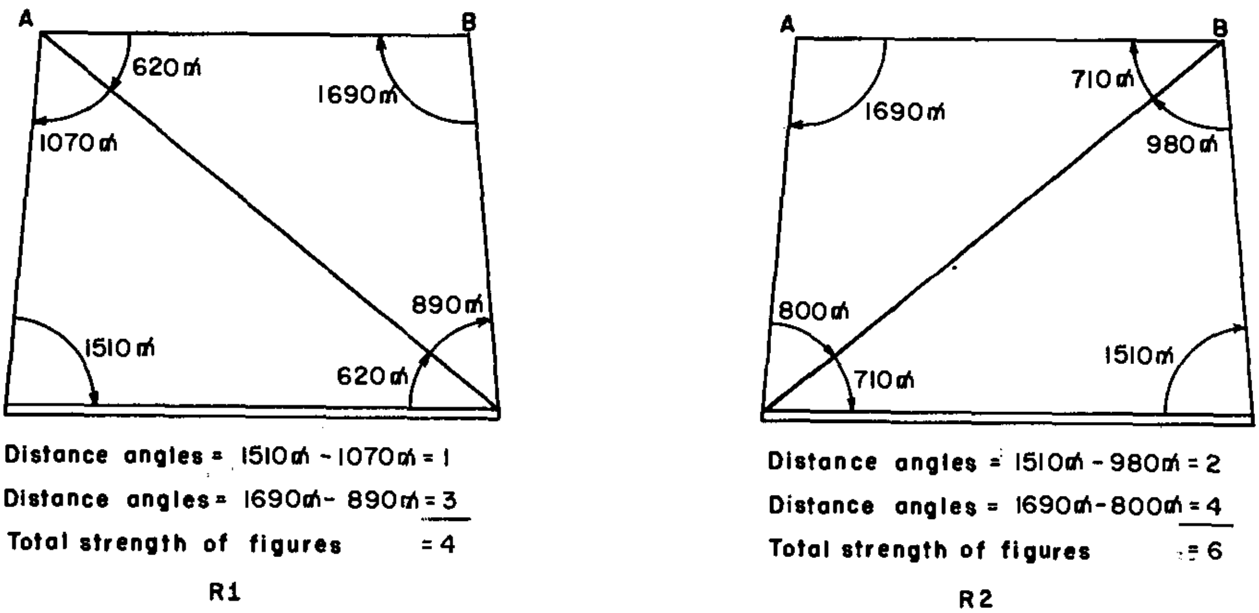
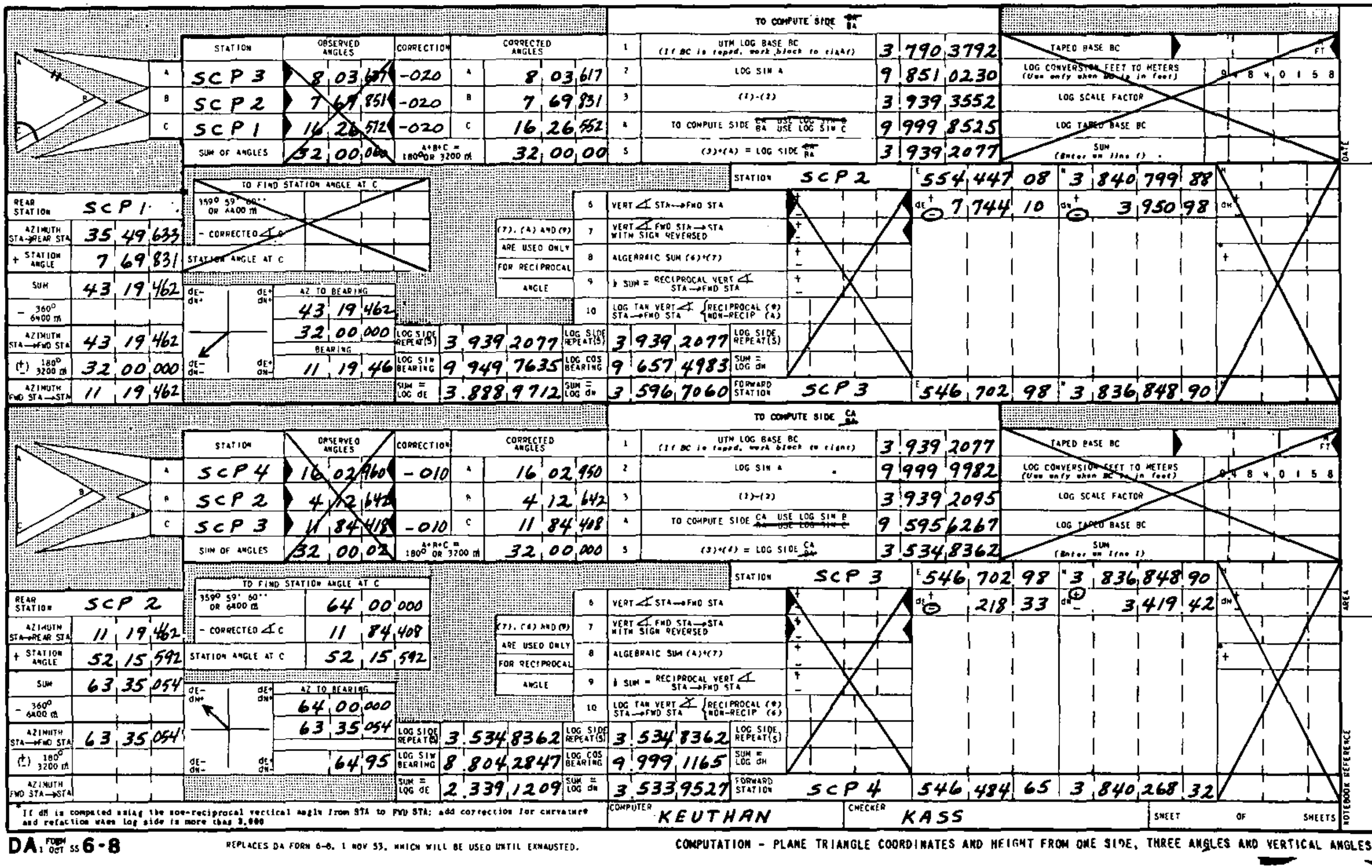



*Figure 78. Determination of R1 and R2 chains.*



**Upper triangle — To compute side BA**

| Station | | Observed angles | Correction | | Corrected angles |
|---|---|---|---|---|---|
| A | SCP 3 | 8 03 637 | -020 | A | 8 03 617 |
| B | SCP 2 | 7 69 851 | -020 | B | 7 69 831 |
| C | SCP 1 | 16 26 572 | -020 | C | 16 26 552 |
| Sum of angles | | 32 00 060 | A+B+C = 180° or 3200 ㎖ | | 32 00 00 |

| | | |
|---|---|---|
| 1 | UTM log base BC (If BC is taped, work block to right) | 3 790 3792 |
| 2 | Log sin A | 9 851 0230 |
| 3 | (1)-(2) | 3 939 3552 |
| 4 | To compute side BA use log sin C | 9 999 8525 |
| 5 | (3)+(4) = log side BA | 3 939 2077 |

| | |
|---|---|
| Taped base BC | |
| Log conversion feet to meters (Use only when BC is in feet) | 9 8 4 0 1 5 8 |
| Log scale factor | |
| Log taped base BC | |
| Sum (Enter on line 1) | |

| | | | |
|---|---|---|---|
| Rear station | SCP 1 | To find station angle at C | |
| Azimuth sta→rear sta | 35 49 633 | 359° 59' 60'' or 6400 ㎖ | |
| + Station angle | 7 69 831 | - Corrected ∠ C | |
| Sum | 43 19 462 | Station angle at C | |
| - 360° 6400 ㎖ | | Az to bearing | 43 19 462 |
| Azimuth sta→fwd sta | 43 19 462 | | 32 00 000 |
| (±) 180° 3200 ㎖ | 32 00 000 | Bearing | 11 19 46 |
| Azimuth fwd sta→sta | 11 19 462 | | |

| | | | | | |
|---|---|---|---|---|---|
| Log side repeat (5) | 3 939 2077 | Log side repeat (5) | 3 939 2077 | Log side repeat (5) | |
| Log sin bearing | 9 949 7635 | Log cos bearing | 9 657 4983 | Sum = log dH | |
| Sum = log dE | 3 888 9712 | Sum = log dN | 3 596 7060 | Forward station | SCP 3 |

| | | |
|---|---|---|
| 6 | Vert ∠ sta→fwd sta | |
| 7 | Vert ∠ fwd sta→sta with sign reversed | |
| 8 | Algebraic sum (6)+(7) | |
| 9 | ½ sum = reciprocal vert ∠ sta→fwd sta | |
| 10 | Log tan vert ∠ sta→fwd sta {reciprocal (9) non-recip (6)} | |

(7), (8) and (9) are used only for reciprocal angle

| Station | E | N |
|---|---|---|
| SCP 2 | 554 447 08 | 3 840 799 88 |
| | dE ⊖ 7 744 10 | dN ⊖ 3 950 98 |
| SCP 3 | 546 702 98 | 3 836 848 90 |

**Lower triangle — To compute side CA**

| Station | | Observed angles | Correction | | Corrected angles |
|---|---|---|---|---|---|
| A | SCP 4 | 16 02 960 | -010 | A | 16 02 950 |
| B | SCP 2 | 4 12 642 | | B | 4 12 642 |
| C | SCP 3 | 11 84 418 | -010 | C | 11 84 408 |
| Sum of angles | | 32 00 020 | A+B+C = 180° or 3200 ㎖ | | 32 00 000 |

| | | |
|---|---|---|
| 1 | UTM log base BC (If BC is taped, work block to right) | 3 939 2077 |
| 2 | Log sin A | 9 999 9982 |
| 3 | (1)-(2) | 3 939 2095 |
| 4 | To compute side CA use log sin B | 9 595 6267 |
| 5 | (3)+(4) = log side CA | 3 534 8362 |

| | |
|---|---|
| Taped base BC | |
| Log conversion feet to meters (Use only when BC is in feet) | 9 8 4 0 1 5 8 |
| Log scale factor | |
| Log taped base BC | |
| Sum (Enter on line 1) | |

| | | | |
|---|---|---|---|
| Rear station | SCP 2 | To find station angle at C | |
| Azimuth sta→rear sta | 11 19 462 | 359° 59' 60'' or 6400 ㎖ | 64 00 000 |
| + Station angle | 52 15 592 | - Corrected ∠ C | 11 84 408 |
| Sum | 63 35 054 | Station angle at C | 52 15 592 |
| - 360° 6400 ㎖ | | Az to bearing | 64 00 000 |
| Azimuth sta→fwd sta | 63 35 054 | | 63 35 054 |
| (±) 180° 3200 ㎖ | | Bearing | 64 95 |
| Azimuth fwd sta→sta | | | |

| | | | | | |
|---|---|---|---|---|---|
| Log side repeat (5) | 3 534 8362 | Log side repeat (5) | 3 534 8362 | Log side repeat (5) | |
| Log sin bearing | 8 804 2847 | Log cos bearing | 9 999 1165 | Sum = log dH | |
| Sum = log dE | 2 339 1209 | Sum = log dN | 3 533 9527 | Forward station | SCP 4 |

| | | |
|---|---|---|
| 6 | Vert ∠ sta→fwd sta | |
| 7 | Vert ∠ fwd sta→sta with sign reversed | |
| 8 | Algebraic sum (6)+(7) | |
| 9 | ½ sum = reciprocal vert ∠ sta→fwd sta | |
| 10 | Log tan vert ∠ sta→fwd sta {reciprocal (9) non-recip (6)} | |

(7), (8) and (9) are used only for reciprocal angle

| Station | E | N |
|---|---|---|
| SCP 3 | 546 702 98 | 3 836 848 90 |
| | dE ⊖ 218 33 | dN ⊕ 3 419 42 |
| SCP 4 | 546 484 65 | 3 840 268 32 |

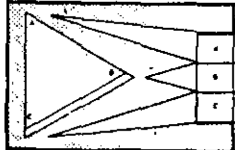
*If dH is computed using the non-reciprocal vertical angle from STA to FWD STA: add correction for curvature and refraction when log side is more than 3,000

Computer: KEUTHAN  Checker: KASS  Sheet ___ of ___ sheets  Date  Area  Notebook reference

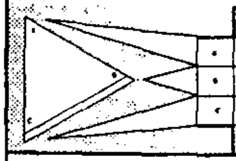
DA FORM 1 OCT 55 6-8  REPLACES DA FORM 6-8, 1 NOV 53, WHICH WILL BE USED UNTIL EXHAUSTED.  COMPUTATION - PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES AND VERTICAL ANGLES

*Figure 79. Solution of R1 chain, fourth-order survey.*

## AUXILIARY COMPUTATION



| | STATION | OBSERVED ANGLES | | | CORRECTION | | CORRECTED ANGLES | | | | TO COMPUTE SIDE CA/BA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | SCP 4 | 8 | 12 | 701 | -.01 | A | 8 | 12 | 691 | 1 | WITH LOG BASE BC | 3 | 790 | 3792 |
| B | SCP 2 | 11 | 82 | 491 | -.02 | B | 11 | 82 | 471 | 2 | LOG SIN A | 9 | 854 | 8288 |
| C | SCP 1 | 12 | 04 | 858 | -.02 | C | 12 | 04 | 838 | 3 | (1) - (2) | 3 | 935 | 5504 |
| | SUM OF ANGLES | 32 | 00 | 05 | A + B + C 180° OR 3200 ⊕ | | 32 | 00 | 000 | 4 | TO COMPUTE SIDE CA USE LOG SIN B | 9 | 962 | 4437 |
| | | | | | | | | | | 5 | (3) + (4) = LOG SIDE CA | 3 | 897 | 9941 |



| | STATION | OBSERVED ANGLES | | | CORRECTION | | CORRECTED ANGLES | | | | TO COMPUTE SIDE BA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1 | WITH LOG BASE BC | 3 | 897 | 9941 |
| A | SCP 3 | 19 | 88 | 052 | -.020 | A | 19 | 88 | 032 | 2 | LOG SIN A | 9 | 967 | 6943 |
| B | SCP 4 | 7 | 90 | 281 | -.020 | B | 7 | 90 | 261 | 3 | (1) - (2) | 3 | 930 | 2998 |
| C | SCP 1 | 4 | 21 | 717 | -.010 | C | 4 | 21 | 707 | 4 | TO COMPUTE SIDE BA USE LOG SIN C | 9 | 604 | 5353 |
| | SUM OF ANGLES | 32 | 00 | 050 | A + B + C 180° OR 3200 ⊕ | | 32 | 00 | 000 | 5 | (3) + (4) = LOG SIDE BA | 3 | 534 | 8351 |

| STATION | | H |
|---|---|---|
| VERT ∠ STA → FWD STA | + − | HI + − |
| VERT ∠ FWD STA → STA WITH SIGN REVERSED | + − | |
| ALGEBRAIC SUM | + − | ± |
| ½ SUM = RECIPROCAL VERT ∠ STA → FWD STA | + − | |
| LOG TAN VERT STA → FWD STA (RECIPROCAL / NON-RECIP) | | |
| LOG SIDE REPEAT (5) | | |
| SUM = LOG dH | | |
| FORWARD STATION | | H |

| COMPARISON OF SIDE LENGTHS | | | |
|---|---|---|---|
| ROUTE 1 | 3 | 534 | 8362 |
| ROUTE 2 | 3 | 534 | 8351 |
| DIFFERENCE | 0 | 000 | 0011 |

TABLE - CORRECTION FOR CURVATURE AND REFRACTION

(*No interpolation necessary for Artillery Survey*)
Use only when dH is computed using non-Reciprocal vertical angles (Sign always plus).

| LOG SIDE (M) | CORR (M) | LOG SIDE (M) | CORR (M) |
|---|---|---|---|
| 3.079 | .1 | 3.712 | 1.8 |
| 3.230 | .2 | 3.736 | 2.0 |
| 3.322 | .3 | 3.784 | 2.5 |
| 3.386 | .4 | 3.824 | 3.0 |
| 3.435 | .5 | 3.857 | 3.5 |
| 3.473 | .6 | 3.886 | 4.0 |
| 3.508 | .7 | 3.912 | 4.5 |
| 3.537 | .8 | 3.934 | 5.0 |
| 3.562 | .9 | 3.955 | 5.5 |
| 3.584 | 1.0 | 3.974 | 6.0 |
| 3.625 | 1.2 | 3.992 | 6.5 |
| 3.658 | 1.4 | 4.007 | 7.0 |
| 3.687 | 1.6 | | |

GIVEN:

Coordinates and Height of STATION.
Azimuth STATION to REAR STATION.

FIELD DATA:

Observe horizontal angles A, B, and C.
Observe vertical angles to all stations of triangle.
Measure height of target (to the nearest 0.1 meter) if vertical angles are measured *at a point other than HI.*
Tape base (BC) unless known from other computations.

GUIDE:

Enter field data in blocks marked.
BC is always the know base.
REAR STATION is station in triangle to which azimuth is known.
*STATION is the station for which survey control is known.*
FORWARD STATION is the station for which survey control is desired.
RECIPROCAL ANGLE is the mean of the vertical angles observed from each end of a side.
NON-RECIPROCAL ANGLE is a vertical angle which has been measured from station to forward station only.
Best results are obtained when RECIPROCAL ANGLES are used to compute height.
Divide the difference between SUM OF ANGLES and (180°) (3200⊕) into three parts and apply as CORRECTION to the OBSERVED ANGLES to obtain CORRECTED ANGLES.
Compute the side (CA or BA) which forms the base of the next triangle.

LIMITATIONS

DISTANCE ANGLES (angles opposite the known base and the computed side) should be greater than (22 1/2°) (400 ⊕) or accuracy may fall below standard.
When reciprocal or non-reciprocal angles are measured to a height of target other than HI use DA Form 6-2b to compute height.

RESULTS:

Coordinates and height of FORWARD STATION.
Azimuth from FORWARD STATION (A) to STATION (B or C).

FORMULAS:

Side CA = $\frac{\text{base BC}}{\text{Sin A}}$ x Sin B; Side BA = $\frac{\text{base BC}}{\text{Sin A}}$ x Sin C

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*Figure 80. Solution of R2 chain, fourth-order survey.*

coordinates of at least one of the ends of the base. The side of the quadrilateral opposite the base in a single quadrilateral or the side common to two quadrilaterals is designated the forward line. The forward line is computed through both pairs of triangles. This gives a basis for checking the length of the forward line. Failure of the two computed lengths to agree indicates either an error in computing or an error in the fieldwork.

*c.* One of the pairs of triangles is of better geometric shape than the other, thus giving better relative strength of figure. The pair determined to be the stronger is designated the R1 chain; the other the R2 chain. Positions are computed only through the R1 chain; the forward line is computed through both chains. The selection of R1 is based on strength factors determined from the strength of figure factors table (fig. 76). The two distance angles of each triangle, rounded off to the nearest value tabulated in the strength of figure table, are used to enter the table. The factors obtained for each triangle of a given chain are then added, and the chain containing the smaller total value is the stronger, or R1, chain. Figure 78 illustrates the determination of strength factors.

*d.* DA Form 6–8 is use for the computation of a quadrilateral. The two triangles forming the R1 chain are computed on the front of the form; the triangles forming the R2 chain, on the back of the form. Only the log length of the forward line of the R2 chain is computed. Spaces are provided on the back of the form for comparing the log lengths of the forward line, as determined through R1 and R2. If the two log lengths agree within 5 in the fifth place of the mantissa, the computations and fieldwork are considered to be correct and E, N and H can then be computed, using the R1 chain. If the comparison results in a greater difference than 5 in the fifth place of the mantissa, the computations and/or fieldwork must be checked. Computations of a quadrilateral are illustrated in figures 79 and 80.

*e.* A survey operation in which quadrilaterals are used should be tied to existing control when possible. A completed quadrilateral is considered to be a closed survey; however a check base should be included to obtain a measure of the accuracy of the scheme. Check bases should be included at every fifth quadrilateral or when the summation of the R1 values in the scheme exceeds 200.

*f.* When it is impossible to observe the diagonals of a quadrilateral, the central point is used. Two central point figures commonly used are shown in figures 81 and 82. Central point figures of six or more sides are not generally used because of the excessive time and the number of personnel required to accomplish the fieldwork. The solution of the central point scheme is similar to the solution of the basic quadrilateral. The R1 and the R2 chains must be determined. In figures 81 and 82, each scheme contains two chains of triangles, one going clockwise around the central point and the other going counterclockwise. In figure 82, if AB were the base and DC the forward line,

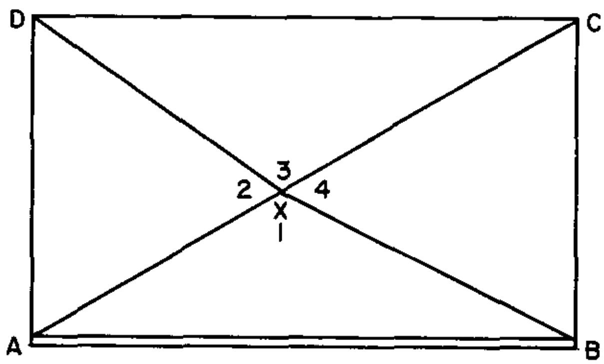



*Figure 81. Central point quadrilateral.*

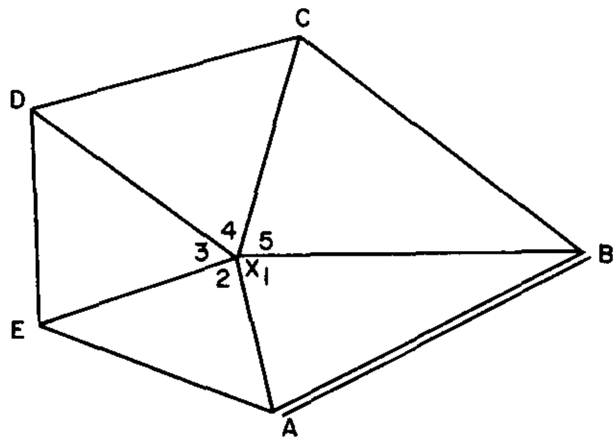



*Figure 82. Central point pentagon.*

the chain of triangles going clockwise would contain four triangles and the chain of triangles going counterclockwise would contain only three triangles. However, the relative strength of the chain of four triangles when compared with the relative strength of the chain of three triangles, may make it the R1 chain.

## Section IV. INTERSECTION

### 231. General

Intersection is a method of triangulation in which only two angles in a triangle are measured. The third angle is determined by subtracting the sum of the two measured angles from 3,200 mils (180°).

### 232. Specifications

See appendix II for specifications and techniques in triangulation.

### 233. Intersection Field Notes

Intersection field notes are maintained in the same manner as triangulation field notes (figs. 67, 68, and 69).

### 234. Limitations

As in triangulation, no distance angle in the triangle should be less than 400 mils (22½°) or greater than 2,800 mils (157½°); an angle between 533 mils (30°) and 2,667 mils (150°) is preferred. The only exception to this is when intersection is used in target area survey when the apex angle should not be less than 150 mils and should preferably be at least 300 mils.

### 235. Intersection Computations

Intersection computations are the same as those used for triangulation except that, on the DA Form 6–8, the unmeasured angle must be computed and the angles in the triangle are not adjusted.

## Section V. RESECTION

### 236. Three-Point Resection

Three-point resection is a method of obtaining control from three visible known points. The fieldwork required for the solution is relatively simple. However, before the fieldwork is begun, several factors must be considered. A map reconnaissance is of prime importance. In figure 83, points A, B, and C are the known points and point P is the occupied station for which coordinates are to be determined. All points should be selected so that angles P1, P2, C, and B are at least 400 mils (22½°) and preferably greater than 533 mils (30°). In addition, if the sum of the angles P1, P2, and A1 is between 2,845 mils and 3,555 mils (160° and 200°), no valid solution is possible. Fieldwork consists of measuring angles P1 and P2 and the vertical angle from P to the known point for which the height is also known, preferably point A.

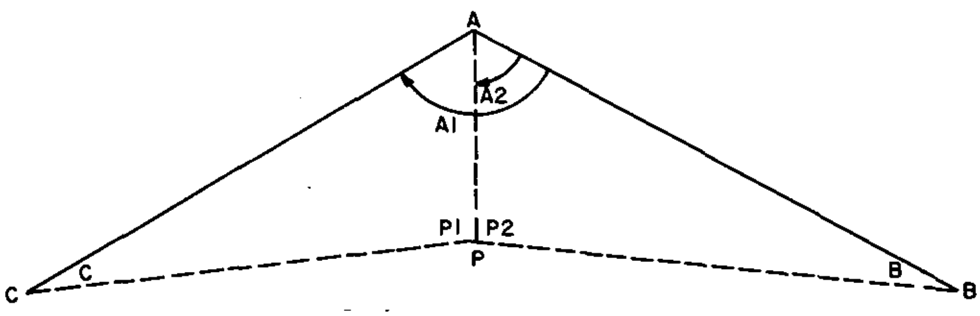
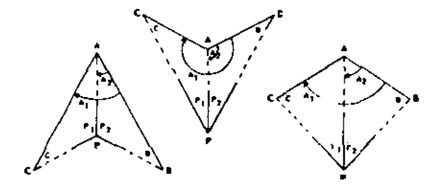



*Figure 83. A three-point resection.*

## COMPUTATION—COORDINATES AND HEIGHT FROM THREE-POINT RESECTION

| | | |
|---|---|---|
| 1 | AZIMUTH A TO C (FROM AUX COMP ON REV) | 18 56 02 |
| 2 | 360° OR 6400mil | |
| 3 | IF (1) IS: MORE THAN (4) / LESS THAN (4); (3) IS: REPEAT (1) / (1) + (2) | 18 56 02 |
| 4 | AZIMUTH A TO B (FROM AUX COMP ON REV) | 14 61 52 |
| 5 | (3) − (4) = ANGLE A1 | 3 94 50 |
| 6 | OBSERVED ANGLE P1 | 8 53 58 |
| 7 | OBSERVED ANGLE P2 | 12 62 86 |
| 8 | (5) + (6) + (7) DO NOT ATTEMPT TO SOLVE PROBLEM WHEN THIS VALUE IS BETWEEN {160° / 2845mil} AND {200° / 3555mil} | 25 10 94 |
| 9 | 180° OR 3200mil | 32 00 00 |
| 10 | 1/2 OF (8) | 12 55 47 |
| 11 | (9) − (10) | 19 44 53 |
| 12 | LOG GRID DISTANCE A TO C (FROM AUX COMP ON REV) | 3.839 6619 |
| 13 | LOG SIN (7) | 9.975 7636 |
| 14 | (12) + (13) | 3.815 4255 |
| 15 | LOG GRID DISTANCE A TO B (FROM AUX COMP ON REV) | 3.862 7442 |
| 16 | LOG SIN (6) | 9.871 1681 |
| 17 | (15) + (16) | 3.733 9123 |

SKETCH:



| IF (14) IS MORE THAN (17) | | | IF (14) IS LESS THAN (17) | | |
|---|---|---|---|---|---|
| 18 | REPEAT (14) | 3.815 4255 | 18 | REPEAT (17) | |
| 19 | REPEAT (17) | 3.733 9123 | 19 | REPEAT (14) | |
| 20 | (18) − (19) | 0.081 5132 | 20 | (18) − (19) | |
| 21 | ANGLE HAVING LOG TAN (20) | 8 95 04 | 21 | ANGLE HAVING LOG TAN (20) | |
| 22 | 45° OR 800mil | 8 00 00 | 22 | 45° OR 800mil | |
| 23 | (21) − (22) | 95 04 | 23 | (21) − (22) | |
| 24 | LOG TAN (23) | 8.971 1692 | 24 | LOG TAN (23) | |
| 25 | LOG TAN (11) | 0.453 7540 | 25 | LOG TAN (11) | |
| 26 | (24) + (25) | 9.424 9232 | 26 | (24) + (25) | |
| 27 | REPEAT (11) | 19 44 53 | 27 | REPEAT (11) | |
| 28 | ANGLE HAVING LOG TAN (26) | 2 64 83 | 28 | ANGLE HAVING LOG TAN (26) | |
| 29 | IF (27) IS: MORE THAN / LESS THAN {90° / 1600mil}; (29) IS: (22) + (28) / (27) − (28) | 22 09 36 | 29 | IF (27) IS: MORE THAN / LESS THAN {90° / 1600mil}; (29) IS: (27) − (28) / (27) + (28) | |
| 30 | IF (27) IS: MORE THAN / LESS THAN {90° / 1600mil}; 30 IS: (27) − (28) / (27) + (28) | 16 79 70 | 30 | IF (27) IS: MORE THAN / LESS THAN {90° / 1600mil}; 30 IS: (27) + (28) / (27) − (28) | |

| | | |
|---|---|---|
| 31 | REPEAT (30) | 16 79 70 |
| 32 | REPEAT (7) | 12 62 86 |
| 33 | (31 + 32) | 29 42 56 |
| 34 | 180° OR 3200mil | 32 00 00 |
| 35 | REPEAT (33) | 29 42 56 |
| 36 | (34) − (35) = ANGLE A2 | 2 57 44 |
| 37 | REPEAT (15) | 3.862 7442 |
| 38 | LOG SIN (30) | 9.998 6692 |
| 39 | (37) + (38) | 3.861 4134 |
| 40 | REPEAT (13) | 9.975 7636 |
| 41 | (39) − (40) | 3.885 6498 |
| 42 | REPEAT (12) | 3.839 6619 |
| 43 | LOG SIN (29) | 9.917 1532 |
| 44 | (42) + (43) | 3.756 8151 |
| 45 | REPEAT (16) | 9.871 1681 |
| 46 | (44) − (45) | 3.885 6470 |
| 47 | REPEAT (41) | 3.885 6498 |
| | DIFFERENCE BETWEEN (46) AND (47) | 3.885 6470 |
| 48 | [MUST BE LESS THAN 0.0001] | 0.000 0028 |
| 49 | 1/2 OF (48) | 0.000 0014 |
| 50 | REPEAT (46) OR (47) WHICHEVER IS SMALLER | 3.885 6470 |
| 51 | (49) + (50) = LOG GRID DISTANCE A TO P | 3.885 6484 |

DATE

AREA

| | | | |
|---|---|---|---|
| REAR STATION B | MAN | | |
| AZ A TO B REPEAT (4) | 14 61 52 | AZ TO BEARING | |
| STA ANGLE REPEAT (36) | 2 57 44 | | 32 00 00 |
| SUM | 17 18 96 | | 17 18 96 |
| − 360° / 6400mil | | BEARING | 14 81 04 |
| AZIMUTH A TO P | 17 18 96 | | |
| (+/−) 180° / 3200mil | 32 00 00 | | |
| AZIMUTH P TO A | 49 18 96 | | |

ΔE− ΔN+ | ΔE+ ΔN+ | ΔE− ΔN− | ΔE+ ΔN−

| | | | |
|---|---|---|---|
| REPEAT (51) | 3.885 6484 | REPEAT (51) | 3.885 6484 |
| LOG SIN BEARING | 9.997 0314 | LOG COS BEARING | 9.066 4131 |
| SUM = LOG ΔE | 3.882 6798 | SUM = LOG ΔN | 2.952 0615 |

| | | | | |
|---|---|---|---|---|
| STATION A | PAC | E 546 702.94 | N 3 836 848.87 | H 329.4 |
| VERT ∢ P TO A WITH SIGN REVERSED | (+) 6 37 | ΔE (+/−) 7 632.73 | ΔN (+/−) 895.49 | ΔH (+/−) 48.1 |
| LOG TAN VERT ∢ | 7.796 1450 | | | 377.5 |
| REPEAT (51) | 3.885 6484 | | | * (+/−) 0.0 |
| SUM = LOG ΔH | 1.681 7934 | | | 377.5 |
| | | | | ** − 4.0 |
| STATION P | 01 | E 554 335.67 | N 3 835 953.38 | H 373.5 |
| COMPUTER | THUDIUM | CHECKER | FRICK | SHEET OF SHEETS |

NOTEBOOK REFERENCE

* DIFFERENCE IN HEIGHTS OF TARGET AND INSTRUMENT FROM GUIDE ON REVERSE

** CORRECTION FOR CURVATURE AND REFRACTION FROM TABLE ON REVERSE

DA FORM 6-19, 1 FEB 58 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. GPO 904828

*Figure 84. Solution of three-point resection, fourth-order survey.*

### AUXILIARY COMPUTATION
### AZIMUTH AND DISTANCE FROM A TO B AND A TO C

| STATION | | E COORDINATE | | N COORDINATE | dE− dN+ / dE+ dN+ |
|---|---|---|---|---|---|
| FROM STATION A | PAC | A | 546 702.94 | A | 3 836 848.87 |
| TO STATION B | MAN | B | 553 925.95 | B | 3 837 836.95 |
| IF A IS LESS THAN B REPEAT A | | AA | 546 702.94 | AA | 3 836 848.87 |
| IF AA IS BLANK, USE A−B, SIGN− IF AA IS FILLED, USE B−AA, SIGN+ | | dE | (+) 7 223.01 | dN | (+) 988.08 |

| | | | |
|---|---|---|---|
| LOG dE | 3.858 7182 | ANGLE HAVING LOG TAN BEARING A TO B | 14 61 52 |
| LOG dN | 2.994 7921 | DETERMINE AZIMUTH FROM BEARING BY PUTTING dE AND dN ON SKETCH AS GUIDE | |
| LOG dE − LOG dN = LOG TAN BEARING A TO B | 0.863 9261 | AZIMUTH A TO B [ENTER IN (4) ON FRONT] | 14 61 52 |

| IF dE IS MORE THAN dN | | IF dE IS LESS THAN dN | |
|---|---|---|---|
| REPEAT LOG dE | 3.858 7182 | REPEAT LOG dN | |
| LOG SIN BEARING A TO B | 9.995 9740 | LOG COS BEARING A TO B | |
| LOG dE − LOG SIN BEARING = LOG GRID DISTANCE A TO B | 3.862 7742 | LOG dN − LOG COS BEARING = LOG GRID DISTANCE A TO B | |

[ENTER LOG GRID DISTANCE A TO B IN (15) ON FRONT]

| STATION | | E COORDINATE | | N COORDINATE | dE− dN+ / dE+ dN+ |
|---|---|---|---|---|---|
| FROM STATION A | PAC | A | 546 702.94 | A | 3 836 848.87 |
| TO STATION C | REY | C | 553 398.65 | C | 3 835 129.58 |
| IF A IS LESS THAN C REPEAT A | | AA | 546 702.94 | AA | |
| IF AA IS BLANK, USE A − C, SIGN − IF AA IS FILLED, USE C − AA, SIGN + | | dE | (+) 6 695.71 | dN | (−) 1 719.29 |

| | | | |
|---|---|---|---|
| LOG dE | 3.825 7966 | ANGLE HAVING LOG TAN BEARING A TO C | 13 43 98 |
| LOG dN | 3.235 3492 | DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AS GUIDE | 32 00 00 / 13 43 98 |
| LOG dE − LOG dN = LOG TAN BEARING A TO C | 0.590 4474 | AZIMUTH A TO C [ENTER IN (1) ON FRONT] | 18 56 02 |

| IF dE IS MORE THAN dN | | IF dE IS LESS THAN dN | |
|---|---|---|---|
| REPEAT LOG dE | 3.825 7966 | REPEAT LOG dN | |
| LOG SIN BEARING A TO C | 9.986 1347 | LOG COS BEARING A TO C | |
| LOG dE − LOG SIN BEARING = LOG GRID DISTANCE A TO C | 3.839 6619 | LOG dN − LOG COS BEARING = LOG GRID DISTANCE A TO C | |

[ENTER LOG GRID DISTANCE A TO C IN (12) ON FRONT]

TABLE - CORRECTION FOR CURVATURE AND REFRACTION

(NO INTERPOLATION NECESSARY FOR ARTILLERY SURVEY)

(SIGN ALWAYS MINUS)

| Log Side (M) | Corr (M) | Log Side (M) | Corr (M) |
|---|---|---|---|
| 3,079 | .1 | 3,712 | 1.8 |
| 3,230 | .2 | 3,736 | 2.0 |
| 3,322 | .3 | 3,784 | 2.5 |
| 3,386 | .4 | 3,824 | 3.0 |
| 3,435 | .5 | 3,857 | 3.5 |
| 3,473 | .6 | 3,886 | 4.0 |
| 3,508 | .7 | 3,912 | 4.5 |
| 3,537 | .8 | 3,934 | 5.0 |
| 3,562 | .9 | 3,955 | 5.5 |
| 3,584 | 1.0 | 3,974 | 6.0 |
| 3,625 | 1.2 | 3,992 | 6.5 |
| 3,658 | 1.4 | 4,007 | 7.0 |
| 3,687 | 1.6 | | |

GIVEN:
Coordinates of stations A, B, and C.
Height of station A.

FIELD DATA:
Observe horizontal angles $P_1$ and $P_2$.
*Observe vertical angle to station A.*
Measure height of instrument (to nearest 0.1 meter).
Estimate height of target at station A, if not known.

GUIDE:
Enter observed field data in blocks marked [ ].
When value in (8) of computation is between 160° (2845⫫) and 200° (3555⫫), *a new station P* or new stations A, B, and/or C must be selected.
Find difference between heights of instrument and target as follows:

| | | |
|---|---|---|
| a | Known or Estimated Height of Target | + 2.5 |
| b | Measured Height of Instrument | − 2.5 |
| c | Algebraic Sum a and b (Enter, with sign, in block marked ✱) | 0.0 |

Enter correction for curvature and refraction in block marked ✱✱

LIMITATIONS:
Angles $P_1$, $P_2$, B, and C should be greater than 22 1/2° (400⫫) or accuracy may fall below standard.

RESULTS:
Coordinates and height of station P.
*Azimuth from station P to station A.*

FORMULAS:

$\tan Z = \frac{AC \sin P_2}{AB \sin P_1}$ or $\tan Z = \frac{AB \sin P_1}{AC \sin P_2}$

If 1/2 (B+C) is more than $\left\{\begin{matrix}90^\circ \\ 1600⫫\end{matrix}\right\}$: If 1/2 (B+C) is more than $\left\{\begin{matrix}90^\circ \\ 1600⫫\end{matrix}\right\}$:

Tan 1/2 (C-B) = Tan (Z - 45°) Tan 1/2 (B+C)  Tan 1/2 (B-C) = Tan (Z - 45°) Tan 1/2 (B+C)

If 1/2 (B+C) is less than $\left\{\begin{matrix}90^\circ \\ 1600⫫\end{matrix}\right\}$: If 1/2 (B+C) is less than $\left\{\begin{matrix}90^\circ \\ 1600⫫\end{matrix}\right\}$:

Tan 1/2 (B-C) = Tan (Z - 45°) Tan 1/2 (B+C)  Tan 1/2 (C-B) = Tan (Z - 45°) Tan 1/2 (B+C)

$$AP = \frac{AB \sin B}{\sin P_2} = \frac{AC \sin C}{\sin P_1}$$

Z = an auxiliary angle required only in the computation (always between 45 and 90 degrees).

*Figure 85. Back of DA Form 6–19.*

### 237. DA Form 6–19

*a.* DA Form 6–19 (figs. 84 and 85) is used for the computation of a three-point resection problem.

*b.* Entries required are the coordinates of points A, B, and C and the horizontal angles and vertical angle measured at point P.

*c.* The formulas to be used are shown on the back of the form.

### 238. Two-Point Resection

Two-point resection is a method of survey similar to three-point resection. In two-point resection, control is obtained from two visible known points. In figure 86, points A and B are inaccessible points of known survey control. Points R and Q are points from which the other three points are visible. The solution of this scheme is the same as that of a quadrilateral except that the angles at points A and B are not measured. As with three-point resection, certain preliminary operations must be performed. A map reconnaissance is required to insure that all interior angles are at least 400 mils (22½°) and preferably greater than 533 mils (30°). Also, points A and B must be visible from R and Q, and R and Q must be intervisible. Fieldwork consists of measuring angles R1, R2, Q1, and Q2 and vertical angles to A from R and Q.

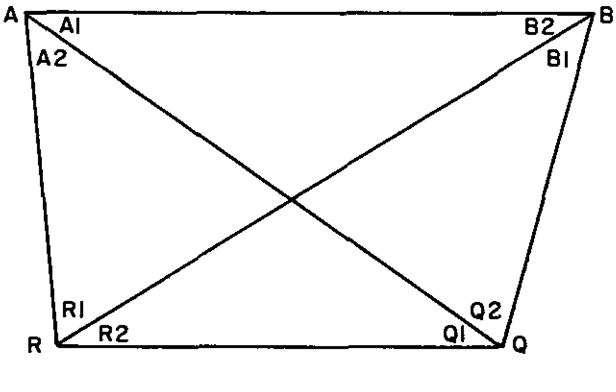



*Figure 86. Two-point resection.*

### 239. DA Form 6–18

*a.* DA Form 6–18 (figs. 87 and 88) is used for the computation of a two-point resection problem. If only the coordinates of point R are desired, the section labeled TO LOCATE STATION Q (lines 36 through 40) is not used. If only the location of point Q is desired, the section labeled TO LOCATE STATION R (lines 41 through 45) is not used.

*b.* Entries required are the coordinates of points A and B and the horizontal and vertical angles at points R and Q.

*c.* The formulas to be used are shown on the back of the form.

### 240. Limitations and Use of Resection

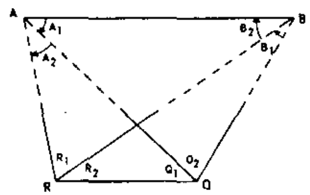
As a general rule, a point located by resection (two- or three-point) should not be used as a point from which to extend survey control unless the location is checked by some other means of survey. However, two-point or three-point resection can be used to locate a battery center or to establish the 01–02 target area base of a field artillery battalion. If known points are available, resection probably would be more rapid than the traverse method and would allow the unit to conduct unobserved fire much sooner. If necessary, corrections can be made later by traversing to a known point. In addition, resection may be used to locate any single point, to check a location determined by some other means of survey, or to verify points of suspended known control.

### 241. Resection Field Notes

Resection field notes are similar to field notes for triangulation, except that the height of target (known or estimated) and the height of instrument (measured to the nearest 0.1 meter) are also recorded in the REMARKS section.

## COMPUTATION - COORDINATES AND HEIGHT FROM TWO-POINT RESECTION

(TM 6-200)




| | | |
|---|---|---|
| 1 | OBSERVED ANGLE $Q_1$ | 5 15 511 |
| 2 | OBSERVED ANGLE $R_2$ | 9 33 681 |
| 3 | (1) + (2) | 14 49 192 |
| 4 | OBSERVED ANGLE $R_1$ | 12 05 431 |
| | | 32 00 000 |
| 5 | (3) + (4) [ENTER ON THIS LINE] | 26 54 623 |
| 6 | $\left\{ \begin{matrix} 180° \\ 3200 \text{ mil} \end{matrix} \right\}$ − (5) = ANGLE $A_2$ | 5 45 377 |
| 7 | OBSERVED ANGLE $Q_2$ | 10 48 492 |
| 8 | REPEAT (3) | 14 49 192 |
| | | 32 00 000 |
| 9 | (7) + (8) [ENTER ON THIS LINE] | 24 97 684 |
| 10 | $\left\{ \begin{matrix} 180° \\ 3200 \text{ mil} \end{matrix} \right\}$ − (9) = ANGLE $B_1$ | 7 02 316 |
| 11 | 1/2 OF (3) | 7 24 596 |
| 12 | LOG SIN (6) | 9.707 7465 |
| 13 | LOG SIN (7) | 9.932 9634 |
| 14 | LOG SIN (2) | 9.899 5800 |
| 15 | (12)+(13)+(14) | 9.540 2899 |
| 16 | LOG SIN (10) | 9.803 5611 |
| 17 | LOG SIN (1) | 9.685 5362 |
| 18 | LOG SIN (4) | 9.966 5671 |
| 19 | (16)+(17)+(18) | 9.455 6644 |
| 20 | IF (19) IS: MORE THAN (15) / LESS THAN (15); (20) IS: (19)−(15) / (15)−(19) | 9.540 2899<br>9.455 6644<br>0.084 6255 |
| 21 | ANGLE HAVING LOG TAN (20) | 8 98 62 |
| 22 | (21) − $\left\{ \begin{matrix} 45° \\ 800 \text{ mil} \end{matrix} \right\}$ | 8 00 00<br>98 62 |
| 23 | LOG TAN (22) | 8.987 3249 |
| 24 | LOG TAN (11) | 9.935 4676 |
| 25 | (23) + (24) | 8.922 7925 |
| 26 | REPEAT (11) | 7 24 60 |
| 27 | ANGLE HAVING LOG TAN (25) | 85 07 |
| 28 | (26)−(27) | 6 39 53 |
| 29 | (26)+(27) | 8 09 67 |
| | IF (19) IS: MORE THAN (15) / LESS THAN (15); (30) IS: (28) / (29); AND (34) IS: (29) / (28) | |
| 30 | REPEAT (28) OR (29), ANGLE $A_1$ | 8 09 67 |
| 31 | REPEAT (6) | 5 45 38 |
| 32 | (30)+(31) | 13 55 05 |
| 33 | REPEAT (10) | 7 02 32 |
| 34 | REPEAT (29) OR (28), ANGLE $B_2$ | 6 39 53 |
| 35 | (33) + (34) | 13 41 85 |
| | **TO LOCATE STATION Q** | |
| 36 | LOG GRID DISTANCE A TO B (FROM AUX COMP ON REV) | 3.479 5695 |
| 37 | LOG SIN (35) | 9.985 9005 |
| 38 | (36) + (37) | 3.465 4700 |
| 39 | REPEAT (13) | 9.932 9634 |
| 40 | (38)−(39) = LOG GRID DISTANCE A TO Q | 3.532 5066 |
| | **TO LOCATE STATION R** | |
| 41 | LOG GRID DISTANCE A TO B (FROM AUX COMP ON REV) | 3.479 5695 |
| 42 | LOG SIN (34) | 9.768 9427 |
| 43 | (41) + (42) | 3.248 5122 |
| 44 | REPEAT (18) | 9.966 5671 |
| 45 | (43)−(44) = LOG GRID DISTANCE A TO R | 3.281 9451 |

### TO LOCATE STATION Q

REAR STATION B: CARLTON

| | |
|---|---|
| AZ A TO B (FROM REV) | 8 30 34 |
| STA ANGLE REPEAT (30) | 8 09 67 |
| SUM | 16 40 01 |
| − 360° / 6400 mil | |
| AZIMUTH A TO Q | 16 40 01 |
| (+/−) 180° / 3200 mil | 32 00 00 |
| AZIMUTH Q TO A | 48 40 01 |

| AZ TO BEARING | |
|---|---|
| | 32 00 00 |
| | 16 40 01 |
| BEARING | 15 59 99 |

| | | | |
|---|---|---|---|
| REPEAT (40) | 3.532 5066 | REPEAT (40) | 3.532 5066 |
| LOG SIN BEARING | 9.999 6649 | LOG COS BEARING | 8.594 0568 |
| SUM = LOG dE | 3.532 1715 | SUM = LOG dN | 2.126 5634 |

| | | E | N | H |
|---|---|---|---|---|
| STATION A | GRUBER | 541 835.70 | 3 835 349.00 | 488.0 |
| VERT ∠ Q TO A WITH SIGN REVERSED | − 13 93 | dE + 3 405.43 | dN − 133.83 | dH − 46.6 |
| LOG TAN VERT ∠ | 8.135 9781 | | | 441.4 |
| REPEAT (40) | 3.532 5066 | | | * + 2.4 |
| SUM = LOG dH | 1.668 4847 | | | 443.8 |
| | | | | ** − 0.8 |
| STATION Q | JIM | 545 241.13 | 3 835 215.17 | 443.0 |

### TO LOCATE STATION R

REAR STATION B

| | |
|---|---|
| AZ A TO B (FROM REV) | 8 30 34 |
| STA ANGLE REPEAT (32) | 13 55 05 |
| SUM | 21 85 39 |
| − 360° / 6400 mil | |
| AZIMUTH A TO R | 21 85 39 |
| (+/−) 180° / 3200 mil | 32 00 00 |
| AZIMUTH R TO A | 53 85 39 |

| AZ TO BEARING | |
|---|---|
| | 32 00 00 |
| | 21 85 39 |
| BEARING | 10 14 61 |

| | | | |
|---|---|---|---|
| REPEAT (45) | 3.281 9451 | REPEAT (45) | 3.281 9451 |
| LOG SIN BEARING | 9.923 9444 | LOG COS BEARING | 9.735 2694 |
| SUM = LOG dE | 3.205 8895 | SUM = LOG dN | 3.017 2145 |

| | | E | N | H |
|---|---|---|---|---|
| STATION A | GRUBER | 541 835.70 | 3 835 349.00 | 488.0 |
| VERT ∠ R TO A WITH SIGN REVERSED | − 27 26 | dE + 1 606.53 | dN − 1 040.43 | dH − 51.2 |
| LOG TAN VERT ∠ | 8.427 4739 | | | 436.8 |
| REPEAT (45) | 3.281 9451 | | | * + 2.4 |
| SUM = LOG dH | 1.709 4190 | | | 439.2 |
| | | | | ** − 0.3 |
| STATION R | BILL | 543 442.23 | 3 834 308.57 | 438.9 |

* DIFFERENCE IN HEIGHTS OF TARGET AND INSTRUMENT FROM GUIDE ON REVERSE

** CORRECTION FOR CURVATURE AND REFRACTION FROM TABLE ON REVERSE

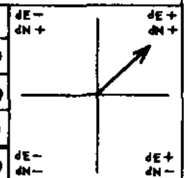
COMPUTER CPL KNOTT — CHECKER SGT STEVENS — SHEET OF SHEETS — NOTEBOOK REFERENCE — AREA — DATE

DA FORM 6-18, 1 APR 56 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. THIS FORM TOGETHER WITH DA FORMS 6-2, 6-d AND 6-19 REPLACES DA FORM 6-2a, 1 OCT 52, WHICH IS OBSOLETE.

*Figure 87. Solution of two-point resection, fourth-order survey.*

## AUXILIARY COMPUTATION
## AZIMUTH AND DISTANCE FROM A TO B

| STATION | | E COORDINATE | | N COORDINATE |
|---|---|---|---|---|
| FROM STATION A | A | 541 835 70 | A | 3 835 349 00 |
| TO STATION B | B | 544 031 60 | B | 3 837 417 80 |
| IF A IS LESS THAN B REPEAT A | AA | 541 835 70 | AA | 3 835 349 00 |
| IF AA IS BLANK, USE A-B, SIGN− IF AA IS FILLED, USE B-AA, SIGN+ | dE | + 2 195 90 | dN | + 2 068 80 |




| | | | |
|---|---|---|---|
| LOG dE | 3.341 6126 | ANGLE HAVING LOG TAN BEARING A TO B | 8 30 34 |
| LOG dN | 3.315 7185 | DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AS GUIDE | |
| LOG dE − LOG dN = LOG TAN BEARING A TO B | 0.025 8941 | AZIMUTH A TO B [ENTER ON FRONT] | 8 30 34 |

| IF dE IS MORE THAN dN | | IF dE IS LESS THAN dN | |
|---|---|---|---|
| REPEAT LOG dE | 3.341 6126 | REPEAT LOG dN | |
| LOG SIN BEARING A TO B | 9.862 0431 | LOG COS BEARING A TO B | |
| LOG dE − LOG SIN BEARING = LOG GRID DISTANCE A TO B | 3.479 5695 | LOG dN − LOG COS BEARING = LOG GRID DISTANCE A TO B | |

[ENTER LOG GRID DISTANCE A TO B IN (36) AND/OR (41) ON FRONT]

TABLE - CORRECTION FOR CURVATURE AND REFRACTION
(NO INTERPOLATION NECESSARY FOR ARTILLERY SURVEY)
(SIGN ALWAYS MINUS)

| Log Side (M) | Corr (M) | Log Side (M) | Corr (M) |
|---|---|---|---|
| 3,079 | .1 | 3,712 | 1,8 |
| 3,230 | .2 | 3,736 | 2,0 |
| 3,322 | .3 | 3,784 | 2,5 |
| 3,386 | .4 | 3,824 | 3,0 |
| 3,435 | .5 | 3,857 | 3,5 |
| 3,473 | .6 | 3,886 | 4,0 |
| 3,508 | .7 | 3,912 | 4,5 |
| 3,537 | .8 | 3,934 | 5,0 |
| 3,562 | .9 | 3,955 | 5,5 |
| 3,584 | 1,0 | 3,974 | 6,0 |
| 3,625 | 1,2 | 3,992 | 6,5 |
| 3,658 | 1,4 | 4,007 | 7,0 |
| 3,691 | 1,6 | | |

GIVEN:
Coordinates of stations A and B.
Height of station A.

FIELD DATA:
Observe horizontal angles $Q_1$, $Q_2$, $R_1$, and $R_2$.
Observe vertical angle(s) from station(s) Q or (and) R to station A.
Measure height(s) of instrument(s) at station(s) Q or (and) R to nearest 0.1 meter.
Estimate height of target at station A, if not known.

GUIDE:
Enter observed field data in blocks marked ▭.
Find difference(s) between heights of instrument(s) and target as follows:

| | | STATION Q | STATION R |
|---|---|---|---|
| a | Known or Estimated Height of Target | + 4 0 | + 4 0 |
| b | Measured Height(s) of Instrument | − 1 6 | − 1 6 |
| c | Algebraic Sum a and b [Enter, with sign, in block(s) marked *] | ⊕ 2 . 4 | ⊕ 2 . 4 |

Enter correction(s) for curvature and refraction in block(s) marked * *.

LIMITATIONS:
Angles $A_1$, $A_2$, $B_1$, $B_2$, $Q_1$, $Q_2$, $R_1$, and $R_2$ should be greater than 22 1/2° (400ṁ) or accuracy may fall below specifications

RESULTS:
Coordinates and height(s) of station(s) Q or (and) R.
Azimuth(s) from station(s) Q or (and) R to station A.

FORMULAS:

$$A_1 + B_2 = Q_1 + R_2$$

$$\text{Tan } Z = \frac{\text{Sin } A_2 \text{ Sin } Q_2 \text{ Sin } R_2}{\text{Sin } B_1 \text{ Sin } Q_1 \text{ Sin } R_1} \quad \text{or} \quad \text{Tan } Z = \frac{\text{Sin } B_1 \text{ Sin } Q_1 \text{ Sin } R_1}{\text{Sin } A_2 \text{ Sin } Q_2 \text{ Sin } R_2}$$

$$\text{Tan } \tfrac{1}{2}(A_1 - B_2) = \text{Tan } \tfrac{1}{2}(A_1 + B_2) \text{ Tan}(Z - 45^\circ) \qquad \text{Tan } \tfrac{1}{2}(B_2 - A_1) = \text{Tan } \tfrac{1}{2}(A_1 + B_2) \text{ Tan}(Z - 45^\circ)$$

$$AQ = \frac{AB \text{ Sin } (B_1 + B_2)}{\text{Sin } Q_2}$$

$$AR = \frac{AB \text{ Sin } B_2}{\text{Sin } R_1}$$

$Z$ = an auxiliary angle required only in the computations (always between 45 and 90 degrees).

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*Figure 88. Back of DA Form 6–18.*

# CHAPTER 10

# TRILATERATION

## 242. General

Trilateration is a method of survey in which the sides, rather than the angles, of a triangle are measured in the field. The interior angles of the triangle are then computed from the length of the sides. The availability of electronic distance-measuring devices makes the use of this method feasible in artillery surveys. Taping the distances would be uneconomical because of the manpower and time involved.

## 243. Employment

Since the range capability of electronic distance-measuring devices exceeds the optical range of issued theodolites and Tellurometers, trilateration can be used in survey operations involving long distances. Trilateration can also be used in operations involving shorter distances, when poor visibility restricts lines of sight.

## 244. Limitations

Trilateration measurements and computations are affected by—

*a.* Unstable atmospheric conditions which influence the probable error of the measured distance.

*b.* Angular distortions resulting from distance errors.

*c.* The quality of vertical control used to reduce slope distances to horizontal distances.

*d.* The requirement to use quadrilateral figures.

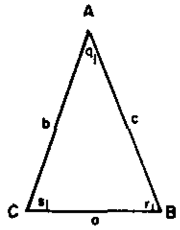
*e.* A minimum permissible interior angle of 400 mils.

*f.* The requirement to obtain direction from another source.

## 245. Computations

DA form 6–7a is used for the computation of angles from measured distances (fig. 89). The angles are then used in conjunction with the side lengths to extend coordinate control, provided a known direction is available. Height is determined by altimetry (ch. 11). The side lengths used on DA Form 6–7a can be UTM grid or sea level distances. If sea level distances are used, they must be converted to UTM grid distances, by use of the log scale factor, when the coordinates are computed on DA Form 6–2. Complete specifications for trilateration are tabulated in appendix II.

## COMPUTATION — PLANE TRIANGLE
(Using Three Sides)
(FM 6-2)




REQUIRED DATA
(UTM grid or sea level distances of sides a, b and c.)

OPTIONAL DATA
Plane UTM grid azimuth line a, b, or c.

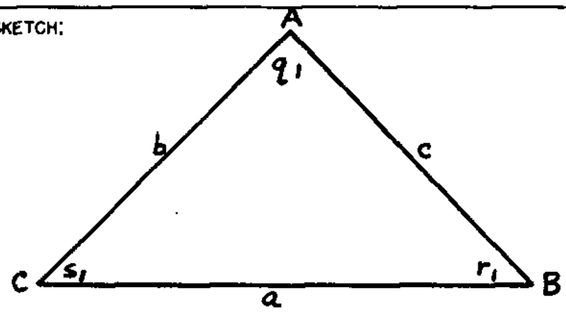
KNOWN AZIMUTH

TO ___ = ___

Plane UTM grid coordinates station A, B, or C.
KNOWN COORDINATES

Sta. ___ E ___
N ___

SKETCH:




NOTE: Always use a as longest known side.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | KNOWN LENGTH a = | 91 27 07 | | | | |
| 2 | KNOWN LENGTH b = | 61 07 25 | 19 | (11) = | 3 785 8457 |
| 3 | KNOWN LENGTH c = | 89 73 53 | 20 | LOG SIN (18) = | 9 977 3187 |
| 4 | (1) + (2) + (3) = | 242 07 85 | 21 | (19) + (20) = | 3 763 1644 |
| 5 | ½ OF (4) = | 121 03 92 | 22 | LOG (1) = | 3 960 3314 |
| 6 | (1) = | 91 27 07 | 23 | (21) — (22) = | 9 802 8330 |
| 7 | (5) — (6) = | 29 76 85 | 24 | ANGLE HAVING LOG SIN (23) = $r_1$ = | 7 00 91 |
| 8 | LOG (7) = | 3 473 7570 | 25 | (13) = | 3 952 9633 |
| 9 | LOG (5) = | 4 082 9260 | 26 | (20) = | 9 977 3187 |
| 10 | (8) + (9) = | 7 556 6830 | 27 | (25) + (26) = | 3 930 2820 |
| 11 | LOG (2) = | 3 785 8457 | 28 | (22) = | 3 960 3314 |
| 12 | (10) — (11) = | 3 770 8373 | 29 | (27) — (28) = | 9 969 9506 |
| 13 | LOG (3) = | 3 952 9633 | 30 | ANGLE HAVING LOG SIN (29) = $S_1$ = | 12 25 44 |
| 14 | (12) — (13) = | 9 817 8740 | | PARTIAL PROOF | |
| 15 | 10,000 0000 + (14) = | 9 817 8740 | 31 | (18) = | 12 73 66 |
| 16 | ½ OF (15) = | 9 908 9370 | 32 | (24) = | 7 00 91 |
| 17 | ANGLE HAVING LOG COS (16) = | 6 36 83 | 33 | (30) = | 12 25 44 |
| 18 | 2 X (17) = $q_1$ = | 12 73 66 | 34 | (31) + (32) + (33) = 180° 3200 m = | 32 00 01 |

REMARK

| COMPUTER | CHECKER | DATE |
|---|---|---|
| PFC GEROLD | SGT KANDRA | 27 JUL 19— |

DA FORM 1 SEP 62 6-7a — REPLACES EDITION OF 1 OCT 52, WHICH IS OBSOLETE.

*Figure 89. Solution of trilateration problem, fourth-order survey, on DA Form 6–7a.*

# CHAPTER 11

# ALTIMETRY

## Section I. GENERAL

### 246. General

*a.* The 4,500-meter surveying altimeter is used in artillery survey to determine the heights of stations that are not optically intervisible and heights that cannot be determined by trigonometric methods. The introduction of electronic distance-measuring equipment into artillery survey has provided the capability of measuring distances between points lacking intervisibility. This capability makes it possible for the artillery to use the trilateration method of survey in extending survey control. Use of the electronic distance-measuring equipment in conjunction with trilateration places added importance on the use of the altimeter.

*b.* The basic principle of altimetry is that the pressure caused by the weight of the column of air above the observer decreases as the observer rises in altitude. If weather conditions and instrument conditions were always standard and never varied, it would be possible to set up a pressure-altitude ratio that would enable an observer to measure the pressure at any given point and then rapidly compute the altitude (height) of that point. In altimetry this is essentially what takes place; however, because weather conditions, instruments, and geological and geographical conditions vary widely and because air varies in density, it is not possible to set up a pressure-altitude ratio which by itself will always produce an accurate result. It is therefore necessary to establish a set of standard conditions to use as a basis for the pressure-altitude ratio. Variations from the standard conditions are converted to corrections and applied as required to compensate for their effect. The standard conditions for altimetry are based on the International Civil Aeronautics Organization (ICAO) standard atmosphere which is commonly accepted by the Army, Navy, and Air Force as having standard values. The standard conditions for altimetry as it is used by the artillery are as follows:

(1) Instrument temperature—75° F.
(2) Air temperature—50° F.
(3) Relative humidity—100 percent.
(4) Latitude—45° N(S).
(5) Altitude—+450 meters.
(6) Gravity acceleration—32.2 feet per second.
(7) Wind—0 MPH.

### 247. Surveying Altimeter

*a.* The altimeter issued to artillery units (fig. 90) is the altimeter, surveying, 4,500-meter, 2-meter divisions; it is normally issued and used in conjunction with the Tellurometer or DME.

*b.* The surveying altimeter is an aneroid barometer which measures atmospheric pressure by mechanical means. The scales are so graduated that air pressure is indicated in units of height (meters). Under standard conditions, it has a range from 300 meters below to 4,500 meters above sea level. The instrument contains an aneroid element consisting of a single vacuum chamber. Expansion or contraction of this chamber is indicated by the rotation of an indicating hand and the movement of a revolution indicator.

*c.* The altimeter has a circular dial with four scales; two scales are outside the circular (annular) mirror, and two scales are inside the mirror (fig. 91). The indicating hand makes nearly four revolutions in measuring throughout the range of the altimeter. A revolution indicator designates which scale

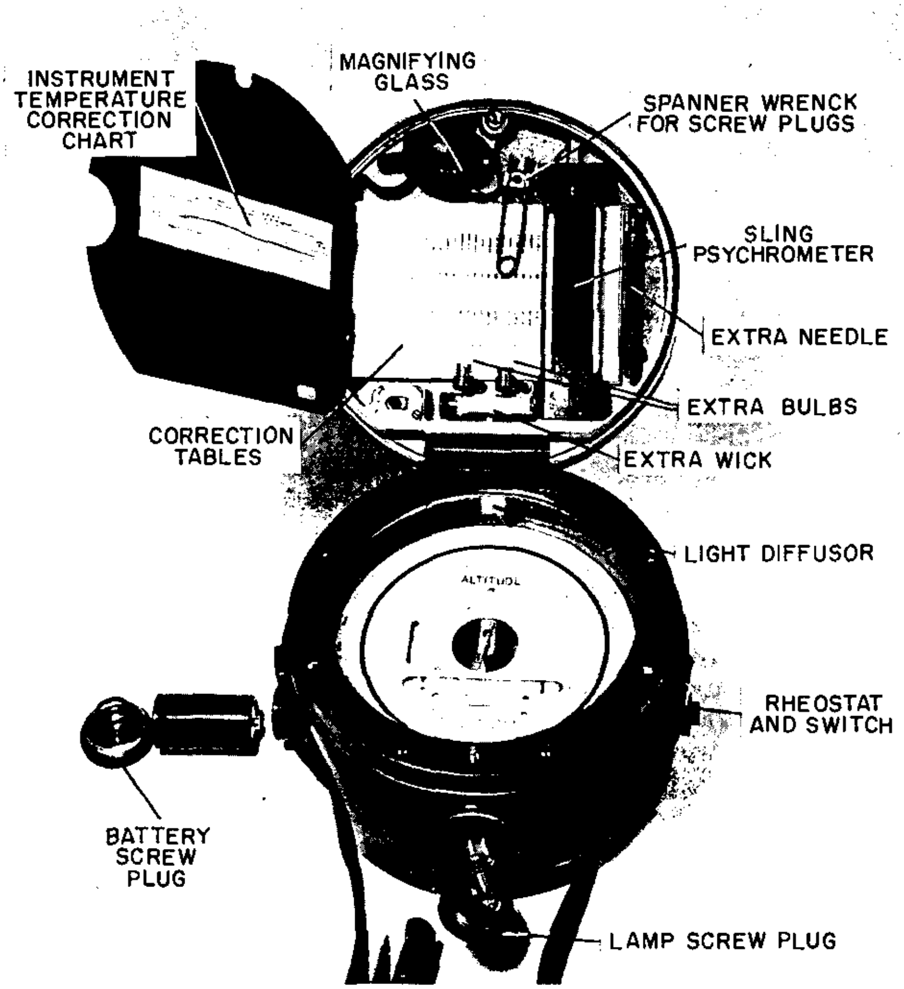



*Figure 90. Surveying altimeter, 4,500-meter, 2-meter divisions.*

should be read. Zero on the dial corresponds to a pressure-height of 300 meters below mean sea level under standard conditions; 4,800 on the dial corresponds to 4,500 meters above mean sea level under standard conditions. The least reading on the scales is 2 meters. Each altimeter dial is custom calibrated for the vacuum chamber and mechanical linkage with which it is to be used. For this reason, the dial, the vacuum chamber, all parts of the mechanical linkage, and the instrument temperature correction chart are not interchangeable with corresponding parts of other altimeters. In the face of the dial is a desiccant condition indicator which becomes pink when moisture within the case is excessive.

*d.* The case is airtight except for a small vent which permits the pressure inside the case to become equal to that outside. The case can be made completely airtight by shifting a movable vent cap to the closed position and closing the lid. The vent normally is left open; however, it should be closed when the instrument is packed for shipping. A built-in night lighting system uses standard flashlight batteries and lamps. Scale lighting is controlled by a switch and rheostat assembly. Batteries should be placed in the case only for night operations. A silica gel desiccant is in a container in the lower part of the case. A reading glass, a folding sling psychrometer, a spanner wrench, calibration charts, correction tables, and spare parts are stored in the lid of the case.

**248. Sling Psychrometer**

*a.* The sling psychrometer provides the wet

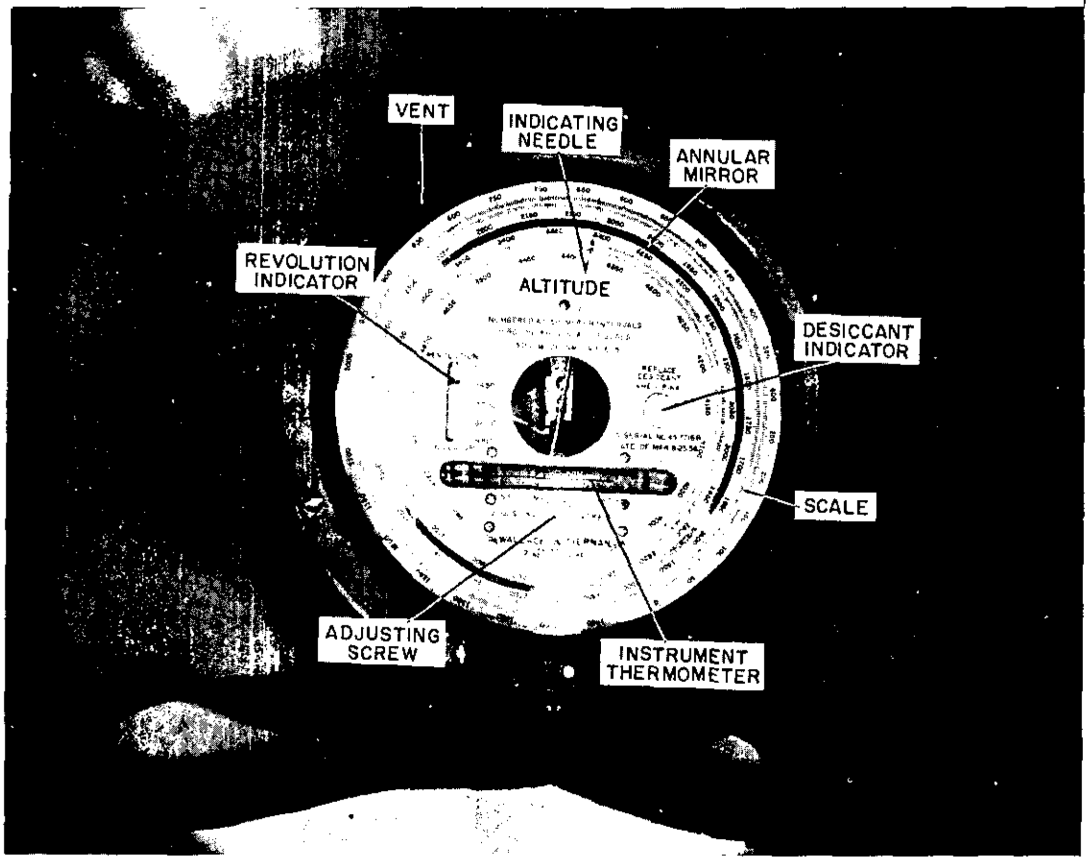



*Figure 91. Altimeter dial.*

bulb and dry bulb temperatures that are used to obtain the correction factor for air temperature and relative humidity. The psychrometer consists of two identical Fahrenheit thermometers (the bulb of one thermometer is covered by a cloth wick) suspended from a bar and enclosed in metal sheaths to prevent breakage. Psychrometer readings are made as follows: Unfold the psychrometer and saturate the wick of the wet bulb thermometer with clean water. Holding the handle of the psychrometer in one hand with the link and thermometer assembly at a right angle to the handle, rotate the psychrometer two or more revolutions per second for at least 1 minute. Immediately read and record the temperatures of both thermometers, first the wet bulb temperature and then the dry bulb temperature. (If the air temperature is below 32° F, only a dry bulb reading is taken and the correction factor is determined from this reading.)

*b.* The thermometers should be checked against a standard thermometer or against each other. When this check is made, the wet bulb reading must be made with a dry wick. A correction factor should be determined for a thermometer that does not agree within 2° of the standard thermometer. If the thermometers are checked against each other and a difference of more than 2° exists, a correction factor should be determined for the wet bulb thermometer and recorded in the instrument case. This correction factor will be applied to all field data determined by the psychrometer.

## 249. Weather Conditions

The accuracy of heights determined by altimetric leveling depends on the stability of prevailing weather conditions. Valid results cannot be obtained during periods of strong or gusty winds or during thunderstorms or other turbulent weather conditions. In general, the best results are obtained when windspeeds are less than 10 miles per hour. When wind velocities exceed 15 miles per hour, altimetry should not be relied on as a method of determining height. Generally weather conditions are most unstable from 1000 to 1400 hours, and an altimeter reading should not be made during these hours if it can be avoided. The atmospheric conditions that prevail during fog, mist, or light rain are usually suitable for altimetric leveling. The altimeter should be shaded from the direct rays of the sun when readings are being taken.

## 250. Care and Maintenance of the Altimeter

*a.* Although the surveying altimeter is a delicate instrument, it is rugged enough to be used for field survey if handled properly and protected from shock. The instrument and its accessories should be kept clean and dry. The window of the instrument is made of clear plastic, which scratches easily. It should be brushed with a camel's-hair brush to remove dust and polished with lens tissue or a soft rag. The window should be waxed periodically. The instrument should not be oiled. Oil will interfere with the operation of the instrument and cause erroneous readings.

*b.* Artillery personnel are not authorized to repair the instrument. They should never remove the window. The spare indicator hand which is issued with the instrument should be replaced by engineer instrument repair personnel if replacement is necessary.

*c.* Artillery survey personnel are authorized to remove and dry or replace the silica gel desiccant in the instrument when the desiccant condition indicator turns pink. The silica gel can be dried by heating it at 300° F for at least 10 minutes.

*d.* Artillery survey personnel are authorized to replace the lamp bulbs for the night lighting system and to insert and remove the batteries for the system. The batteries should not be inserted until the instrument is to be used at night, and they should be removed when the night work is completed.

*e.* Artillery survey personnel are authorized to replace a broken thermometer in the sling psychrometer. A thermometer can be replaced by removing the screwcap from the end of the psychrometer head. The cork disc for the cap must be in place when the cap is replaced.

# Section II. USE OF THE ALTIMETER

## 251. Methods of Altimetry

*a.* Two methods of altimetry are employed in artillery survey. These methods are—

(1) The leapfrog method (para 258) which is of primary interest to the artillery since this method is particularly suited for use in conjunction with Tellurometer or DME systems.

(2) The single-base method (para 261) which is of secondary interest to the artillery but may be used in special situations.

*b.* Both methods of altimetry employ a base station and field stations. A base station is a station or point of known height; a field station is a station for which the height is to be determined.

*c.* Both methods of altimetry require simultaneous readings of the altimeter scales at the base station and at the field station(s). These simultaneous scale readings, corrected and adjusted for instrumental differences, are compared to determine the differences in height between the base station and the field station(s). The wet and dry bulb temperatures, made at the base station at the time of the simultaneous readings, are used as arguments to determine the correction factor from the air temperature and relative humidity correction chart (fig. 92). This correction is applied to the difference in the adjusted scale readings to obtain the corrected difference in height between stations.

*d.* The field station and base station make simultaneous readings by coordinating the time by radio communication or by using a prearranged observing schedule. Consequently, the watch of the field station observer must be synchronized with the watch of the base station observer.

*e.* During normal weather conditions, a

TABLE I

AIR TEMPERATURE & RELATIVE HUMIDITY CORRECTION FACTOR FOR ALTITUDE

| Temperature Below Freezing | | Dry Bulb Temperature Degrees F. | Wet Bulb Temperature Degrees F. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 32 | 34 | 35 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | |
| Deg. F. | Factor | 32 | 0.967 | | | | | | | | | | | | | | | | | | 32 |
| -65 | 0.772 | 34 | 0.971 | 0.971 | | | | | | | | | | | | | | | | | 34 |
| -60 | 0.782 | 36 | 0.974 | 0.975 | 0 975 | | | | | | | | | | | | | | | | 36 |
| -55 | 0.792 | 38 | 0.978 | 0.978 | 0.979 | 0.979 | | | | | | | | | | | | | | | 38 |
| -50 | 0.802 | 40 | 0.982 | 0.982 | 0.983 | 0.983 | 0.984 | | | | | | | | | | | | | | 40 |
| -45 | 0.812 | 42 | 0.985 | 0.986 | 0.986 | 0.987 | 0.987 | 0.988 | | | | | | | | | | | | | 42 |
| -40 | 0.822 | 44 | 0.989 | 0.989 | 0.990 | 0.990 | 0.991 | 0.991 | 0.992 | | | | | | | | | | | | 44 |
| -38 | 0.826 | 46 | 0.992 | 0.993 | 0.993 | 0.994 | 0.995 | 0.995 | 0.996 | 0.996 | | | | | | | | | | | 46 |
| -36 | 0.830 | 48 | 0.996 | 0.997 | 0.997 | 0.998 | 0.998 | 0.999 | 0.999 | 1.000 | 1.000 | | | | | | | | | | 48 |
| -34 | 0.834 | 50 | 1.000 | 1.000 | 1.001 | 1.001 | 1.002 | 1.002 | 1.003 | 1.003 | 1.004 | 1.005 | | | | | | | | | 50 |
| -32 | 0.838 | 52 | 1.003 | 1.004 | 1.004 | 1.005 | 1.005 | 1.006 | 1.006 | 1.007 | 1.008 | 1.008 | 1.009 | | | | | | | | 52 |
| -30 | 0.842 | 54 | 1.007 | 1.008 | 1.008 | 1.008 | 1.009 | 1.010 | 1.010 | 1.011 | 1.011 | 1.012 | 1.012 | 1.013 | | | | | | | 54 |
| -28 | 0.846 | 56 | 1.011 | 1.011 | 1.012 | 1.012 | 1.013 | 1.013 | 1.014 | 1.014 | 1.015 | 1.016 | 1.016 | 1.017 | 1.017 | | | | | | 56 |
| -26 | 0.850 | 58 | 1.014 | 1.015 | 1.015 | 1.016 | 1.017 | 1.017 | 1.018 | 1.018 | 1.019 | 1.019 | 1.020 | 1.020 | 1.021 | 1.022 | | | | | 58 |
| -24 | 0.854 | 60 | 1.018 | 1.019 | 1.019 | 1.020 | 1.020 | 1.021 | 1.021 | 1.022 | 1.022 | 1.023 | 1.024 | 1.024 | 1.025 | 1.026 | 1.026 | | | | 60 |
| -22 | 0.858 | 62 | 1.022 | 1.022 | 1.023 | 1.023 | 1.024 | 1.024 | 1.025 | 1.025 | 1.026 | 1.027 | 1.027 | 1.028 | 1.028 | 1.029 | 1.030 | 1.031 | | | 62 |
| -20 | 0.862 | 64 | 1.026 | 1.026 | 1.027 | 1.027 | 1.027 | 1.028 | 1.028 | 1.029 | 1.030 | 1.030 | 1.031 | 1.032 | 1.032 | 1.033 | 1.034 | 1.034 | 1.035 | | 64 |
| -18 | 0.866 | 66 | | 1.030 | 1.030 | 1.031 | 1.031 | 1.032 | 1.032 | 1.033 | 1.033 | 1.034 | 1.034 | 1.035 | 1.036 | 1.037 | 1.037 | 1.038 | 1.039 | 1.040 | 66 |
| -16 | 0.870 | 68 | | 1.033 | 1.034 | 1.034 | 1.035 | 1.035 | 1.036 | 1.036 | 1.037 | 1.038 | 1.038 | 1.039 | 1.040 | 1.040 | 1.041 | 1.042 | 1.043 | 1.043 | 68 |
| -14 | 0.874 | 70 | | | 1.037 | 1.033 | 1.038 | 1.039 | 1.039 | 1.040 | 1.041 | 1.041 | 1.042 | 1.063 | 1.043 | 1.044 | 1.045 | 1.046 | 1.046 | 1.047 | 70 |
| -12 | 0.878 | 72 | | | 1.041 | 1.042 | 1.042 | 1.042 | 1.043 | 1.044 | 1.044 | 1.045 | 1.046 | 1.046 | 1.047 | 1.048 | 1.048 | 1.049 | 1.050 | 1.051 | 72 |
| -10 | 0.882 | 74 | | | | 1.045 | 1.046 | 1.046 | 1.047 | 1.047 | 1.048 | 1.049 | 1.049 | 1.050 | 1.051 | 1.051 | 1.052 | 1.053 | 1.054 | 1.054 | 74 |
| - 8 | 0.886 | 76 | | | | 1.049 | 1.049 | 1.050 | 1.050 | 1.051 | 1.052 | 1.052 | 1.053 | 1.054 | 1.054 | 1.055 | 1.056 | 1.057 | 1.057 | 1.058 | 76 |
| - 6 | 0.890 | 78 | | | | | 1.053 | 1.054 | 1.054 | 1.055 | 1.055 | 1.056 | 1.057 | 1.057 | 1.058 | 1.058 | 1.059 | 1.060 | 1.061 | 1.062 | 78 |
| - 4 | 0.894 | 80 | | | | | 1.057 | 1.057 | 1.058 | 1.058 | 1.059 | 1.060 | 1.060 | 1.061 | 1.062 | 1.062 | 1.063 | 1.064 | 1.065 | 1.065 | 80 |
| - 2 | 0.898 | 82 | | | | | | 1.061 | 1.061 | 1.062 | 1.063 | 1.063 | 1.064 | 1.065 | 1.065 | 1.066 | 1.067 | 1.067 | 1.068 | 1.069 | 82 |
| 0 | 0.902 | 84 | | | | | | 1.064 | 1.065 | 1.066 | 1.066 | 1.067 | 1.068 | 1.068 | 1.069 | 1.070 | 1.070 | 1.071 | 1.072 | 1.073 | 84 |
| 2 | 0.906 | 86 | | | | | | | 1.069 | 1.069 | 1.070 | 1.071 | 1.071 | 1.072 | 1.073 | 1.073 | 1.074 | 1.075 | 1.076 | 1.076 | 86 |
| 4 | 0.910 | 88 | | | | | | | 1.072 | 1.073 | 1.073 | 1.074 | 1.075 | 1.075 | 1.076 | 1.077 | 1.078 | 1.078 | 1.079 | 1.080 | 88 |
| 6 | 0.914 | 90 | | | | | | | | 1.076 | 1.077 | 1.078 | 1.078 | 1.079 | 1.080 | 1.081 | 1.081 | 1.082 | 1.083 | 1.084 | 90 |
| 8 | 0.919 | 92 | | | | | | | | 1.080 | 1.081 | 1.081 | 1.082 | 1.083 | 1.084 | 1.084 | 1.085 | 1.086 | 1.087 | 1.087 | 92 |
| 10 | 0.923 | 94 | | | | | | | | | 1.084 | 1.085 | 1.086 | 1.087 | 1.087 | 1.088 | 1.089 | 1.089 | 1.090 | 1.091 | 94 |
| 12 | 0.927 | 96 | | | | | | | | | 1.088 | 1.089 | 1.090 | 1.090 | 1.091 | 1.092 | 1.092 | 1.093 | 1.094 | 1.095 | 96 |
| 14 | 0.931 | 98 | | | | | | | | | | 1.093 | 1.093 | 1.094 | 1.095 | 1.095 | 1.096 | 1.097 | 1.097 | 1.098 | 98 |
| 16 | 0.935 | 100 | | | | | | | | | | 1.096 | 1.097 | 1.097 | 1.098 | 1.099 | 1.100 | 1.100 | 1.101 | 1.102 | 100 |
| 18 | 0.939 | 102 | | | | | | | | | | | 1.100 | 1.101 | 1.102 | 1.102 | 1.103 | 1.104 | 1.105 | 1.106 | 102 |
| 20 | 0.943 | 104 | | | | | | | | | | | 1.104 | 1.105 | 1.105 | 1.106 | 1.107 | 1.108 | 1.108 | 1.109 | 104 |
| 22 | 0.947 | 106 | | | | | | | | | | | | 1.108 | 1.109 | 1.110 | 1.111 | 1.111 | 1.112 | 1.113 | 106 |
| 24 | 0.951 | 108 | | | | | | | | | | | | 1.112 | 1.113 | 1.113 | 1.114 | 1.115 | 1.116 | 1.117 | 108 |
| 26 | 0.955 | 110 | | | | | | | | | | | | | 1.116 | 1.117 | 1.118 | 1.119 | 1.119 | 1.120 | 110 |
| 28 | 0-959 | 112 | | | | | | | | | | | | | 1.120 | 1.121 | 1.122 | 1.122 | 1.123 | 1.124 | 112 |
| 30 | 0.963 | 114 | | | | | | | | | | | | | | 1.125 | 1.125 | 1.126 | 1.127 | 1.128 | 114 |
| | | | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | |

This chart is to be used to obtain the temperature and relative humidity corrections required when using the single-base method of altimeter leveling. Use only with altimeters set and calibrated in meters according to the Smithsonian Meteorological Table No. 51.

EXAMPLE OF USE OF CHART

Assume altimeter "A" reads 900 meters and "B" reads 1100 meters, dry bulb 80°F, wet bulb 60°F. Find 80 in dry bulb temperature column, follow across to 60 of wet bulb temperature column. Read correction factor 1.063. Corrected altitude difference = (1100-900) (1.063) = 212.6 meters. Interpolate the correction factor to the nearest .001

(continued on facing page)

*Figure 92. Temperature and relative humidity chart.*

majority of the heights determined by altimetry will be correct within 3 meters, and the maximum error will seldom exceed 5 meters, provided the following precautions are taken:

(1) Temperature correction is applied to the individual instrument.

(2) Comparison adjustment is made.

(3) The air temperature and relative humidity correction factor is applied.

(4) Difference in height between the base station and field station is less than 200 meters.

(5) Distance between the base station and field station is less than 20,000 meters.

*f.* Tables II and III, Tabulated Correction Factors for Latitude and Altitude, are contained in the lid of the altimeter. Since these

TABLE 1 (continued)

AIR TEMPERATURE & RELATIVE HUMIDITY CORRECTION FACTOR FOR ALTITUDE

| | | | | | | | | | Wet Bulb Temperature Degrees F. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dry Bulb Temperature Degrees F. | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 106 | 108 | 110 | |
| 68 | 1.044 | | | | | | | | | | | | | | | | | | | | | | 68 |
| 70 | 1.048 | 1.049 | | | | | | | | | | | | | | | | | | | | | 70 |
| 72 | 1.052 | 1.052 | 1.053 | | | | | | | | | | | | | | | | | | | | 72 |
| 74 | 1.055 | 1.056 | 1.057 | 1.058 | | | | | | | | | | | | | | | | | | | 74 |
| 76 | 1.059 | 1.060 | 1.061 | 1.062 | 1.063 | | | | | | | | | | | | | | | | | | 76 |
| 78 | 1.063 | 1.063 | 1.064 | 1.065 | 1.066 | 1.067 | | | | | | | | | | | | | | | | | 78 |
| 80 | 1.066 | 1.067 | 1.068 | 1.069 | 1.070 | 1.071 | 1.072 | | | | | | | | | | | | | | | | 80 |
| 82 | 1.070 | 1.071 | 1.072 | 1.073 | 1.074 | 1.075 | 1.076 | 1.077 | | | | | | | | | | | | | | | 82 |
| 84 | 1.074 | 1.074 | 1.075 | 1.076 | 1.077 | 1.078 | 1.080 | 1.081 | 1.082 | | | | | | | | | | | | | | 84 |
| 86 | 1.077 | 1.078 | 1.079 | 1.080 | 1.081 | 1.082 | 1.083 | 1.084 | 1.086 | 1.087 | | | | | | | | | | | | | 86 |
| 88 | 1.081 | 1.082 | 1.083 | 1.084 | 1.085 | 1.086 | 1.087 | 1.088 | 1.089 | 1.091 | 1.092 | | | | | | | | | | | | 88 |
| 90 | 1.085 | 1.085 | 1.086 | 1.087 | 1.088 | 1.090 | 1.091 | 1.092 | 1.093 | 1.094 | 1.096 | 1.097 | | | | | | | | | | | 90 |
| 92 | 1.088 | 1.089 | 1.090 | 1.091 | 1.092 | 1.093 | 1.094 | 1.096 | 1.097 | 1.098 | 1.099 | 1.101 | 1.102 | | | | | | | | | | 92 |
| 94 | 1.092 | 1.093 | 1.094 | 1.095 | 1.096 | 1.097 | 1.098 | 1.099 | 1.100 | 1.102 | 1.103 | 1.104 | 1.106 | 1.107 | | | | | | | | | 94 |
| 96 | 1.096 | 1.096 | 1.097 | 1.098 | 1.099 | 1.101 | 1.102 | 1.103 | 1.104 | 1.105 | 1.107 | 1.108 | 1.109 | 1.111 | 1.112 | | | | | | | | 96 |
| 98 | 1.100 | 1.100 | 1.101 | 1.102 | 1.103 | 1.104 | 1.105 | 1.107 | 1.108 | 1.109 | 1.110 | 1.112 | 1.113 | 1.115 | 1.116 | 1.118 | | | | | | | 98 |
| 100 | 1.103 | 1.104 | 1.105 | 1.106 | 1.107 | 1.108 | 1.109 | 1.110 | 1.111 | 1.113 | 1.114 | 1.115 | 1.117 | 1.118 | 1.120 | 1.122 | 1.123 | | | | | | 100 |
| 102 | 1.106 | 1.107 | 1.108 | 1.109 | 1.110 | 1.112 | 1.113 | 1.114 | 1.115 | 1.116 | 1.118 | 1.119 | 1.120 | 1.122 | 1.124 | 1.125 | 1.127 | 1.128 | | | | | 102 |
| 104 | 1.110 | 1.111 | 1.112 | 1.113 | 1.114 | 1.115 | 1.116 | 1.118 | 1.119 | 1.120 | 1.121 | 1.123 | 1.124 | 1.126 | 1.127 | 1.129 | 1.130 | 1.132 | 1.134 | | | | 104 |
| 106 | 1.114 | 1.115 | 1.116 | 1.117 | 1.118 | 1.119 | 1.120 | 1.121 | 1.122 | 1.124 | 1.125 | 1.126 | 1.128 | 1.129 | 1.131 | 1.132 | 1.134 | 1.136 | 1.137 | 1.139 | | | 106 |
| 108 | 1.118 | 1.118 | 1.119 | 1.120 | 1.121 | 1.123 | 1.124 | 1.125 | 1.126 | 1.127 | 1.129 | 1.130 | 1.131 | 1.133 | 1.135 | 1.136 | 1.138 | 1.139 | 1.141 | 1.143 | 1.144 | | 108 |
| 110 | 1.121 | 1.122 | 1.123 | 1.124 | 1.125 | 1.127 | 1.127 | 1.128 | 1.130 | 1.131 | 1.132 | 1.134 | 1.135 | 1.137 | 1.138 | 1.140 | 1.142 | 1.143 | 1.145 | 1.146 | 1.148 | 1.150 | 110 |
| 112 | 1.125 | 1.126 | 1.127 | 1.128 | 1.129 | 1.130 | 1.131 | 1.132 | 1.133 | 1.135 | 1.136 | 1.137 | 1.139 | 1.140 | 1.142 | 1.144 | 1.145 | 1.147 | 1.148 | 1.150 | 1.152 | 1.153 | 112 |
| 114 | 1.129 | 1.129 | 1.130 | 1.131 | 1.132 | 1.133 | 1.135 | 1.136 | 1.137 | 1.138 | 1.140 | 1.141 | 1.142 | 1.144 | 1.145 | 1.147 | 1.149 | 1.151 | 1.152 | 1.154 | 1.156 | 1.157 | 114 |
| 116 | 1.132 | 1.133 | 1.134 | 1.135 | 1.136 | 1.137 | 1.138 | 1.139 | 1.141 | 1.142 | 1.143 | 1.145 | 1.146 | 1.148 | 1.149 | 1.151 | 1.153 | 1.154 | 1.156 | 1.158 | 1.159 | 1.161 | 116 |
| 118 | 1.136 | 1.137 | 1.138 | 1.139 | 1.140 | 1.141 | 1.142 | 1.143 | 1.144 | 1.146 | 1.147 | 1.148 | 1.150 | 1.151 | 1.153 | 1.154 | 1.156 | 1.158 | 1.160 | 1.161 | 1.163 | 1.165 | 118 |
| 120 | 1.139 | 1.140 | 1.141 | 1.142 | 1.143 | 1.144 | 1.146 | 1.147 | 1.148 | 1.149 | 1.151 | 1.152 | 1.153 | 1.155 | 1.156 | 1.158 | 1.160 | 1.162 | 1.164 | 1.165 | 1.167 | 1.169 | 120 |
| 122 | 1.143 | 1.144 | 1.145 | 1.146 | 1.147 | 1.148 | 1.149 | 1.150 | 1.151 | 1.152 | 1.154 | 1.156 | 1.157 | 1.159 | 1.160 | 1.162 | 1.164 | 1.166 | 1.167 | 1.169 | 1.171 | 1.173 | 122 |
| 124 | 1.147 | 1.148 | 1.149 | 1.150 | 1.151 | 1.152 | 1.153 | 1.154 | 1.155 | 1.157 | 1.158 | 1.159 | 1.161 | 1.162 | 1.164 | 1.166 | 1.167 | 1.169 | 1.171 | 1.172 | 1.174 | 1.176 | 124 |
| 126 | 1.150 | 1.151 | 1.152 | 1.153 | 1.154 | 1.155 | 1.157 | 1.158 | 1.159 | 1.160 | 1.162 | 1.163 | 1.164 | 1.166 | 1.168 | 1.169 | 1.171 | 1.173 | 1.174 | 1.176 | 1.178 | 1.180 | 126 |
| | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 106 | 108 | 110 | |

*Figure 92*—Continued.

factors are insignificant for artillery purposes, these tables are not used.

## 252. Reading Altimeter Scales

The procedure for reading the scales of the altimeter is as follows:

*a.* Place the instrument as nearly level as possible with the dial in the horizontal position. The instrument must be protected from the sun and wind.

*b.* Tap the window of the instrument lightly to overcome any lag caused by static electricity.

*c.* Position the eye above the dial so that the indicating hand and its reflection in the annular mirror coincide. (Care must be taken to select the reflection of the hand and not its shadow.) This step eliminates parallax in reading the scales.

*d.* Determine the scale to be read by noting the position of the revolution indicator.

*e.* Read the proper scale under the indicating hand by visual interpolation to the nearest 0.5 meter. The reading glass is used to facilitate reading the scale. Care must be taken to insure that the correct scale is read, since the scales are numbered concentrically and increase in value in a counterclockwise direction.

## 253. Corrections and Adjustments

*a.* The temperature correction for the individual instrument should be applied to the scale reading of each instrument (para 254). The application of this correction provides the *corrected scale reading*.

*b.* The comparison adjustment should be applied to the corrected scale reading of the field station instrument (para 255). The application of this adjustment provides the *adjusted scale reading*.

*c.* The *difference* between the *corrected scale reading* of the base station and the *adjusted scale reading* of the field station should be corrected for air temperature and relative humidity (para 256) to obtain the corrected difference in height between stations.

## 254. Individual Instrument Temperature Correction

*a.* Each surveying altimeter is calibrated at a temperature of 75° F. An instrument temperature other than 75° will change the value of the scale reading, and a correction must be made for the difference.

*b.* A mercury alloy thermometer is mounted in the dial of each altimeter and is used to determine the individual instrument temperature each time a scale reading is made. The correction for instrument temperature is determined from the instrument temperature correction chart fastened in the lid of each instrument. *This chart is different for each instrument.* Figure 93 illustrates the temperature correction chart for one instrument. To obtain the correction which should be applied to an instrument reading:

(1) Locate the position along the bottom of the graph which corresponds to the scale reading, taken to the nearest 100 meters.

(2) Project this point upward along the vertical line of the graph to the curved line of the graph.

(3) From the point of intersection of the projected line and the curved line, project a second line to the left, parallel to the horizontal lines on the graph.

(4) At the intersection of the projected horizontal line with the left side of the graph, determine the meters correction per degree Fahrenheit, noting the sign of the correction.

(5) Multiply this factor by the difference between the instrument temperature at which the scale reading was taken and 75° F. (The sign of the product is the sign of the correction.)

(6) Apply this value to the altimeter scale reading. If the instrument temperature was above 75° F, add the value algebraically. If the instrument temperature was below 75° F, subtract the value algebraically. This correction provides the *corrected scale reading*.

*c.* The following example illustrates the application of an individual instrument temperature correction:

(1) 2431.5 (scale reading).

(2) 50° F (instrument temperature).

(3) 75° −50°=25° (number of degrees to which correction is to be applied).

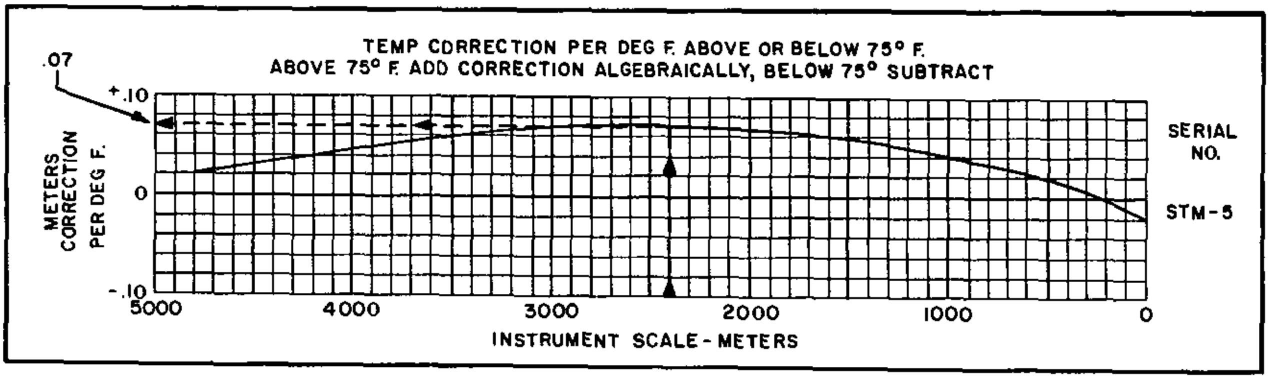



*Figure 93. Instrument temperature correction chart.*

A ALTIMETER

DESIGNATION ALTIMETRY LEAPFROG DATE 2 AUG 19

WEATHER: CLEAR-WARM CHIEF OF PARTY: BROWN

INSTRUMENT # 7716 OBSERVER: WRIGHT

| STATION | TIME | INSTR TEMP | SCALE READING | INSTR TEMP CORRECTION | CORRECTED SCALE READING | TEMPERATURE DRY | WET | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| ARBUCKLE | 1505 | 81 | 712.0 | +0.2 | 712.2 | | | | NO WIND |
| ARBUCKLE | 1530 | 82 | 712.5 | +0.2 | 712.7 | 88 | 76 | | |
| BN SCP-2 | 1550 | 85 | 688.0 | +0.3 | 688.3 | 89 | 77 | | |
| BN SCP-2 | 1650 | 88 | 687.5 | +0.4 | 687.9 | 90 | 77 | | |
| GRUBER | 1730 | 86 | 790.0 | +0.3 | 790.3 | 89 | 76 | | |
| GRUBER | 1755 | 86 | 790.0 | +0.3 | 790.3 | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | |

COLUMN 1 STATION AT WHICH "A" ALTIMETER READING IS TAKEN
2 TIME OF OBSERVATION
3 INSTRUMENT TEMPERATURE
4 "A" ALTIMETER SCALE READING
5 INSTRUMENT TEMPERATURE CORRECTION (SEE PARA 178)
6 CORRECTED SCALE READING, ALGEBRAIC SUM OF COLUMNS 4 AND 5
7 DRY BULB TEMPERATURE (SEE PARA 180)
8 WET BULB TEMPERATURE (SEE PARA 180)

*Figure 94. Altimeter A recorder's notes for altimetry (leapfrog).*

(4) +0.07 meter (correction per degree) (from correction chart, fig. 93).

(5) 25° x 0.07=1.75 meters (correction to be applied).

(6) 2431.5 − (+1.8) = 2429.7 (corrected scale reading).

## 255. Comparison Adjustment

*a.* The base station instrument is placed at a station of known height. The field station altimeter is placed beside the base station instrument at the same height. The *initial comparison* is made by taking simultaneous readings of the two altimeters and recording in the field notebook (DA Form 5–72, Level, Transit and General Survey Record) the time, instrument temperature, and scale reading for each. The data for each station instrument is recorded in a field notebook located at each station (figs. 94 and 95). In addition, for comparison purposes, the corrected scale readings for both the base station and the field station are recorded in the field station field notebook (fig. 96).

*b.* After the field survey is completed, the *final comparison* is made and recorded in the same manner as the initial comparison.

*c.* The time lapse between the initial comparison and the final comparison should be held to a minimum, less than 4 hours if possible.

*d.* If the initial comparison agrees with the final comparison, then the comparison adjustment is considered standard for all altimeter readings taken in between. If the initial and final comparisons do not agree, then a comparison adjustment graph must be constructed

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B ALTIMETER

DESIGNATION ALTIMETRY LEAPFROG DATE 2 AUG 19__

WEATHER: CLEAR WARM CHIEF OF PARTY. BROWN

INSTRUMENT # 7715 OBSERVER: KUTCHALL

| STATION | TIME | INST. TEMP. | SCALE READING | INST TEMP CORRECTION | CORRECTED SCALE READING | COMPARISON ADJUSTMENT | ADJUSTED SCALE READING | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| ARBUCKLE | 1505 | 81 | 710.0 | +0.5 | 710.5 | | | | |
| BN SCP. 1 | 1530 | 82 | 702.0 | +0.6 | 702.6 | +1.3 | 703.9 | | |
| BN SCP. 1 | 1550 | 82 | 702.5 | +0.6 | 703.1 | +1.1 | 704.2 | | |
| BN SCP. 3 | 1650 | 84 | 691.0 | +0.7 | 691.7 | +0.2 | 691.9 | | |
| BN SCP. 3 | 1730 | 87 | 691.0 | +1.0 | 691.0 | -0.4 | 690.6 | | |
| GRUBER | 1755 | 87 | 790.0 | +1.0 | 791.0 | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | |

COLUMN 1 STATION AT WHICH "B" ALTIMETER READING IS TAKEN
2 TIME OF OBSERVATION
3 INSTRUMENT TEMPERATURE
4 "B" ALTIMETER SCALE READING
5 INSTRUMENT TEMPERATURE CORRECTION (SEE PARA 178)
6 CORRECTED SCALE READING, ALGEBRAIC SUM OF COLUMNS 4 AND 5
7 COMPARISON ADJUSTMENT (PARA 179)
8 ADJUSTED SCALE READING, ALGEBRAIC SUM OF COLUMNS 6 AND 7

SAB

*Figure 95. Altimeter B recorder's notes for altimetry (leapfrog).*

to determine the adjustment for intermediate stations (fig. 96). The procedures for preparing and using the graph are as follows:

(1) Set up the graph by assigning time values to the vertical lines in the field station field book, to include the observing period from initial to final comparisons.

(2) Assign "difference in corrected scale reading" values to the horizontal lines, to include the difference between the initial and final comparisons.

(3) Use initial watch time and the difference in the corrected scale readings to plot the initial comparison point on the graph.

(4) Use final watch time and the difference in the corrected scale readings to plot the final comparison point on the graph.

(5) Join the two points with a straight line.

(6) Using the watch time for each intermediate station occupied by the field station instrument as the argument, read the comparison adjustment for that station from the left side of the graph.

(7) Then, enter the comparison adjustment in the appropriate column of the field station field notebook (opposite the time observed) and apply the comparison adjustment algebraically to the corrected scale reading to determine the adjusted

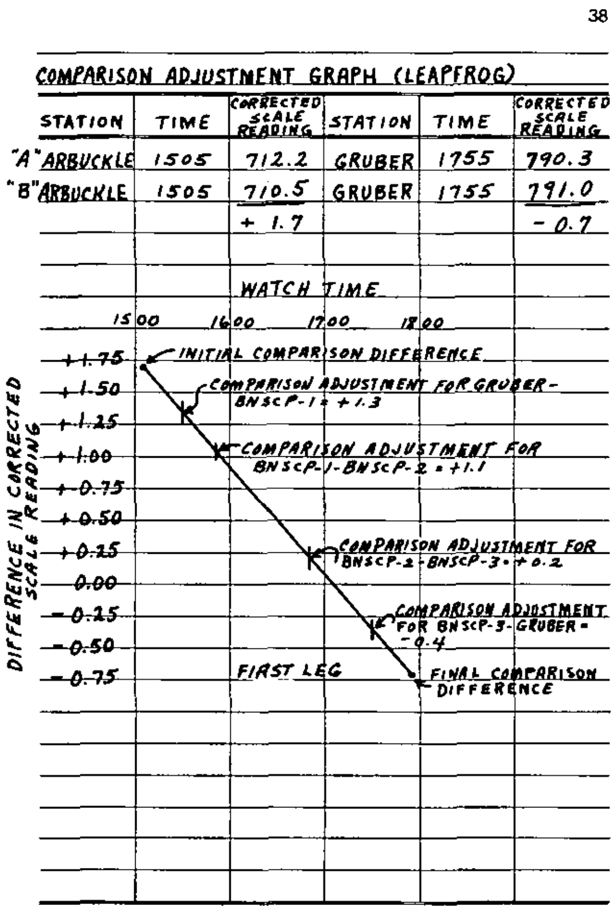



*Figure 96. Comparison adjustment graph.*

*scale reading* for the station of interest.

### 256. Correction for Air Temperature and Relative Humidity

*a.* Because the pressure exerted by a column of air is affected by changes in temperature and relative humidity, a correction factor must be applied to the difference in height between stations. The correction factor can be obtained by making a psychrometer reading (para 248) each time a scale reading is made by the base station altimeter (except comparison readings) and recording the wet and dry bulb temperatures in the base station field notebook opposite the scale reading (fig. 94).

*b.* If the wet and dry bulb temperatures are known, the correction factor can be determined from table I, Air Temperature and Relative Humidity Correction Factor for Altitude (fig. 92), one of the tables in the lid of the altimeter. The chart is entered at the top with the wet bulb temperature and on the left side with the dry bulb temperature. The intersection of the two columns is the correction factor. This correction factor is applied by multiplying it by the difference between the corrected scale reading of the base station altimeter and the adjusted scale reading of the field station altimeter. The correction factor should be interpolated to the nearest thousandth in table I.

### 257. Precautions and Limitations To Be Observed When Establishing Heights by Altimetry

*a.* The base and field station altimeters should be observed under similar conditions in the field and protected from the sun and strong wind. The altimeter should be shaded when it is being moved between stations.

*b.* The altimeter must be in a horizontal position when observations are made, preferably on a level and stable surface.

*c.* The altimeter should be cushioned against road shock, and sudden jarring should be avoided at all times.

*d.* Observations should not be made at midday.

*e.* Observations should not be made during thunderstorms or high winds.

*f.* Intervals between comparison readings should not exceed 4 hours.

*g.* Watches at base and field stations must be synchronized.

*h.* The difference in height between the base and field station(s) should be less than 200 meters.

*i.* The field station(s) should be less than 20,000 meters from the base station.

## Section III. PROCEDURES AND COMPUTATIONS

### 258. Leapfrog Method

*a.* The leapfrog method of altimetry is conducted in the manner implied by its name. Two altimeters, designated A and B, are read simultaneously at a starting base (known) station (fig. 97). Then altimeter A is left at the base station, and altimeter B is moved to the first field station. The two altimeters are again read simultaneously, and the corrected difference in height is applied to the height of the base station to give the height of the first field station. Altimeter A is then moved from the base station, bypassing the first field station, to the second field station. Altimeter B is left at the first field station, which becomes the base station, and again simultaneous readings are made. The difference between the two altimeter readings, with appropriate corrections, is applied to the height of the first field station to determine the height of the second field station. The altimeters are then brought together at the second field station, and comparison readings are made. The station of known height, the first field station, and the second field station comprise the first leg of the altimetric survey. The same procedure is then followed from the second field station through the third field station to another comparison at the fourth field station to establish the second leg. (The term "leg," as used in altimetry, is the survey between stations where comparison readings are made with the altimeters.)

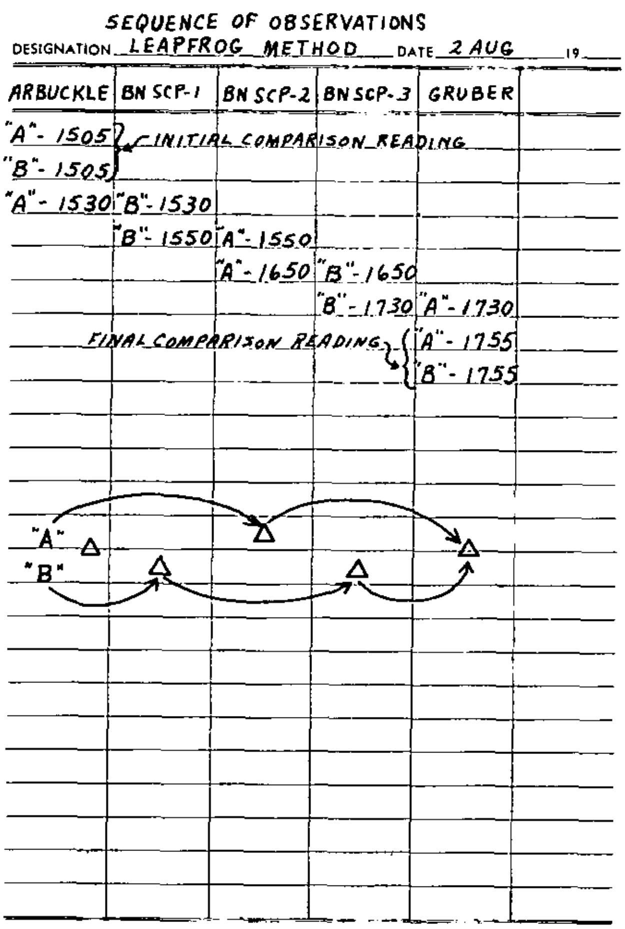



*Figure 97. Sequence of observations, leapfrog method.*

*b.* The advantage of the leapfrog method is that the altimeters are usually close together and operate under nearly the same atmospheric conditions. In effect, the base station is carried along with the field altimeters by the comparisons at alternate stations. The leapfrog method will determine the difference in height under normal weather conditions with an average error of ±3 meters when the difference in height between stations does not exceed 200 meters and the distance between *alternate* stations does not exceed 20,000 meters.

*c.* The leapfrog method of altimetry can be speeded up by the use of more altimeters or by a comparison of altimeter readings at every third or fourth field station instead of at alternate stations. Although the latter procedure may save time and fieldwork, it may result in reduced accuracy of the measurements because the comparisons span a greater distance and a longer period of time. This factor must be considered in selecting the leapfrog technique for an altimeter survey.

*d.* The field procedure for the leapfrog method of altimetry is as follows:

(1) A station of known height is used as the base station.

(2) The initial comparison reading is made at the base station with all altimeters to be used in the survey. For ease in recording and in performing subsequent computations, the initial reading and all subsequent readings should be made at even 5-minute intervals.

(3) For all readings made by the altimeter A recorder, except comparison readings, a psychrometer reading is made and the wet and dry bulb temperatures are recorded in the field notebook opposite the scale reading. The altimeter A recorder reads and records the psychrometer readings at the time of each observation regardless of whether the altimeter A sta-

tion is designated as the base or field station.

(4) The comparison adjustment is always made on the corrected scale reading of altimeter B regardless of whether the altimeter B station is designated as the base or field station.

(5) When a station is occupied by an altimeter, the altimeter is read at 5-minute intervals for a sufficient period of time to insure that simultaneous readings are being made at the base and field stations. It is important that some method of communication or signals be established before the survey is begun to insure coordination during the observations and to preclude occupation of a station longer than necessary or leaving the station too soon. Readings may be started immediately upon the arrival of the altimeter recorder at the field station unless there has been an appreciable change in weather since he left the previous station. In that event, it may be necessary to wait 5 to 10 minutes until the instrument settles.

## 259. Recording Altimeter Readings

*a*. Altimeter and psychrometer readings are recorded in the field notebook that accompanies each altimeter used in the survey. For the leapfrog method, the following data is recorded in the notebook of altimeter A (fig. 94):

(1) Station at which observation is made.
(2) Time of observation.
(3) Instrument temperature.
(4) Scale readings.
(5) Instrument temperature correction.
(6) Corrected scale readings.
(7) Wet and dry bulb temperatures.

*Note*. Items 2, 3, 4, and 7 above are field data determined by reading the scales at each station. Items 5 and 6 are values determined as a result of these field readings.

*b*. The following data is recorded in the field notebook of altimeter B (fig. 95):

(1) Station at which observation is made.
(2) Time of observation.
(3) Instrument temperature.
(4) Scale readings.
(5) Instrument temperature correction.
(6) Corrected scale readings.
(7) Comparison adjustment.
(8) Adjusted scale readings.

*Note*. Items 2, 3, and 4 above are field data determined by reading the scales at each station. Items 5, 6, 7, and 8 are values determined as a result of these field readings. The comparison adjustment (item 7) is extracted from the comparison adjustment graph that is constructed for each leg in the field notebook.

## 260. Computations

*a*. Heights of stations are computed on DA Form 6–27, Computation—Altimetric Height (fig.98). Each column of the form is designed to be used to determine the height of one field station. As an aid in extracting the correct data from the field books for entry on the form, the time of observation should be entered in the FIELD STATION NAME block. The following data is extracted from the field books and entered in the appropriate blocks on the form. The wet and dry bulb temperatures and the corrected scale reading from the field book of altimeter A and the adjusted scale reading from the field book of altimeter B. The air temperature and relative humidity correction factor is extracted from table I and applied to the difference in scale readings by using five-place logarithms (use available tables and round off if necessary). The known height of the base station (block 16) is the height of the starting station in meters. The reverse side of the form (fig. 99) contains a block for height conversion, if height conversion is necessary.

*b*. In the leapfrog method, the height determined for the first field station (block 18) becomes the known height of the second field station (block 16) and so forth for each successive station throughout the scheme.

## 261. Single-Base Method

The field procedure for the single-base method of altimetry is identical with that of the leapfrog method with the following two exceptions:

*a*. In the single-base method, after the initial

COMPUTATION - ALTIMETRIC HEIGHT
(SINGLE-BASE OR LEAPFROG METHOD)

LINE DESIGNATION: BASE STATION ARBUCKLE - BN ScP-1, BN ScP-2, BN ScP-3, GRUBER

SHEET OF SHEETS

| | FIELD STATION NAME / TIME | 1530 BN ScP-1 | 1550 BN ScP-2 | 1650 BN ScP-3 | 1730 GRUBER | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | FIELD STATION DRY BULB TEMPERATURE READING (±) | | | | | | | |
| 2 | BASE STATION DRY BULB TEMPERATURE READING (±) | 88 | 89 | 90 | 89 | | | |
| 3 | ALGEBRAIC SUM (1) AND (2) (±) | | | | | | | |
| 4 | ½ OF (3) (±) | | | | | | | |
| 5 | FIELD STATION WET BULB TEMPERATURE READING | | | | | | | |
| 6 | BASE STATION WET BULB TEMPERATURE READING | 76 | 77 | 77 | 76 | | | |
| 7 | (5) + (6) | | | | | | | |
| 8 | ½ OF (7) | | | | | | | |
| 9 | FIELD STATION ADJUSTED SCALE READING | 703.9 | 688.3 | 691.9 | 790.3 | | | |
| 10 | BASE STATION SCALE READING | 712.7 | 704.2 | 687.9 | 690.6 | | | |
| 11 | IF (9) IS MORE THAN (10), USE (9) − (10), SIGN (+). IF (9) IS LESS THAN (10), USE (10) − (9), SIGN (−). | 703.9<br>(±) 8.8 | 688.3<br>(±) 15.9 | (+) 4.0 | (+) 99.7 | (±) | (±) | (±) |
| 12 | CORRECTION FACTOR FROM: TABLE I | 1.085 | 1.087 | 1.089 | 1.086 | | | |
| | TABLE II (±) | | | | | | | |
| | TABLE III (±) | | | | | | | |
| | HEIGHT CORRECTION FACTOR (I + II + III) | 1.085 | 1.087 | 1.089 | 1.086 | | | |
| 13 | LOG (12) | 0.035 43 | 0.036 23 | 0.037 03 | 0.035 83 | | | |
| 14 | LOG (11) | 0.944 48 | 1.201 40 | 0.602 06 | 1.998 70 | | | |
| 15 | (13) + (14) | 0.979 91 | 1.237 63 | 0.639 09 | 2.034 53 | | | |
| 16 | KNOWN HEIGHT OF BASE STATION | 405.1 | 395.6 | 378.3 | 382.7 | | | |
| 17 | NUMBER HAVING LOG (15) (Use same sign as (11)) | (±) 9.5 | (±) 17.3 | (+) 4.4 | (+) 108.3 | (±) | (±) | (±) |
| 18 | ALGEBRAIC SUM (16) AND (17) = HEIGHT OF FIELD STATION | 395.6 | 378.3 | 382.7 | 491.0 | | | |

COMPUTER: KEUTHAN  CHECKER: BLOXOM  DATE: 3 AUG 19—

DA FORM 6-27, SEP 54   EDITION OF 1 JUL 52 IS OBSOLETE

Figure 98. Computations, DA Form 6–27.

GIVEN

FOR SINGLE-BASE METHOD: For each field station, altimeter scale reading at base station and adjusted scale reading at field station (taken at same time); dry bulb temperature and wet bulb temperature at base station and field station (temperature at base station interpolated to time of readings at field station); height of base station.

FOR LEAPFROG METHOD: For each leg; altimeter scale reading at base station and adjusted scale reading at first field station (taken at same time); dry bulb temperature and wet bulb temperature at base station and first field station (taken at same time); height of base station. Adjusted scale reading at first field station (base station for second half of leg) and altimeter scale reading at second field station (taken at same time); dry bulb temperature and wet bulb temperature at first and second field stations (taken at same time).

GUIDE

FOR LEAPFROG METHOD: Height of base station for each field station except the first field station is height computed for previous field station.

FOR BOTH METHODS: Use known heights to nearest one-tenth meter. Convert known height to meters when given in feet or yards.

Use logarithms to five places.

When known height of base station in step (16) is below sea level, use step (16) as a negative value and proceed with computation.

Refer to TM 6-200 for additional information.

RESULTS

FOR SINGLE-BASE METHOD: It can be expected that heights determined will have a maximum error of 4 meters and an average error of 1 1/2 meter when observations using standard equipment are made as prescribed.

FOR LEAPFROG METHOD: It can be expected that heights determined will have a maximum error of 2 meters and an average error of 1/2 meter when observations using standard equipment are made as prescribed.

FORMULA

D = C(B - A) + E
A = base station adjusted scale reading
B = field station adjusted scale reading
C = height correction factor
D = height of field station
E = known height of base station

HEIGHT CONVERSION - BASE STATION

| FEET TO METERS | | BASE STATION | YARDS TO METERS | | BASE STATION |
|---|---|---|---|---|---|
| 1 | HEIGHT IN FEET | 1 329.1 | 1 | HEIGHT IN YARDS | |
| 2 | LOG OF HEIGHT | 3.12356 | 2 | LOG OF HEIGHT | |
| 3 | LOG CONVERSION FACTOR | 9.48402 | 3 | LOG CONVERSION FACTOR | 9.96114 |
| 4 | (2) + (3) | 2.60758 | 4 | (2) + (3) | |
| 5 | NUMBER HAVING LOG (4) = HEIGHT IN METERS | 405.1 | 5 | NUMBER HAVING LOG (4) = HEIGHT IN METERS | |

GPO 861598

*Figure 99. DA Form 6–27, reverse side.*

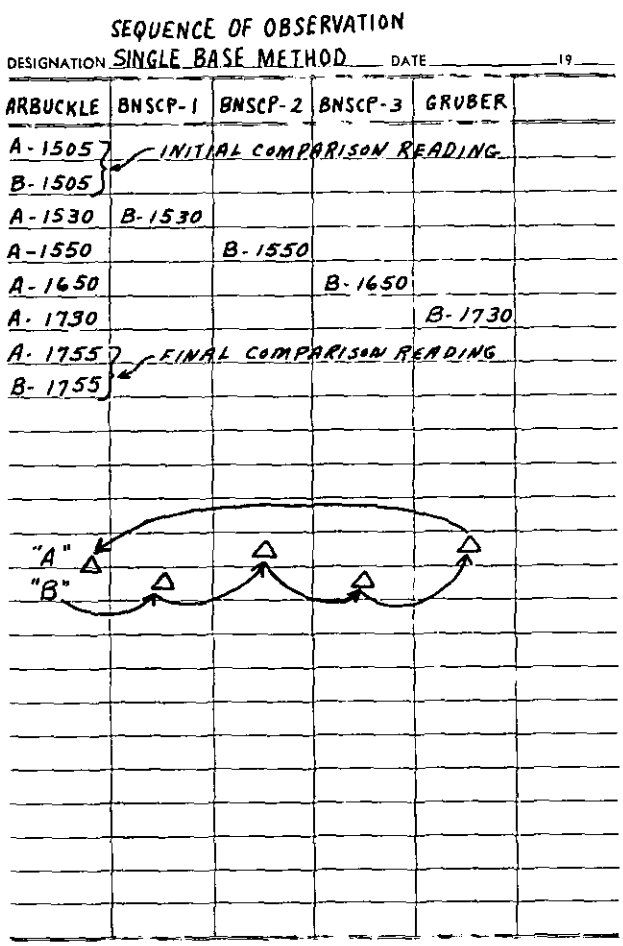



*Figure 100. Sequence of observations, single-base method.*

comparison readings are made at the base station, the altimeter A recorder remains in position at the base station and makes readings at 5-minute intervals throughout the observing period. After the initial comparison, the altimeter B recorder visits the field stations in sequence and makes simultaneous readings. After the readings have been made at the last field station, altimeter B is returned to the base station and a final comparison is made. For economy of time and effort, more than one field altimeter can be used in conjunction with the base altimeter with no reduction in accuracy.

*b*. The computation of heights of stations on DA Form 6–27 for the single-base method is the same as that for the leapfrog method except for one difference. In the single-base method, the known height of the base station (block 16) remains the same for the computation of heights of all field stations, since the base station remains fixed throughout the observing period. A sample of the sequence of observations is shown in figure 100.

# PART THREE
# DIRECTION DETERMINATION

## CHAPTER 12
## ORIENTATION FOR ARTILLERY

### Section I. INTRODUCTION

#### 262. General

Orientation as used in artillery survey refers to laying weapons and target-locating devices with reference to a common direction, or azimuth. Orientation is more important than horizontal position because an azimuth error increases as the distance from its origin increases. The artillery surveyor must furnish weapons and target acquisition elements with grid azimuths. However, he will be working with true, magnetic, and assumed azimuths as well.

#### 263. True Azimuth

True azimuth is an azimuth referenced to true north as defined by the axis of rotation of the earth. Geodetic, laplace, astronomic, and gyro azimuths are all treated as true azimuths by the artillery surveyor. Each of these azimuths contains some error due to geodetic considerations. In some cases, the error, or difference, between these azimuths may exceed 0.1 mil. Artillery surveyors are not required to take these errors into account. All of these azimuths depend basically on astronomic azimuth. Geodetic azimuth is the most accurate because in general it represents an adjustment from a large number of astronomic azimuths. Laplace azimuth is the next most accurate. It represents a single astronomic azimuth which has been corrected for local deflection of the vertical, as determined by the geodetic survey scheme. The uncorrected astronomic and gyro azimuths differ from the true azimuth by the same amount. Azimuth gyros currently in use by the artillery depend on calibration against another true azimuth, usually an astronomic azimuth.

#### 264. Grid Azimuth

Grid azimuth is an azimuth referenced to grid north. It differs from true azimuth by the amount of the grid convergence. The grid-convergence must be computed and applied to a true azimuth before it can be used by the artillery.

#### 265. Magnetic Azimuth

Magnetic azimuth is an azimuth referenced to the local direction of the earth's magnetic field. It is not accurate enough to place adjacent artillery units or target acquisition devices on a common azimuth. It will vary throughout the day by 4 to 6 mils. Magnetic storms will cause large variations that cannot be predicted. Local magnetic irregularities will cause errors that frequently exceed 20 mils. The primary use of magnetic azimuth should be as a check against gross survey errors. It may also be used as the assumed azimuth for a false grid. When a magnetic false azimuth is used, units working together should be tied together by a directional traverse.

### Section II. SOURCES OF AZIMUTH

#### 266. Geodetic Azimuth

Geodetic azimuth is obtained from existing local survey. In an area where there is an established survey, the trig list for the area will show the geodetic azimuth to several points for each station. It can be assumed that in a well-surveyed area the established points have been adjusted to each other so that the azimuth computed between two intervisible points will be a good geodetic azimuth of the same order as the original survey. In general, a more accurate azimuth will result if the points chosen for the computation are some distance apart. Geodetic azimuth may be given by higher headquarters as part of the starting data.

### 267. Azimuth From Coordinates

A starting azimuth may be obtained by computations between points established by U.S. Army surveyors. Caution must be used when computing between points recently established, since, in general, they will not have been adjusted and will not have a proper relationship to each other. Azimuth computations from coordinates of first-, second-, or third-order surveys will generally yield a comparable degree of accuracy, whereas computations from coordinates of fourth- or fifth-order surveys cannot be *assumed* to yield an acceptable accuracy. Fourth-order surveys will yield an acceptable accuracy, provided the azimuth has been adjusted. In fifth-order surveys, use should be made of the azimuth being carried through the scheme rather than relying on computations.

### 268. Directional Traverse

Directional traverse is used to carry an azimuth from a source to an orienting line. The method used is the same as that used for position traverse except that the measured distance between stations is not required and, in general, longer lines of sight may be used. See chapter 8 for instructions for turning angles and carrying azimuth through a traverse.

### 269. Astronomic and Gyro Azimuths

The method of obtaining an astronomic azimuth is explained in chapter 13. The method of obtaining a gyro azimuth is explained in chapter 14. Both types of azimuths are treated as true azimuth and must be corrected for grid convergence before use. In general, determination of astronomic or gyro azimuth is made on one end of the line requiring azimuth so that directional traverse will not be required.

### 270. Determination of Grid Convergence

True azimuths must be converted to grid azimuths. The computations for grid convergence are performed on DA Form 6—20 (figs. 101 and 102.) This form was originally designed for use in converting astronomic azimuth to grid azimuth. It can easily be adapted for use in computing convergence for gyro or geodetic azimuth. The left-hand side of the form is used for the computations if geographic coordinates are used. The right-hand side of the form is used for the computations if UTM coordinates are used. If both geographic and UTM coordinates are available, the computations should be made on both sides of the form and no further check on the computations is required. If the computations are made on one side of the form only, independent computations must be made by another computer to furnish a check. The instructions on the form suffice.

### 271. Grid Azimuth From UTM Maps

A grid azimuth can be obtained from a map by selecting an instrument station and two orienting points which can be accurately scaled from the map. A line is drawn on the map through each orienting point and the instrument station. The grid azimuth of each line is then scaled from the map. The orienting points should be so located that the difference in the azimuth of the points is as near 1,600 mils as practicable and the distance to each point from the instrument station is near 5 kilometers. An error of 25 meters in either point will create an error of 5 mils in azimuth at 5 kilometers. The two orienting points should be near 1,600 mils apart in azimuth to give a check on both the map and the map scaling. An angle-measuring instrument is set up over the selected instrument station in accordance with instructions in chapter 7. The angle between the two orienting points is measured and compared with the difference between the scaled azimuths. If the difference between the scaled azimuths and the measured angle is greater than 10 mils, another orienting point must be selected and the process repeated. If the two values now agree within 10 mils, they may be used as the grid azimuths. If the difference between the values still exceeds 10 mils, a new instrument station must

**COMPUTATION - CONVERGENCE (ASTRONOMIC AZIMUTH TO UTM GRID AZIMUTH)**
**TABLE NUMBERS REFER TO TM 6-300-19 65**

| | | | |
|---|---|---|---|
| STATION | Bn SCP | AZIMUTH MARK | STATION OAK |
| LONGITUDE OF STATION | 17 35 32 E (W) | UTM GRID ZONE | |
| EASTING OF STATION | 633 600 | | |
| LATITUDE OF STATION | 5 38 17 (N) S | NORTHING OF STATION | 3 349 600 |

| | | | | | |
|---|---|---|---|---|---|
| 1 | LONGITUDE OF STATION | 17 35 32 | 11 | EASTING OF STATION | 633 600 |
| 2 | LONGITUDE OF CENTRAL MERIDIAN (FROM TABLE ON REVERSE) | 17 60 00 | 12 | | 500 000 |
| 3 | IF (1) IS: MORE THAN (2) — (3) IS: (1) − (2); LESS THAN (2) — (2) − (1) | 17 35 32 / 24 68 | 13 | IF (11) IS: MORE THAN (12) — (13) IS: (11) − (12); LESS THAN (12) — (12) − (11) | 133 600 / 133 600 |
| 4 | IF (1) IS IN DEGREES, USE (8) OF CONVERSION COMP ON REVERSE; IF (1) IS IN MILS, REPEAT (3) | 24 .68 | 14 | REPEAT (13) WITH DECIMAL POINT MOVED LEFT SIX PLACES | 0 .133 600 |
| 5 | LOG (4) | 1 . 392 345 | 15 | LOG (14) | 9 . 125 806 |
| 6 | LOG SIN LATITUDE OF STATION | 9 . 702 544 | 16 | LOG OF FUNCTION XY (TABLE 6) (18874) | 4 275 864 |
| 7 | (5) + (6) | 1 . 094 889 | 17 | (15) + (16) | 3 . 401 670 |
| 8 | NUMBER HAVING LOG (7) = FIRST TERM IN SECONDS OR MILS | 12 .44 | 18 | LOG CONVERSION SECONDS TO MILS | 7 693 575 |
| 9 | SECOND TERM (TABLE 8 OR 8-MILS, USE (3) AND LATITUDE) | 0 .00 | 19 | IF (1) IS IN DEGREES, REPEAT (17); IF (1) IS IN MILS, USE (17)+(18) | 1 . 095 245 |
| | | | 20 | NUMBER HAVING LOG (19) = FIRST TERM IN SECONDS OR MILS | 12 .45 |
| | | | 21 | SECOND TERM (TABLE 7, USE (11) AND NORTHING) | 0 .00 |
| 10 | (8)+(9)= CONVERGENCE IN SECONDS OR MILS. WHEN STATION IS IN NORTH LATITUDE AND— IF (1) IS: MORE THAN (2) — IN WEST LONG (10) IS: +, IN EAST LONG (10) IS: −; LESS THAN (2) — IN WEST LONG −, IN EAST LONG +. WHEN STATION IS IN SOUTH LATITUDE AND— IF (1) IS: MORE THAN (2) — IN WEST LONG (10) IS: −, IN EAST LONG (10) IS: +; LESS THAN (2) — IN WEST LONG +, IN EAST LONG − | + (−) 12 .44 | 22 | (20) − (21) = CONVERGENCE IN SECONDS OR MILS. WHEN STATION IS IN NORTH LATITUDE IF (11) IS: MORE THAN (12) — (22) IS: −; LESS THAN (12) — +. WHEN STATION IS IN SOUTH LATITUDE IF (11) IS: MORE THAN (12) — (22) IS: +; LESS THAN (12) — − | + (−) 12 .45 |

IF (10) AND (22) DIFFER BY MORE THAN {04" / 0.02 mil} REDETERMINE COORDINATES AND RECOMPUTE ALL COMPUTATIONS

| | | | |
|---|---|---|---|
| 23 | CONVERGENCE | IF (1) IS IN DEGREES, USE (18) OF CONVERSION COMP ON REVERSE; IF (1) IS IN MILS, REPEAT (22) | + (−) 12 .45 |

**SUMMARY OF ASTRONOMIC AZIMUTHS AND COMPUTATION OF UTM GRID AZIMUTH**

| | | ASTRONOMIC AZIMUTH TO AZIMUTH MARK | | REMARKS |
|---|---|---|---|---|
| 24 | SET NR 1 | 40 33 8 | | |
| 25 | SET NR 2 | | | |
| 26 | SET NR 3 | | | |
| 27 | SET NR | | | |
| 28 | SET NR | | | |
| 29 | SET NR | | | |
| 30 | SUM | 40 33 8 | | |
| 31 | MEAN (SIGN +) | +40 33 8 | + | |
| 32 | CONVERGENCE REPEAT (23) | + (−) 12 4 | + − | |
| 33 | ALGEBRAIC SUM OF (31) AND (32) = GRID AZIMUTH TO MARK | 40 21 4 | | |

| | | | |
|---|---|---|---|
| COMPUTER SMITH | CHECKER JONES | SHEET 1 OF 1 SHEETS | |
| NOTEBOOK REFERENCE 4-8-6 | AREA Round Hill | DATE 29 MAY 1965 | |

**DA FORM 6-20**

*Figure 101. Entries on front of DA Form 6–20.*

**TABLE – CENTRAL MERIDIAN OF UTM GRID ZONES**

| ZONE NR | DEGREES W LONG | MILS W LONG | ZONE NR | DEGREES W LONG | MILS W LONG | ZONE NR | DEGREES E LONG | MILS E LONG | ZONE NR | DEGREES E LONG | MILS E LONG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 177 | 3146.67 | 16 | 87 | 1546.67 | 31 | 3 | 53.33 | 46 | 93 | 1653.33 |
| 2 | 171 | 3040.00 | 17 | 81 | 1440.00 | 32 | 9 | 160.00 | 47 | 99 | 1760.00 |
| 3 | 165 | 2933.33 | 18 | 75 | 1333.33 | 33 | 15 | 266.67 | 48 | 105 | 1866.67 |
| 4 | 159 | 2826.67 | 19 | 69 | 1276.67 | 34 | 21 | 373.33 | 49 | 111 | 1973.33 |
| 5 | 153 | 2720.00 | 20 | 63 | 1120.00 | 35 | 27 | 480.00 | 50 | 117 | 2080.00 |
| 6 | 147 | 2613.33 | 21 | 57 | 1013.33 | 36 | 33 | 586.67 | 51 | 123 | 2186.67 |
| 7 | 141 | 2506.67 | 22 | 51 | 906.67 | 37 | 39 | 693.33 | 52 | 129 | 2293.33 |
| 8 | 135 | 2400.00 | 23 | 45 | 800.00 | 38 | 45 | 800.00 | 53 | 135 | 2400.00 |
| 9 | 129 | 2293.33 | 24 | 39 | 693.33 | 39 | 51 | 906.67 | 54 | 141 | 2506.67 |
| 10 | 123 | 2186.67 | 25 | 33 | 586.67 | 40 | 57 | 1013.33 | 55 | 147 | 2613.33 |
| 11 | 117 | 2080.00 | 26 | 27 | 480.00 | 41 | 63 | 1120.00 | 56 | 153 | 2720.00 |
| 12 | 111 | 1973.33 | 27 | 21 | 373.33 | 42 | 69 | 1226.67 | 57 | 159 | 2826.67 |
| 13 | 105 | 1866.67 | 28 | 15 | 266.67 | 43 | 75 | 1333.33 | 58 | 165 | 2933.33 |
| 14 | 99 | 1760.00 | 29 | 9 | 160.00 | 44 | 81 | 1440.00 | 59 | 171 | 3040.00 |
| 15 | 93 | 1653.33 | 30 | 3 | 53.33 | 45 | 87 | 1546.67 | 60 | 177 | 3146.67 |

**CONVERSION COMPUTATION**

| DEGREES, MINUTES, AND SECONDS TO SECONDS | | | SECONDS TO DEGREES, MINUTES, AND SECONDS | | |
|---|---|---|---|---|---|
| 1 | REPEAT (3) | ° ′ ″ | 9 | REPEAT (22) OF COMPUTATION | |
| 2 | NUMBER OF DEGREES IN (1) | | 10 | NUMBER OF TIMES 3600 DIVIDES INTO (9) = NUMBER OF DEGREES IN (9) | ° |
| | | X60 | 11 | REPEAT (9) | |
| 3 | (2) X 60 | | 12 | NUMBER IN (10) X 3600 | |
| 4 | NUMBER OF MINUTES IN (1) | | 13 | (11) – (12) | |
| 5 | (3) + (4) | | 14 | NUMBER OF TIMES 60 DIVIDES INTO (13) = NUMBER OF MINUTES IN (9) | ′ |
| | | X60 | 15 | REPEAT (13) | |
| 6 | (5) X 60 | | 16 | NUMBER IN (14) X 60 | |
| 7 | NUMBER OF SECONDS IN (1) | | 17 | (15)-(16)=NUMBER OF SECONDS IN (9) | ″ |
| 8 | (6) + (7) ENTER IN (4) ON FRONT | | 18 | (10) + (14) + (17) = CONVERGENCE [ENTER IN (23) ON FRONT] | ° ′ ″ |

GIVEN:

UTM grid zone of area of operation.
UTM grid coordinates of station to nearest meter.
Latitude and longitude of station to nearest second or one-hundredth mil (DA Form 6-10, 6-10a, or 6-11).
A value of astronomic azimuth for each set of observations (DA Form 6-10, 6-10a, or 6-11).

GUIDE:

When using a mil-graduated instrument, - -
a. (1) through (5), (7) through (10), and (20) through (22) of computation are computed using hundredth-mil values.
b. (6) and (24) through (33) of computation are computed using tenth-mil values.

Compare (10) and (22) and, if they differ by more than 4 seconds or 0.02 mils, redetermine coordinates and recompute all computations.

LIMITATIONS:

This form should not be used when accuracies greater than third-order are required.

RESULTS:

A value of UTM grid azimuth from the mean values of astronomic azimuth and the grid convergence at the station.

FORMULAS:

UTM grid azimuth = Astronomic azimuth + convergence.

USING UTM GRID COORDINATES:

Convergence = $(XV)q - (XVI)q^3$

$(XV)$ = a variable function based on latitude of station (obtained from TM 6-300-19__, "Army Ephemeris for 19__").

$q$ = 0.000 001 times the distance in meters from central meridian of UTM grid zone to station.

$(XVI)q^3$ = second term of convergence computation (obtained from TM 6-300-19__, "Army Ephemeris for 19__").

USING GEOGRAPHIC COORDINATES:

Convergence = $(XII)p + (XIII)p^3$

$(XII)$ = 10,000 times sine of latitude of station.

$p$ = 0.0001 times distance in seconds or mils of arc from central meridian of UTM grid zone to station.

$(XIII)p^3$ = second term of convergence computation (obtained from TM 6-300-19__, "Army Ephemeris for 19__").

**DA FORM 6-20**

*Figure 102. Auxiliary computations and instructions on back of DA Form 6-20.*

be selected. Works of man, such as roads, railroads, and church steeples, are usually accurately located on maps and should be given first preference as map spots. The centerline of a road may be selected as an azimuth line instead of an orienting point. Streams and ridgelines also make good map spots.

## 272. Magnetic Azimuth

The direction of the earth's magnetic field is determined by use of the aiming circle. For operation of the aiming circle, see paragraphs 145 through 156. A correction is applied to the aiming circle to convert the magnetic azimuth to grid azimuth. The angle between true north and magnetic north is called the magnetic declination. It is named east if the needle points east of true north and west if the needle points west of true north. The horizontal clockwise angle between grid north and magnetic north is called the declination constant or the grid azimuth of magnetic north. The grid-magnetic

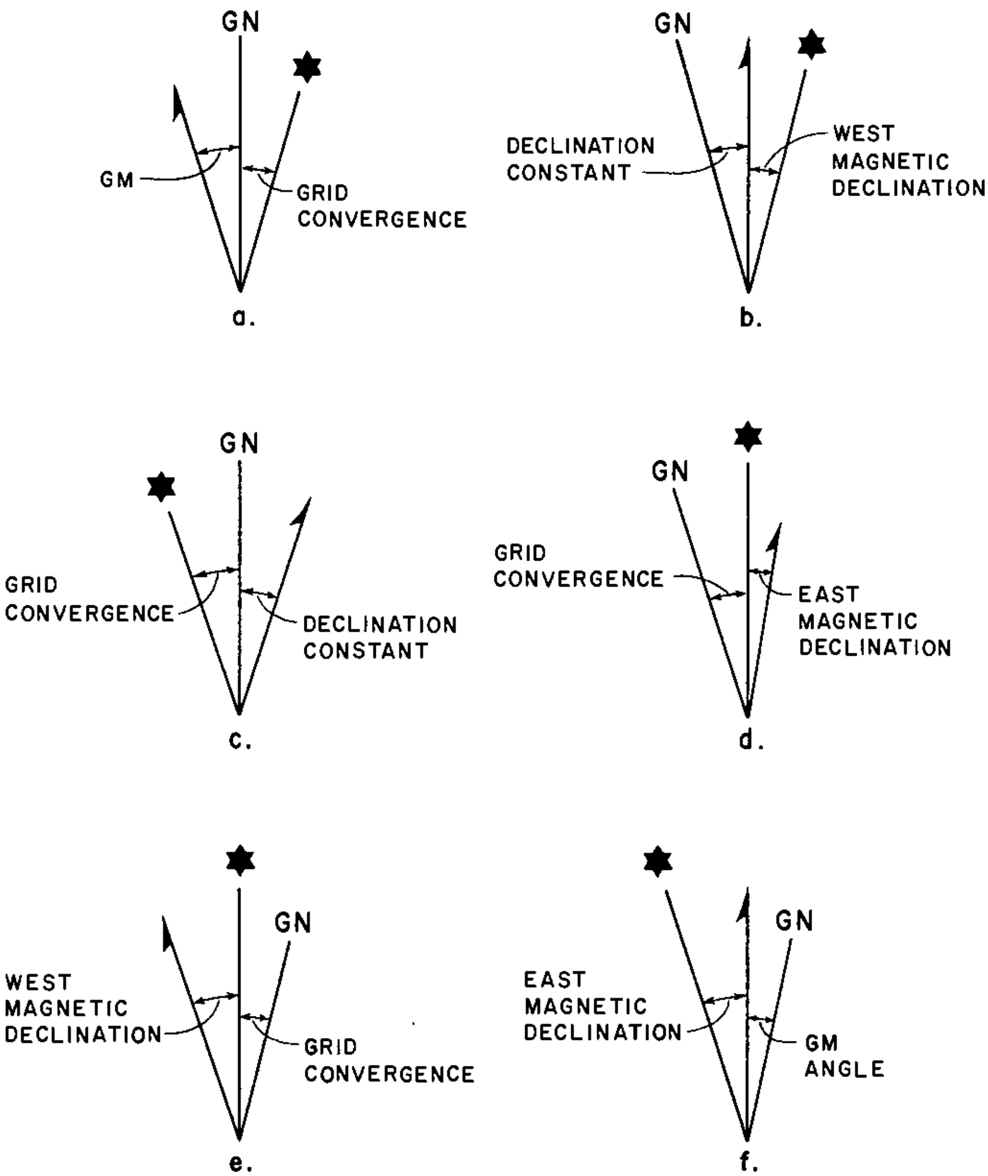



*Figure 103. Declination diagrams.*

angle is the angle between grid north and magnetic north and is always the smaller of the two angles between these lines. The grid convergence is the angle between grid north and true north. On the margin of a military map, a declination diagram shows two of these values from which the others may be derived. There are six possible diagram arrangements (fig. 103). Shown under the declination diagram is the effective year of the diagram with an annual rate of change. When a person arrives in a new area and has no opportunity to declinate a compass at a declination station, he may obtain the declination constant from the declination diagram on a local map. In two cases (b and c, fig. 103), the declination constant is shown directly on the diagram. In two cases (a and f, fig. 103), the grid-magnetic angle shown on the diagram must be subtracted from 6,400 to obtain the declination constant. In one case (d, fig. 103), the declination constant is the sum of the grid convergence and the magnetic declination. In the remaining case (e, fig. 103), the sum of the grid convergence and the magnetic declination must be subtracted from 6,400 to obtain the declination constant. In all cases, the declination constant must then be corrected for the annual change. The annual rate of change is multiplied by the number of years since the date of the diagram. If the annual change is listed as easterly, the product is added to the declination constant. If the annual change is listed as westerly, the product is subtracted from the declination constant.

## 273. Detecting Hidden Magnetic Disturbance

The presence of a hidden magnetic disturbance can be detected by measuring the magnetic azimuth of a line from both ends. A difference in the two measurements in excess of the normal reading error of the instrument indicates the presence of a local magnetic disturbance (fig. 104). If both stations selected are on the same side of the disturbance, the difference in the measurements is much smaller than if the stations were on opposite sides of the disturbance. The magnetic azimuths must continue to be measured from additional stations until the difference in the measurements is tolerable. This precaution should be taken each time the compass is used except at a declination station, when it may be assumed that higher

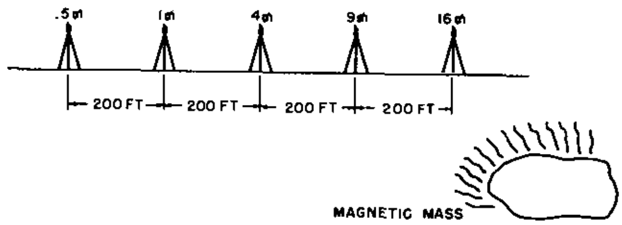



*Figure 104. Detecting hidden magnetic disturbance.*

headquarters has tested the site and found it free of magnetic disturbance.

## 274. Declination Stations

Corps artillery, division artillery, and, in some cases, artillery battalion survey teams will establish declination stations for use by field artillery battalions in declinating their aiming circles. A declination station is a point free of local magnetic disturbance with two or more orienting points of known grid azimuth. The site selected for a declination station should be free of visible magnetic disturbance, accessible from the local road net, and centrally located to the using units. The procedure in paragraph 273 should be followed to determine that the area is free of hidden magnetic disturbance. One of the methods outlined in this section which does not involve the magnetic field should be used to establish a grid azimuth to two or more orienting points. The identification of the station, a description of each orienting point, and the grid azimuth of each point should be written on a tag and the tag attached to the witness stake at the station. The following minimum distances from common magnetic disturbances are prescribed:

| | |
|---|---|
| Powerline | 150 meters |
| Electronic equipment | 150 meters |
| Railway tracks | 75 meters |
| Tanks and trucks | 75 meters |
| Light trucks | 50 meters |
| Wire or barbed wire fences | 30 meters |
| Helmets, etc | 10 meters |

## 275. Procedure for Declinating the Aiming Circle at a Declination Station

When a declination station is available, the procedures in declinating the aiming circle are as follows:

*a.* Set up the aiming circle in the prescribed manner. Level the instrument and perform the checks outlined in paragraph 156.

*b*. Set the known grid detection to the azimuth mark on the scales of the instrument and, with the lower motion (nonrecording), sight on the azimuth mark.

*c*. Release the magnetic needle. With the upper motion (recording), center the needle through the magnetic needle magnifier.

*d*. Read the declination constant directly from the scales (to 0.5 mil).

*e*. Relevel the aiming circle; repeat *b* through *d* above. Determine a second declination constant by using a second known azimuth mark if one is available; if a second known azimuth mark is not available, use the same azimuth mark.

*f*. Compare the two declination constants determined. If they vary more than 2 mils, repeat the entire procedure. If they agree within 2 mils, determine the mean and record it to the nearest 1 mil on the notation strip of the aiming circle.

## 276. When To Declinate the Aiming Circle

Certain rules prescribe how often and under what circumstances the aiming circle should be declinated to determine and to keep current the declination constant. These rules are as follows:

*a*. As a general rule, the aiming circle should be redeclinated when it is moved 25 miles or more from the area in which it was last declinated. A move of any appreciable distance (a few miles) may change the relationship of grid north and magnetic north as measured by the instrument. In some locations, a move of less than 25 miles may require redeclination of the aiming circle.

*b*. The aiming circle must be redeclinated after an electrical storm or after receiving a severe shock, such as a drop from the bed of a truck to the ground. The magnetic needle is a delicately balanced mechanism, and any shock may cause a significant change in the declination constant for the instrument.

*c*. The aiming circle should be redeclinated every 30 days to guard against changes which may have occurred due to accidents to the instrument which were not reported. If a radical change is observed, the instrument should be redeclinated again within a few days to determine if the observed change was due to a magnetic storm or is a real change in the characteristic of the instrument.

*d*. The aiming circle should be declinated when it is initially received and redeclinated when it is returned from ordnance repair. Variations in the declination constant due to the time of day are not significant enough to warrant a redeclination at any specific time.

## 277. Azimuth by Simultaneous Observations

*a*. Because of the great distances of celestial bodies from the earth, the directions to a celestial body at any instant from two or more close points on the earth are approximately equal. The difference between the azimuths is primarily due to the fact that the azimuths at different points are measured with respect to different horizontal planes. This difference can be determined. The principles in *b* below provide a simple and rapid means of transmitting direction between points by simultaneous observations. In general, it is easier and more accurate to observe an astronomic azimuth at each location.

*b*. A master station is established at a point which can be identified on a large-scale map and from which the grid azimuth to an azimuth mark is known or has been determined. Flank stations are established at points which can be identified on a large-scale map and at which it is desired to determine common grid azimuths. Wire or radio communication must be available between each flank station and the master station. An observing instrument is set up at the master station and oriented on the azimuth mark. An observing instrument is set up at each flank station and oriented on an azimuth mark to which the azimuth is desired. (Direction can be transmitted to more than one flank station at the same time.) A prominent celestial body at an altitude between 10° and 65° is selected by the observer at the master station and identified to the observer at each flank station. The observer at the master station must wear a lip or throat microphone so that he can transmit information at the same time that he is observing a celestial body. A loudspeaker, headset, or other device must be provided the observer at each flank station so that he can hear instructions from the observer at the master station. The master station observer reports his coordinates (encoded if necessary) to each flank station observer, and each flank station observer notifies the master station observer when he is ready to observe. When all observers are ready, the observer at the master station announces "*Ready—begin tracking—3—2—1—tip.*" Pointings are made on the celestial body as explained in chapter 13, depending on which instrument is used. However, each flank station observer, if he is observing the sun, keeps his vertical crosshair (crossline) tangent to the leading edge of the sun and approximately bisects the sun with the horizontal crosshair (crossline). The master station observer announces "*Tip*" the instant the star is at the intersection of the crosshairs or the instant the sun is tangent to both crosshairs. The master station observer records the readings on the horizontal and vertical scales (fig. 105). Each flank observer records the reading on the horizontal scale when observing the sun and the readings on the horizontal and vertical scales when observing a star (fig. 106). The vertical angle is read at the flank stations only as an aid in identification. All observers then plunge their telescopes and repeat the procedure with the telescopes in the reverse position, using the procedure required for their instrument. With the aiming circle, two readings are taken. If observing the sun, each flank station observer tracks with the vertical crosshair tangent to the trailing edge of the sun. After both point-

DESIGNATION SIMULTANEOUS OBSERVATION DATE 28 JUL 19

| STATION | T | HORIZONTAL ∡ MILS | MEAN | VERTICAL READING | VERTICAL ∡ MILS |
|---|---|---|---|---|---|
| WT | D | 0000.140 | | | |
| | R | 3200.154 | 0000.147 | | |
| ADAMS | MN | 6049.430 | | | +393.672 |
| SUN | $t_0$ D | 6048.177 | 6049.577 | 1197.024 | +402.976 |
| | °+ R | 2850.977 | | 5184.367 | +384.367 |

CHIEF OF PARTY: SGT DICK[14]
WEATHER: COOL-CLEAR OBSERVER: SGT AHERN
INSTRUMENT NO: $T_2$ #181 RECORDER: CPL SCHUVER

REMARKS

STATION ADAMS IS MASTER STATION LOCATED 15M SW OF JUNCTION DUMP RD AND EL RD. STATION IS 1" PIPE SET IN 6"x6" CONCRETE BLOCK FLUSH WITH GROUND.
AZ MK IS LIGHTNING ROD ON TOP OF WATER TOWER 1000M SW OF ADAMS.
COMPUTATIONS OF AZ TO SUN:

| | |
|---|---|
| AZ ADAMS TO WT | 4305.253 ₥ |
| ∡ WT-ADAMS-SUN | 6049.430 ₥ |
| | 10354.683 |
| | − 6400.000 |
| AZ ADAMS TO SUN: | 3954.683 ₥ |

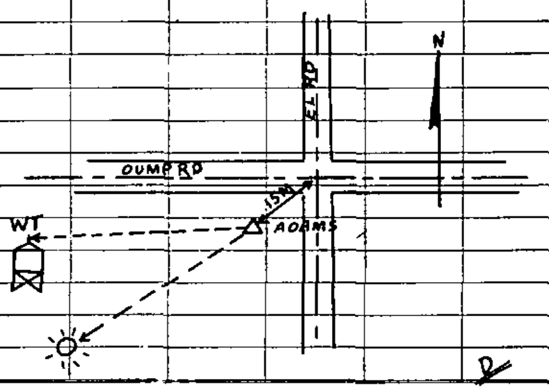
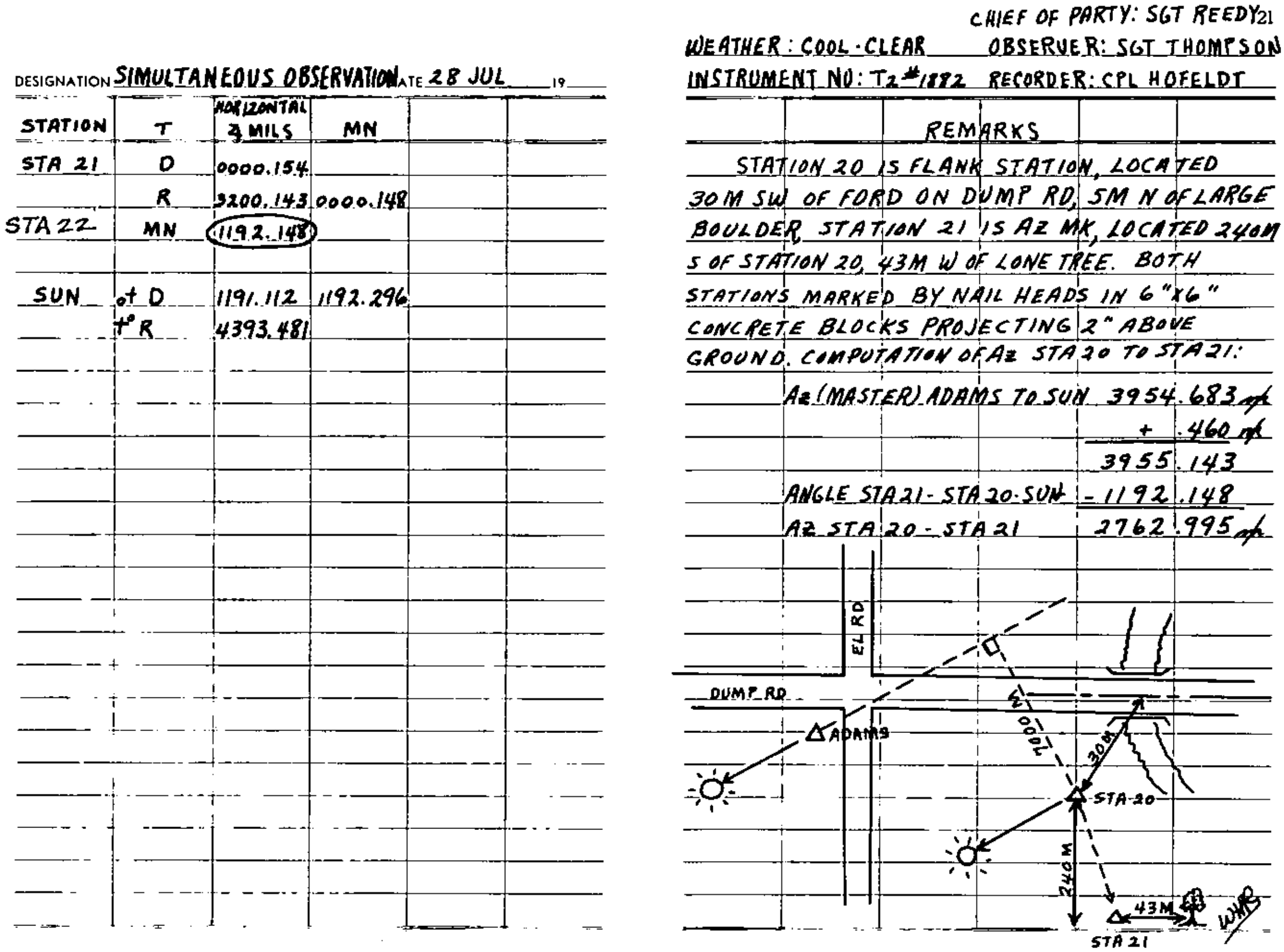



*Figure 105. Recorder's notes made at the master station for a simultaneous observation.*



CHIEF OF PARTY: SGT REEDY 21
WEATHER: COOL-CLEAR OBSERVER: SGT THOMPSON
INSTRUMENT NO: T2 #1892 RECORDER: CPL HOFELDT

DESIGNATION SIMULTANEOUS OBSERVATION DATE 28 JUL 19

| STATION | T | HORIZONTAL ∡ MILS | MN |
|---|---|---|---|
| STA 21 | D | 0000.154 | |
| | R | 3200.143 | 0000.148 |
| STA 22 | MN | 1192.148 | |
| SUN | ⊙ D | 1191.112 | 1192.296 |
| | ⊙ R | 4393.481 | |

REMARKS

STATION 20 IS FLANK STATION, LOCATED 30 M SW OF FORD ON DUMP RD, 5M N OF LARGE BOULDER. STATION 21 IS AZ MK, LOCATED 240M S OF STATION 20, 43M W OF LONE TREE. BOTH STATIONS MARKED BY NAIL HEADS IN 6"x6" CONCRETE BLOCKS PROJECTING 2" ABOVE GROUND. COMPUTATION OF AZ STA 20 TO STA 21:

| | |
|---|---|
| Az (MASTER) ADAMS TO SUN | 3954.683 ₥ |
| | + .460 ₥ |
| | 3955.143 |
| ANGLE STA 21 - STA 20 - SUN | - 1192.148 |
| Az STA 20 - STA 21 | 2762.995 ₥ |



*Figure 106. Recorder's notes made at a flank station for a simultaneous observation.*

ings, each flank station observer acknowledges if the observation was successful. He reports "*Take again*" if the observation was not successful. After each set of pointings in which one or more flank stations tracked successfully, the horizontal angle at the master station, from the azimuth mark to the celestial body, is determined from the observed data. This horizontal angle is then added to the grid azimuth from the master station to the azimuth mark to obtain the grid azimuth to the observed celestial body. This grid azimuth and the mean vertical angle to the celestial body are transmitted to each flank station.

*c.* At each flank station, the locations of both stations are plotted on a large-scale map (fig. 107). A line is then drawn on the map representing the azimuth to the celestial body at the master station. The perpendicular distance (D) to this line from the flank station is then measured.

*d.* A line is drawn on the nomograph shown in figure 108 (also contained in TM 6–300–( ), Army Ephemeris) to connect the mean observed altitude at the master station (H) and the distance (D). This line will intersect the center scale (C) at a point corresponding to the correction in mils (or seconds) to be applied to the azimuth at the master station to determine the correct azimuth from the flank station to the celestial body. When the nomograph is used, it may be necessary to multiply the indicated value in meters by 10, 100, etc. In this case, the indicated correction in mils (or seconds) must also be multiplied by the same number. The correction is applied to the grid azimuth of the

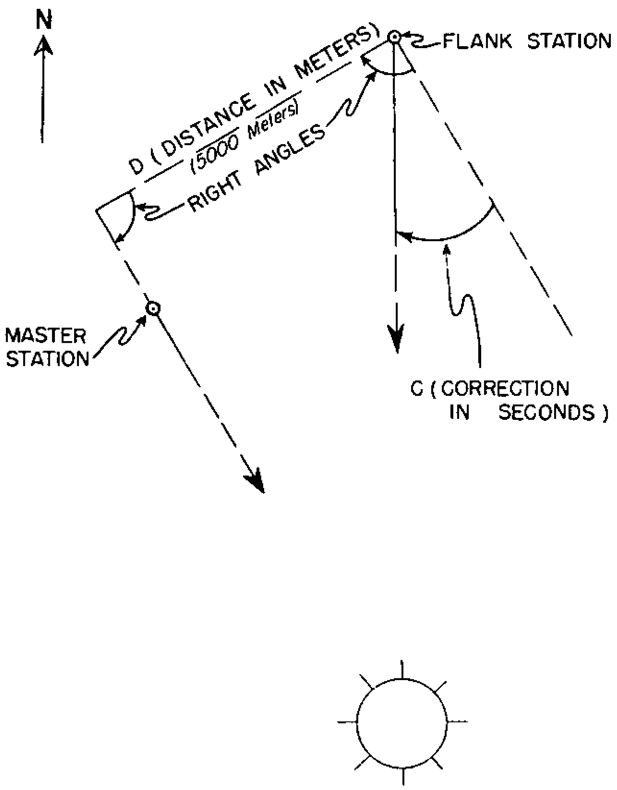



*Figure 107. Relative locations of the master station, the flank station, and the celestial body.*

celestial body (determined at the master station) in accordance with the following rules:

(1) When the flank station is to the left of the line from the master station to the celestial body, the correction is added to the azimuth.

(2) When the flank station is to the right of the line from the master station to the celestial body, the correction is subtracted from the azimuth.

*e.* The corrected azimuth obtained in *d* above is the grid azimuth of the celestial body from the flank station. The mean of the observed horizontal angle at the flank station, from the azimuth mark to the celestial body, is then subtracted from this azimuth to obtain the grid azimuth to the azimuth mark. For this subtraction, it may be necessary to add 6,400 mils or 360° to the azimuth of the celestial body.

*f.* If necessary, the master station may use an assumed starting azimuth to the azimuth mark.

## 278. Example of Computations for Simultaneous Observations

The following example illustrates the transmission of direction to one flank station by simultaneous observations:

*a.* Mean recorded angles:

Master station

Horizontal angle=2191.421 mils
Vertical angle = 720.063 mils

Flank station

Horizontal angle=1715.063 mils

*b.*

| | |
|---|---|
| Grid azimuth to azimuth mark at master station: | 1874.537 |
| Mean observed horizontal angle at master station: | +2191.421 |
| Grid azimuth to star at master station: | 4065.958 |
| Correction from nomograph (*c* below): | +0.680 |
| Grid azimuth to star at flank station: | 4066.638 |
| Mean horizontal angle at flank station: | —1715.063 |
| Grid azimuth to azimuth mark at flank station: | 2351.575 |

*c.* The relative locations of the master station and flank station and the star are shown in figure 107. The distance (D) is scaled from this figure to enter the nomograph in figure 108. The correction to the azimuth of the star is scaled from the nomograph as +0.68 mil and is used in the computation above to convert the grid azimuth of the star from the master station to the flank station.

## TABLE 13. Grid Azimuth Correction, Simultaneous Observation

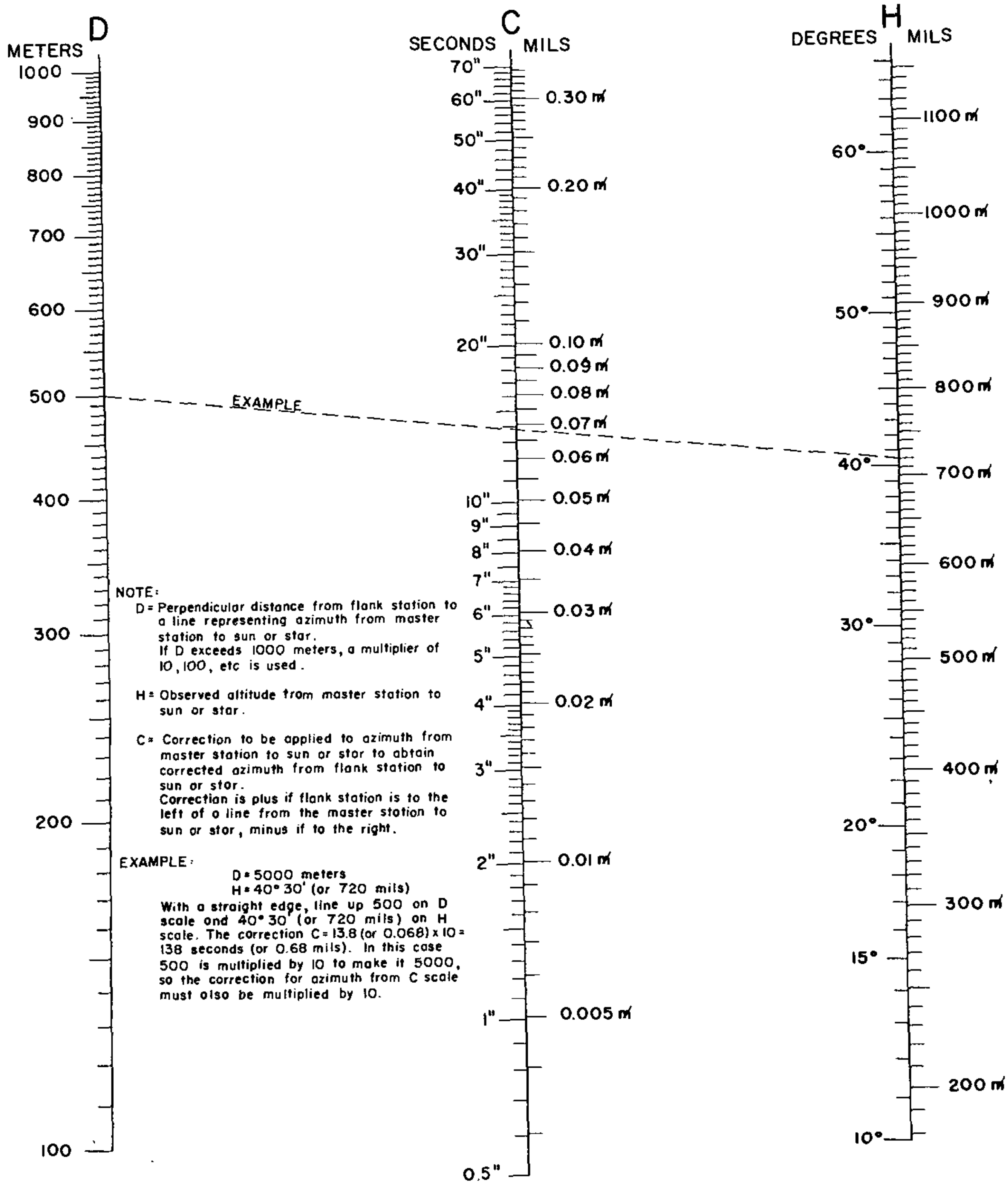



*Figure 108. Simultaneous observation, grid azimuth correction nomograph.*

# CHAPTER 13

# ASTRONOMIC AZIMUTH

## Section I. GENERAL

### 279. General

*a.* The tactical situation will dictate the time and place that astronomic azimuth may be taken. The artillery surveyor must select the celestial body and method of computation which will give the required accuracy in the time available. Astronomic observation is the fastest independent method of determining direction available and should be the first choice if visibility and other required conditions can be met.

*b.* Both the geographic and UTM coordinates of the observing station are required for computations. The position selected, within the area dictated by the tactical situation, should be such that one of these values is either known or can be scaled from a map. The effects of refraction on observations are discussed in paragraph 294.

*c.* The specifications and the limitations discussed in this chapter are intended to meet the most stringent artillery requirement. When a lesser accuracy will suffice, some of the requirements may be lowered to meet the tactical situation.

### 280. The Celestial Sphere

In practical astronomy, it is assumed that the sun and stars are attached to a giant sphere, the center of which is the earth. The stars are so far away from the earth that the radius of the sphere is assumed to be infinite. Some parts of the celestial sphere are related to parts of the earth (fig. 109).

*a.* The points at which the extensions of the earth's rotating axis intercept the celestial sphere are called the *north* and *south celestial poles,* respectively.

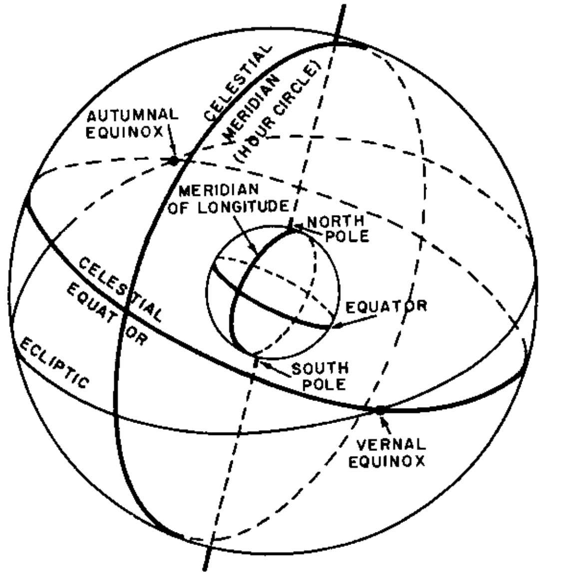



*Figure 109. The celestial sphere.*

*b.* The plane forming the earth's equator when extended to the celestial sphere inscribes the *celestial equator* on the celestial sphere.

*c.* The extension to the celestial sphere of any plane forming a meridian of longitude on the earth forms a corresponding meridian on the celestial sphere which is called a *celestial meridian* or *hour circle.*

*d.* The *ecliptic* is the great circle cut on the celestial sphere by the plane of the earth's orbit. Since the sun lies in the plane of the ecliptic, the apparent path of the sun follows the ecliptic. The ecliptic intersects the celestial equator at two points at an angle of about 23½°. These points are called the *equinoxes.*

*e.* The point at which the apparent sun, moving from south to north, crosses the celestial equator is known as the *vernal equinox*. This is the point on the celestial sphere used as a reference for sidereal time and the apparent places of the stars.

## 281. Observer's Position

*a.* The *zenith* and *nadir* of the observer's position on the earth's surface are the two points on the celestial sphere where the extended plumbline of the observer's instrument intersects the sphere. The zenith is the point directly above the position, and the nadir is the point directly below the position.

b. The observer's geographic locations are as follows:

(1) The latitude of the observer's location is the angular distance of that point north and south of the equator.

(2) The longitude of the observer's location is the angular distance of the observer's meridian east or west of the Greenwich meridian, as measured on the equator.

c. The line of longitude which passes through the observer's position is called the *observer's meridian.* The celestial meridian which passes through the zenith is called the *observer's hour circle* (fig. 110). Both meridians lie in the same plane.

*d.* The *observer's horizon* is a circle on the celestial sphere, formed by a plane tangent to the earth at the observer's location and perpendicular to the plumbline of the observer's instrument (fig. 110).

*e.* A *vertical circle* is any great circle on the celestial sphere passing through the zenith and nadir of a point (fig. 110).

*f.* The *prime vertical* is the vertical circle perpendicular to the observer's meridian at the zenith, which intersects the horizon at points directly east and west of the observer (fig. 110).

## 282. Position of a Celestial Body

The system of locating a celestial body on the celestial sphere is much the same as that of locating the observer on the earth. The two coordinates in this system are *right ascension* (*RA*) and *declination* (*dec*) (fig. 111). This system is used to list the stars in the Army Ephemeris.

*a.* Right ascension is comparable to longitude and is the angle in hours (h), minutes (m), and seconds (s) measured eastward from the vernal equinox to the hour circle of a celestial body.

*b.* The declination of a celestial body is com-

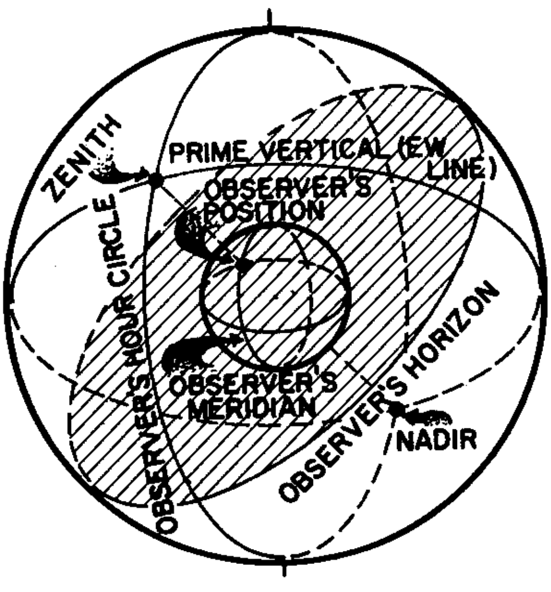



***Figure 110. Elements relative to observer's position.***

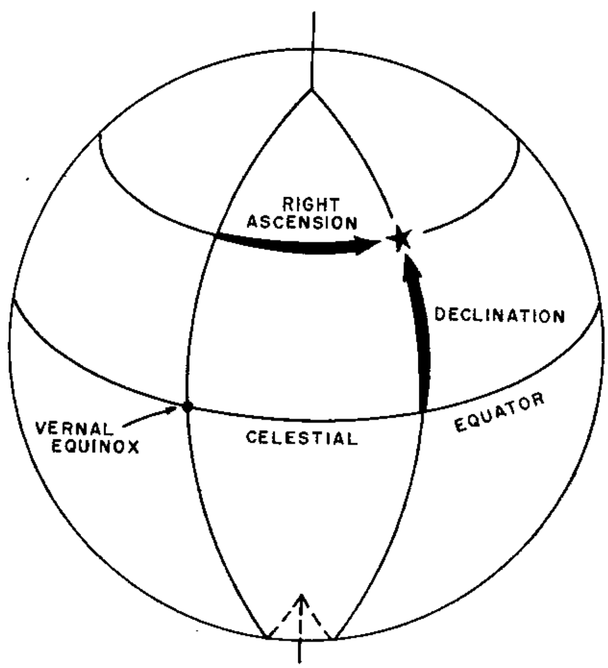



***Figure 111. Locating a celestial body.***

parable to latitude and is the angle measured north or south of the celestial equator to a celestial body. If the celestial body is north of the celestial equator, the declination is (+); if it is south, the declination is minus (—).

### 283. Astronomic Triangle

Determination of azimuth by astronomic observations involves the solution of a spherical triangle visualized on the celestial sphere (fig. 112). This triangle is called the *astronomic triangle* or the *PZS triangle*. The desired azimuth to the celestial body is determined by solving the triangle for the value of the azimuth angle. This value can be computed when three other parts of the triangle are known. The letters PZS stand for the three vertices of the triangle; namely, the celestial *pole* (*P*) the *zenith* (*Z*), and the *star* or *sun* (*S*). The three sides of the triangle are the *polar distance*, the *coaltitude*, and the *colatitude*. The three angles are the *parallactic angle*, the *azimuth angle*, and the *local hour angle*. When a survey is conducted

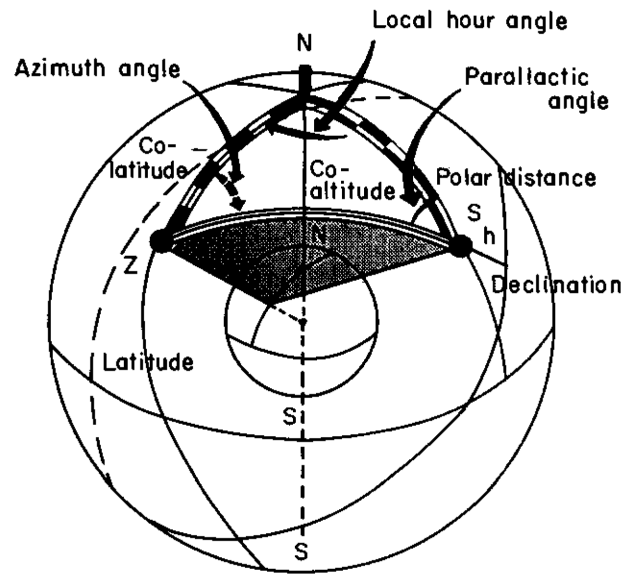



*Figure 112. Celestial sphere with three sides and three angles of the astronomic (PZS) triangle.*

south of the equator, the north pole is used unless computations are performed by the hour-angle method, in which case the south pole is used. The azimuth angle may be either east or west of the pole used.

### 284. The Sides of the Triangle

Each side of the astronomic triangle is the cofunction of a known or measured value. The cofunction is defined as 1,600 mils, or 90° minus the function. Thus, the colatitude, or PZ side of the triangle, is equal to 1,600 mils minus the latitude. The coaltitude, or SZ side, is 1,600 mils minus the altitude. The polar distance, or PS side, is 1,600 mils minus the declination. In most cases, the formulae used by the artillery have been arranged so that the known or measured value is used rather than the cofunction.

### 285. The Angles of the Triangle

The angles of the astronomic triangle are as follows:

*a. Parallactic Angle.* The parallactic angle is the interior angle at the celestial body and is used in the formula for determining azimuth by the hour-angle method but cancels out in the computations.

*b. Azimuth Angle.* The azimuth angle is the interior angle of the astronomic triangle at the zenith. This angle is the result of computations and is used to determine the true azimuth to the celestial body from the observer. The angle can be either to the east or west of the observer's meridian, depending on whether the celestial body is east or west of the observer's meridian. When the south pole is used to determine the azimuth angle, the angle must be changed to the north by adding 3,200 mils.

*c. Local Hour Angle.* The local hour angle is the interior angle of the astronomic triangle at the pole and is used in the hour-angle method of determining azimuth.

## Section II. TIME

### 286. General

*a.* Time is an angular measurement. One complete rotation of the earth is 1 day. Each day is divided into 24 hours of 60 minutes each, and each minute is divided into 60 seconds. In artillery computations, angular measurements are usually expressed in mils. Table 5 in the Army Ephemeris is used to convert time to mils.

*b.* Solar time is the hour angle of the sun plus 12 hours. Since the apparent sun does not move at a uniform rate, time is based on the mean movement of the sun. Greenwich mean time (GMT) is the hour angle of the mean sun from the meridian of Greenwich plus 12 hours. Mean time is the hour angle of the mean sun from the standard time zone meridian plus 12 hours.

## 287. Standard Time and Time Zones

Watch times are based on standard time zones, each of which covers a portion of the earth. In a zone of operations, survey personnel using astronomic observations must know the time zone on which their watch time is based. The time zone on which a watch time is based can be determined from the survey information center (SIC). (Time zone corrections are given in table II.) Local mean time (LMT) changes 1 hour for each change of 15° of longitude. Since the sun appears to move from east to west, time increases from west to east and decreases from east to west. For example, with Greenwich as a baseline for time measurement, time decreases 1 hour for each change of 15″ of longitude (arc) westward from Greenwich. Time differs in whole hours from Greenwich mean time at 15° W, 30° W, 45° W, etc. (table II). To standardize the time within a certain area, lines of longitude at which time differs from Greenwich mean time in whole hours are used. A time zone area extending 7½° from each side of these lines has the same time as that meridian unless otherwise specified by civil authorities. For example, the time zone for the 45° W meridian would extend from 37° 30′ W to 52° 30′ W. In the United States there are four time zones. These zones are based on the 75° W, 90° W, 105° W, and 120° W meridians and are called eastern, central, mountain, and Pacific standard times, respectively.

*Table II. Time Zone Corrections, Local Mean Time to Greenwich Mean Time.*

| Time zone | | Correction (hours) | Time zone | | Correction (hours) |
|---|---|---|---|---|---|
| Z | Greenwich (GMT) | 0 | Z | Greenwich (GMT) | 0 |
| A | 15° E | −1 | N | 15° W | +1 |
| B | 30° E | −2 | O | 30° W | +2 |
| C | 45° E | −3 | P | 45° W | +3 |
| D | 60° E | −4 | Q | 60° W | +4 |
| E | 75° E | −5 | R | 75° W | +5 |
| F | 90° E | −6 | S | 90° W | +6 |
| G | 105° E | −7 | T | 105° W | +7 |
| H | 120° E | −8 | U | 120° W | +8 |
| I | 135° E | −9 | V | 135° W | +9 |
| K | 150° E | −10 | W | 150° W | +10 |
| L | 165° E | −11 | X | 165° W | +11 |
| M | 180° E | −12 | Y | 180° W | +12 |

*Note.* Each of these zones is named by local civil authority. For example, in the United States, time zone *Q* corresponds to *eastern daylight saving time;* time zone *R* corresponds to *eastern standard time* and *central daylight saving time;* time zone *S* corresponds to *central standard time* and *mountain daylight saving time;* time zone *T* corresponds to *mountain standard time* and *Pacific daylight saving time;* and time zone *U* corresponds to *Pacific standard time.*

## 288. Source of Accurate Time

*a.* All major nations furnish a radio time signal of a high order of accuracy for use by scientists and navigators. The method of obtaining the correct time from such radio signals is explained in detail in TM 5–441. These radio signals are the preferred and most accurate time source.

*b.* The survey information center is issued a chronometer which is capable of maintaining time to an accuracy sufficient for artillery survey use. For the use of those artillery surveyors who are not equipped with a radio which will receive the time signals referred to in *a* above, the SIC furnishes accurate time. The SIC maintains, in a bound book such as DA Form 5–72, a log of the chronometer so that time accurate to 0.2 second can be furnished by telephone, radio, or direct comparison of watches. The record is kept in the following manner:

| Date | Time | Chronometer | | | Chronometer correction | | | Diff sec | Elapsed time days | Daily rate |
|---|---|---|---|---|---|---|---|---|---|---|
| | | h | m | s | h | m | s | | | |
| Jan 2 | 0800 | 08 | 43 | 27.3 | 0 | 43 | 27.3 | | | |
| Jan 3 | 0800 | 08 | 43 | 29.5 | 0 | 43 | 29.5 | −2.2 | 1 | −2.20 |
| Jan 7 | 1700 | 08 | 43 | 39.1 | 0 | 43 | 39.1 | −9.6 | 4.375 | −2.18 |

The date and time is obtained from one of the radio time signals listed in TM 5–441. Computations can be simplified if the signal is obtained at the same time each day. A comparison of the chronometer time and the radio time should be made to the nearest 0.1 second to provide time accurate to 0.2 second. The chronometer correction at the time of the comparison is the difference between the chronometer time and the time obtained by radio. The sign of the correction should reduce the chronometer time to correct time. The difference column is the change in the correction between the current chronometer comparison and the last chronometer comparison. The sign of this difference should reduce the previous chronometer correction to the current correction. This should be in seconds of time. The elapsed time is the difference in decimal parts of a day between the last two comparisons. The daily rate is obtained by dividing the difference column by the elapsed time in days and carries the same sign as the difference column. The daily rate is a measure of the amount of time the chronometer loses or gains in a day. The chronometer should be wound at the same time each day in order to maintain a uniform rate. The chronometer must never be allowed to run down and should never be set. When the survey information center is moved, the chronometer must be handled with care.

*c.* Message center time is used to synchronize military tactical operations and, in general, is not accurate enough for astronomic use. However, when observing the stars (sun) by the altitude method, or Polaris by the Polaris method, it will usually suffice. The habit of using time from the SIC should be formed in order to obtain the most accurate time possible.

## 289. Greenwich Mean Time

All computations of astronomic observations in the artillery are based on Greenwich mean time (fig. 113). Greenwich mean time is determined for the local mean time of observation by applying a correction for the difference in hours between local mean time and Greenwich mean time. For example, if the longitude of the observer is 92° 13′ 42″ W and the civil, or mean, time at that point is based on the standard time of the 90° W meridian, a 6-hour difference, or correction, must be applied to the local mean time of observation in order to determine the Greenwich mean time of observation.

## 290. Apparent Solar Time

As noted in paragraph 286, the mean position of the sun is used to measure mean time. When observations are made on the sun, the actual or apparent sun is observed. Consequently, when astronomic computations involving the hour angle of the sun are performed, apparent solar time is used (fig. 114). The actual hour angle of the sun referred to the observer's meridian is the local apparent time plus 12 hours. The local apparent time is obtained by changing the time of observation to Greenwich mean time, which is the basis for the tables of the Army Ephemeris, TM 6–300–( ). The equation of time, which is the differ-

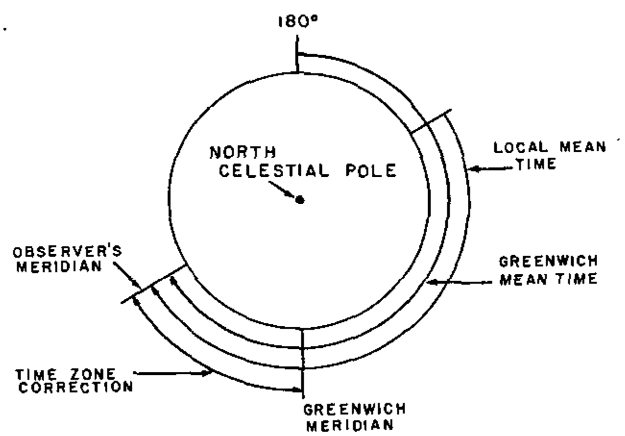



*Figure 113. Greenwich mean time.*

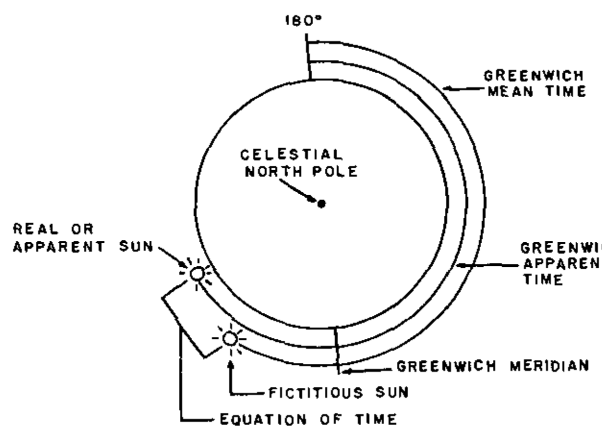



*Figure 114. Apparent solar time.*

ence between the mean sun and the apparent sun, is then obtained from table 2 of the Army Ephemeris and is added to Greenwich mean time to obtain Greenwich apparent time (GAT). The longitude of the observer's meridian at the time of observation is then added to, or subtracted from, the Greenwich apparent time. The result is local apparent time. In west longitude, the longitude of the observer's meridian is subtracted from the Greenwich apparent time; in east longitude, it is added. These computations may be performed in hours, degrees or mils, whichever is most convenient. All times must be converted to the same unit before performing the addition or subtraction, and the final answer must be reduced to mils for use in computations.

## 291. Sidereal Time

Time is an angular measurement of the rotation of the earth using various reference points. The basic reference point for sidereal time is the vernal equinox. One sidereal day is the length of time it takes the earth to complete one revolution with respect to the vernal equinox. The sidereal day is nearly 4 minutes longer than the solar day. The rotation of the earth on its own axis added to the rotation of the earth around the sun to complete one revolution of the earth with respect to the sun takes less time than one revolution of the earth with respect to a fixed point in space.

*a.* The position of the stars on the celestial sphere with respect to the vernal equinox is an angle called the right ascension. Because the stars move so slowly in space, they can be listed in terms of right ascension and the listing will not change. If the time of observation is converted to sidereal time which is also referred to the vernal equinox, the hour angle of the star can be obtained by simple addition.

*b.* The local sidereal time, which is the hour angle of the meridian of observation referred to the vernal equinox, is obtained by converting the time of observation to Greenwich mean time by applying the time zone correction. Greenwich mean time is then converted to Greenwich sidereal time (GST) by obtaining the sidereal time of $0^h$ Greenwich from table 2 of the Army Ephemeris and adding the correction for the fraction of a day as contained in table 4. The longitude of the observer's meridian is then applied to Greenwich sidereal time to obtain local sidereal time (LST) (fig. 115).

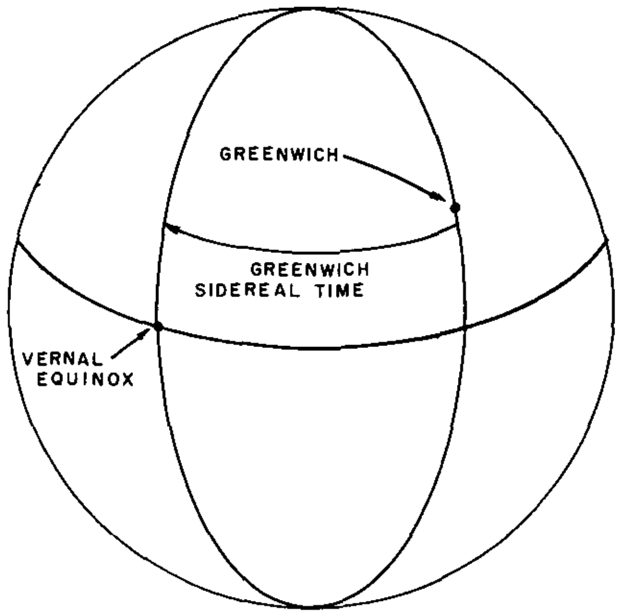



*Figure 115. Sidereal time.*

# Section III. DETERMINING FIELD DATA

## 292. General

Field data for determining azimuth by astronomic observation consists of the horizontal angle between an azimuth mark and the observed celestial body, the vertical angle to the body, the time of the observation, the temperature at the time of the observation, the approximate azimuth to the azimuth mark, and the location of the observing station in both geographic and grid coordinates. All of these should be observed and recorded at all astronomic stations.

## 293. Selection of Site

Within the limits imposed by the tactical situation, the exact point selected for the observations can improve the accuracy of the observations and make the computations simpler. Refraction is the first major consideration in the selection of a site. The site must be so located that the effect of refraction is reduced as much as possible. Both the geographic and UTM coordinates of the site are required in computations. These are usually obtained by scaling the position from a map. The point selected should be one that can be located easily on a map. An alternate to map spotting is to select a survey control point and use the surveyed coordinates.

## 294. Refraction

When light rays pass through transparent substances of different densities the light rays are bent. This effect is called refraction. It is easy to observe this effect when looking obliquely into a pond of clear water. When looking straight down into the water, the effect is not visible. Light rays are also bent, but to a lesser degree, when they pass through layers or bodies of air at different temperatures or densities. Refraction is still great enough, however, to affect the angles measured. When observing a star (sun), the observer's line of sight passes through the earth's atmosphere out into space. The earth's atmosphere is composed of numerous layers of air of different densities. As the line of sight passes through each layer, it is bent slightly. The sum of all the bending is the vertical refraction. The effect of refraction is not visible when the observer looks straight up. When the observer looks horizontally the vertical refraction is maximum. The mean vertical refraction correction for average conditions has been computed and is listed in table 1 of the Army Ephemeris. The probable error of this correction is not too large for artillery survey purposes. Since no correction can be made for horizontal refraction, it is adviseable to avoid an instrument position where there is a large variation in local temperature.

## 295. Temperature

In units equipped with a thermometer, the temperature at the time of observation should be recorded. Temperature, to the nearest degree, and the vertical angle are used to enter table 1a or 1b of the Army Ephemeris to determine the refraction correction.

## 296. Determining Horizontal and Vertical Angles

*a.* The instruments used to observe celestial bodies are the aiming circle, the T16 theodolite, or the T2 theodolite. Instructions for use of these instruments are found in chapter 7. Angles are determined in astronomic observations in much the same manner as in any other method of survey; i. e., the angles are determined by comparing the mean pointing to one station with the mean pointing to another. Since celestial bodies appear to be moving, the technique of pointing is slightly modified. Also, since the sun presents such a large target, special techniques must be employed to determine its center.

*b.* Vertical angles are usually larger than in normal field operations. Consequently, errors in leveling can cause large errors in the horizontal angles. More than normal care is required in leveling. The plate level should be checked after each pointing on the star or sun. If the vertical angle exceeds 800 mils, leveling becomes even more critical. Since the level vial is perpendicular to the line of sight, leveling will not require additional time.

*c.* A "position" is a complete set of data starting with the initial pointing on the azimuth mark and ending with the pointing on the azimuth mark with the telescope reversed. At least three positions which agree are required for a check. The position may be started with the telescope in the direct or reverse position, and some time will be saved if alternate positions are started with the telescope reversed. Agreement between positions or sets is checked by plotting the mean horizontal angles and vertical angles against the mean times of the pointings. The plot should be a straight line within the limits of accuracy of the instrument. This plot should be made by the recorder before the instrument operator removes his instrument from the tripod.

## 297. Use of the Theodolite With Solar Circle for Sun Observations

The T16 theodolite and the later model T2 theodolite are equipped with a solar circle on the reticle (fig. 116). The solar circle permits an observer to view the sun in such a manner that the vertical and horizontal crosslines of the instrument are directly over the center of the sun. The initial pointing on the azimuth mark is made with the telescope in the direct position. The telescope is then pointed toward the sun. The sun is placed on the solar circle and tracked by using both the horizontal and vertical tangent screws. When the sun is nearly centered in the solar circle, the observer warns the recorder by saying *"Ready."* At the word *"Ready,"* the recorder looks at his watch, getting the second beat in mind. The observer centers the sun in the solar circle and announces *"Tip."* At the word *"Tip,"* the recorder enters the time in the record book. The observer checks the plate level and levels the collimation level bubble and then reads the vertical and horizontal circle readings. The recorder must have recorded the time before accepting the angles. The telescope is then plunged, and the process is repeated with the telescope in the reverse position. With the telescope still in the reverse position, the final pointing is made on the azimuth mark. The mean data can now be determined.

***Caution:* Do not view the sun directly through the telescope unless the sun filter has been affixed to the eyepiece.**

### 298. Use of Instruments Without the Solar Circle for Sun Observations

*a.* The early model T2 theodolite and the aiming circle are not equipped with a solar circle for pointing on the center of the sun. To achieve measurements to the center of the sun, the observer measures the angles to one side of the sun with the telescope in the direct position and then to the other side of the sun with the telescope in the reverse position (fig. 117). The resulting mean angle is the angle to the center of the sun. This method of determining the center of the sun is called the quadrant method and can be used either when the sun is viewed directly through a sun filter or when the image of the sun is projected onto a card held to the rear of the eyepiece of the telescope. To determine the correct quadrant in which to place the image of the sun, the observer first determines the direction the sun is moving. If the motion of the sun is through the first and third quadrants (from first to third or from third to first) as viewed through the telescope or on the card, the image of the sun should be placed in the second and fourth quadrants. If the motion of the sun is through the second and fourth quadrants (from second to fourth or from fourth to second), the image of the sun should be placed in the first and third quadrants.

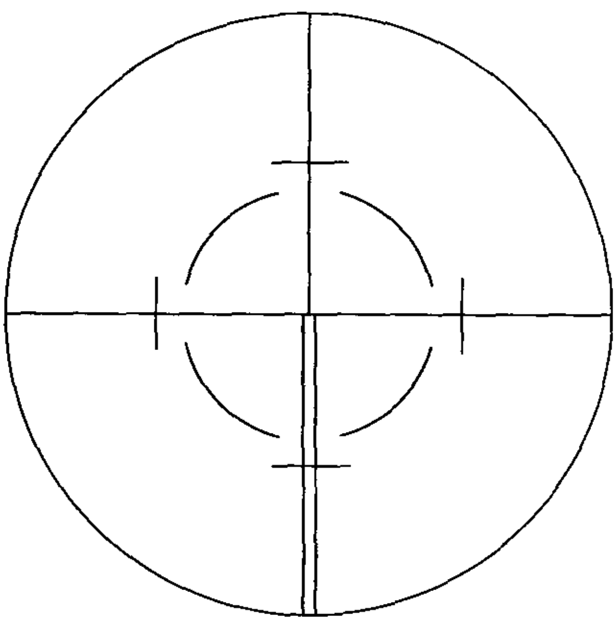



*Figure 116. T16 theodolite reticle with solar circle.*

*b.* The instrument is set up over the station selected. With the telescope in the direct position, the observer makes the initial pointing on the azimuth mark. In those instruments with double vertical crosslines, the quadrants selected must be such that the double crossline is not used. The image of the sun is placed in the telescope so that it is in the proper quadrant and position. When a card is used for morning observation with the telescope in the direct position, the disc should be in the third quadrant hanging on the horizontal crosshair and slightly over the vertical crosshair.

*c.* Using the vertical motion, the observer maintains the sun's image tangent to the horizontal crosshair and allows the movement of the sun to bring the sun tangent to the vertical crosshair. The observer alerts the recorder by calling *"Ready"* and announces *"Tip"* at the exact moment when the image of the sun is tangent to both crosshairs. At the word *"Ready"* the recorder looks at his watch, getting the second beat in mind. At the word *"Tip,"* the recorder writes the time in the record book to the nearest second. The instru-

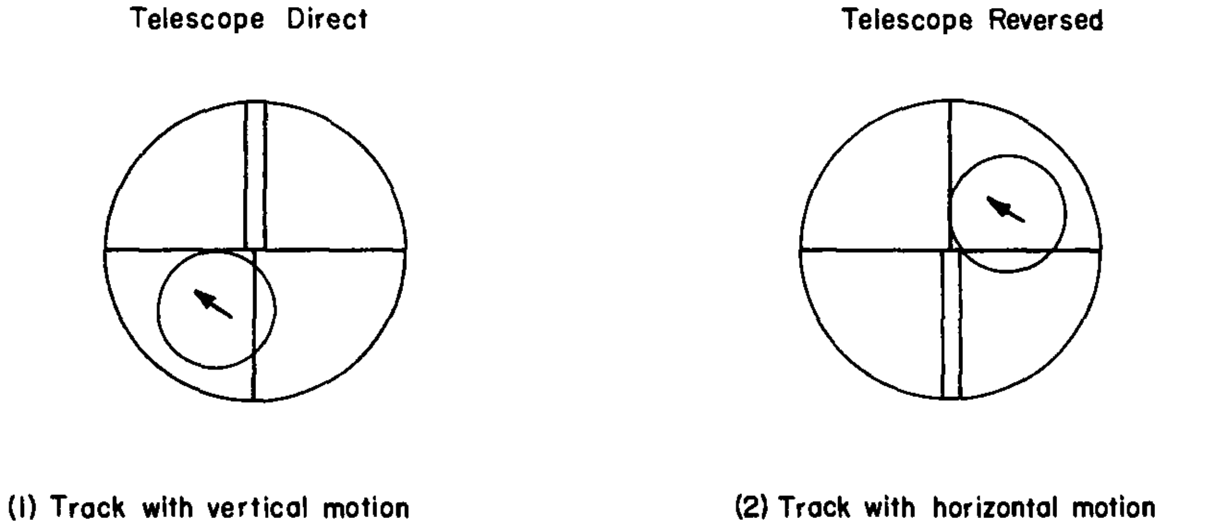



Figure a. Sun's actual motion on card with T-2 theodolite (AM observations)

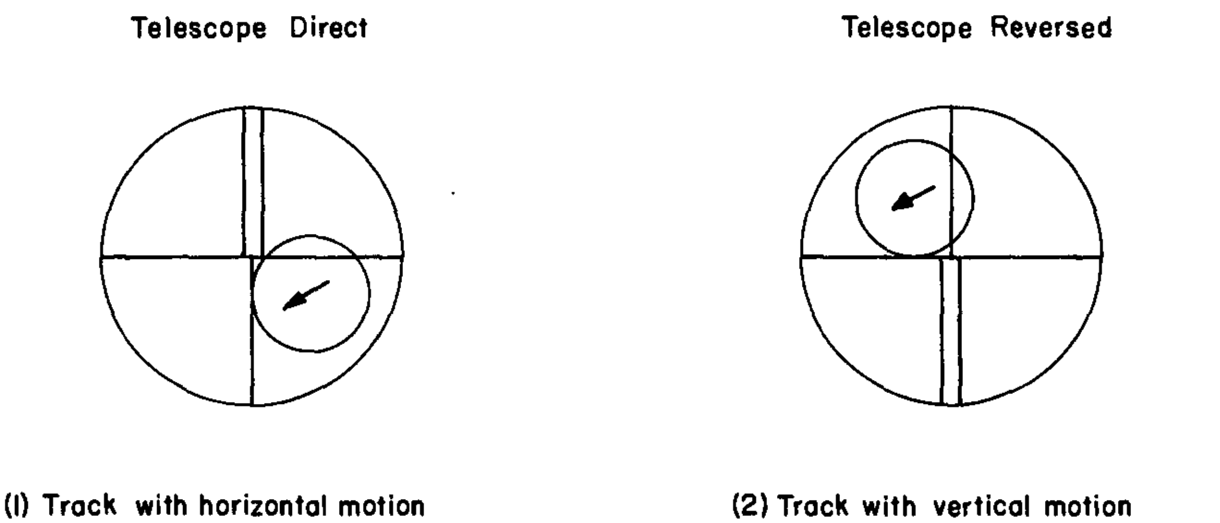



Figure b. Sun's actual motion on card with T-2 theodolite (PM observations)

*Figure 117. Method of observing to determine the mean center of the sun.*

ment operator glances at the level vial to verify that the instrument is level, brings the collimation level vial into adjustment, and reads the horizontal and vertical angles. The recorder enters each angle in turn and repeats it as entered. The telescope is then reversed, and the operation is repeated in the opposite quadrant. After the reverse pointing on the sun and with the telescope still in the reverse position, the instrument is turned to the azimuth mark and the horizontal and vertical angles are read and recorded. The mean of the direct and reverse pointings are the horizontal and vertical angles to the center of the sun.

## 299. Stellar Observations

Stellar observations are made by pointing the intersection of the horizontal and vertical crosslines at the star. Both the horizontal and vertical motions are used. In the final refining of the pointing, it is best to maintain the horizontal crosshair on the star while allowing the movement of the star to bring the vertical crosshair in alinement. The observer alerts the recorder by calling *"Ready"* and announces *"Tip"* when the vertical and horizontal crosshairs are on the center of the star. The procedure for recording is identical with that used for observations on the sun as described in paragraphs 297 and 298.

## 300. Approximate Azimuth

The approximate azimuth to the azimuth mark is required by the computer to determine the proper quadrant for the computed azimuth and to provide a check against gross blunders. The approximate azimuth is normally measured with an M2 compass. An intelligent estimate by the instrument operator will suffice if the M2 compass is not available.

## 301. Geographic Coordinates of the Observing Station

The geographic coordinates (latitude and longitude) of the observing station must be

DESIGNATION Sun Observation DATE 24 Jun 19 65

Weather: Clear-Hot

Chief of Party: SSgt Cech
Inst Oper: Sp/4 Warren

Instrument Nr: T-2 5429 Recorder: Sp/4 Barnes

| Station | T | Time h | m | s | Horizontal ∡ Mils | Mean | Vertical Reading | Vertical ∡ Mils | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| WT | D | | | | 0001.205 | | | | Latitude: 34° 39' 48" N |
| | R | | | | 3200.179 | 0000.192 | | | Longitude: 98° 24' 18" W |
| SD 260 | MN∡ | 09 | 26 | 11 | 3759.590 | | | +859.500 | Watch Correction: "SLOW" |
| | | | | | | | | | +4m 21s |
| Sun | D | 09 | 25 | 36 | 3753.944 | | 743.527 | +856.473 | Temp: 110°F |
| | R | 09 | 26 | 46 | 0565.619 | 3759.782 | 5662.526 | +862.526 | Approx. Azimuth: 4291 Mils |
| | | | | | | | | | Station SD 260 is |
| WT | D | | | | 0800.562 | | | | located 10 M S of bldg |
| | R | | | | 4000.527 | 0800.544 | | | 3077. Station is 0.30 cal |
| SD 260 | MN∡ | 09 | 29 | 16 | 3767.960 | | | +870.771 | cartridge case set in |
| | | | | | | | | | triangular concrete block. |
| Sun | D | 09 | 28 | 42 | 4565.322 | | 732.238 | +867.762 | Azimuth mark is shaft |
| | R | 09 | 29 | 49 | 1371.681 | 4568.504 | 5673.780 | +873.780 | supporting light on top |
| | | | | | | | | | of OCS water tower. |
| WT | D | | | | 1600.433 | | | | |
| | R | | | | 4800.402 | 1600.418 | | | |
| SD 260 | MN∡ | 09 | 32 | 43 | 3777.580 | | | +883.271 | |
| | | | | | | | | | |
| Sun | D | 09 | 32 | 16 | 5374.836 | | 719.749 | 880.251 | |
| | R | 09 | 33 | 20 | 2181.160 | 5377.998 | 5686.291 | 886.291 | |

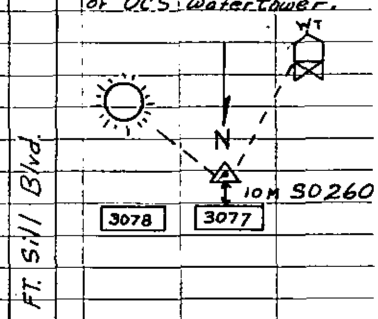



*Figure 118. Recorder's notes for observations on the sun.*

known for the hour-angle method of computing an astronomic azimuth. The latitude of the station must be known for the altitude method. For both methods, it is desirable to know the geographic coordinates for the computation of convergence.

*a.* If the geographic coordinates of the station are not known, they are determined, if possible, by measuring from a large-scale map. If the grid coordinates of the station are known, they should be used to accurately plot the location of the station on the map. If the grid coordinates of the station are not known, the location of the station must be plotted on the map by *careful map inspection.*

*b.* If the geographic coordinates of the station are not known and a large-scale map is not available but the accurate grid coordinates are known, the geographic coordinates must be determined by conversion of the grid coordinates (ch. 16).

*c.* If the geographic coordinates cannot be determined by any means, azimuth cannot be determined by the altitude or hour-angle method of computing an astronomic azimuth.

## 302. Recording Field Data

*All data* will be recorded for each station, regardless of the method of computation. This provides a means of checking the accuracy of the field data against gross blunders. Figures 118 through 120 give examples of field notes for astronomic observations. Readings should be made and recorded to 0.001 mil for the T2 theodolite, to 0.1 mil for the T16 theodolite, and to 0.5 mil for the aiming circle.

STAR (DENEB)
DESIGNATION OBSERVATION DATE 24 Jun 19 65

Chief of Party: Sgt Brown 16
Weather: Clear-Warm Instr: Oper: Sgt Jones
Instrument Nr: T-2 # 5459 Recorder: Cpl Smith

| Station | T | h m | s | Horizontal ∡ Mils | Mean | Vertical Reading | Vertical ∡ Mils | REMARKS |
|---|---|---|---|---|---|---|---|---|
| WT | D | | | 0000.327 | | | | Latitude 34° 31' 48" N |
| | R | | | 3200.342 | 0000.334 | | | Longitude 98° 24' 18" W |
| SD 260 | MN∡ | 23 11 | 17 | 3146.84 | | | +825.38 | Temp 83°F |
| | | | | | | | | Watch Corr: "Slow" +4m 28s |
| DENEB | D | 23 10 | 47 | 3146.532 | | 776.078 | +823.922 | Approx Az: 4291 Mils |
| | R | 23 11 | 47 | 6347.826 | 3147.179 | 773.162 | +826.838 | Station SD 260 is |
| | | | | | | | | located 10 MS of Bldg 3077. |
| WT | D | | | 0800.532 | | | | Station is 0.30 CAL |
| | R | | | 4000.552 | 0800.542 | | | cartridge case set in |
| SD 260 | MN∡ | 23 14 | 11 | 3148.25 | | | +834.31 | triangular concrete |
| | | | | | | | | block. Azimuth mark is |
| DENEB | D | 23 13 | 34 | 3948.203 | | 767.189 | +832.811 | Shaft supporting light |
| | R | 23 14 | 48 | 0749.383 | 3948.793 | 764.191 | +835.809 | on top OCS water |
| | | | | | | | | tower. |
| WT | D | | | 1600.423 | | | | |
| | R | | | 4800.441 | 1600.432 | | | |
| SD 260 | MN∡ | 23 18 | 04 | 3149.97 | | | +846.44 | |
| | | | | | | | | |
| DENEB | D | 23 17 | 32 | 4749.774 | | 754.513 | +845.487 | |
| | R | 23 18 | 36 | 1551.028 | 4750.401 | 752.607 | +847.393 | |

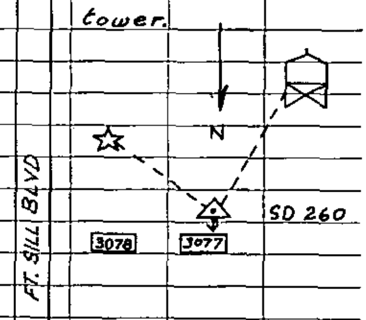



*Figure 119. Recorder's notes for observations on the star Deneb.*

Star Observation

DESIGNATION Polaris DATE 24 Jun 1965

Chief of Party: SSgt Corrigan 7

Weather: Clear-Cool Inst Opr: Sp/4 Warren

Instrument Nr: T-2 #1881 Recorder: Sp/4 Barnes

| Station | T | Time h | m | s | Horizontal ∡ Mils | Mean | Vertical Reading | Vertical ∡ Mils | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| WT | D | | | | 0001.000 | | | | Latitude: 34° 39' 48" N |
| | R | | | | 3201.126 | 0001.063 | | | Longitude: 98° 24' 18 W |
| SD 260 | Mn ∡ | 22 | 03 | 02 | 2117.042 | | | +616.321 | Approx Azimuth: 4291 ₥ |
| | | | | | | | | | Watch Corr: "Slow" +4' 28" |
| Polaris | D | 22 | 02 | 37 | 2117.990 | | 983.811 | +616.189 | Station SD 260 is |
| | R | 22 | 03 | 27 | 5318.220 | 2118.105 | 5416.453 | +616.453 | located 10M S of bldg |
| | | | | | | | | | 3077. Station is 0.30 |
| WT | D | | | | 0001.000 | | | | cal cartridge case |
| | R | | | | 3200.986 | 0000.993 | | | set in triangular |
| SD 260 | Mn ∡ | 22 | 06 | 04 | 2117.238 | | | +616.388 | Concrete block. Azimuth |
| | | | | | | | | | mark is shaft supporting |
| Polaris | D | 22 | 05 | 37 | 2118.088 | | 983.770 | +616.230 | light on top of OCS |
| | R | 22 | 06 | 31 | 5318.374 | 2118.231 | 5416.546 | +616.546 | water tower. |
| | | | | | | | | | |
| WT | D | | | | 0001.000 | | | | |
| | R | | | | 3201.247 | 0001.124 | | | |
| SD 260 | Mn ∡ | 22 | 09 | 06 | 2117.433 | | | +616.494 | |
| | | | | | | | | | |
| Polaris | D | 22 | 08 | 42 | 2118.422 | | 983.554 | +616.446 | |
| | R | 22 | 09 | 30 | 5318.692 | 2118.557 | 5416.542 | +616.542 | |

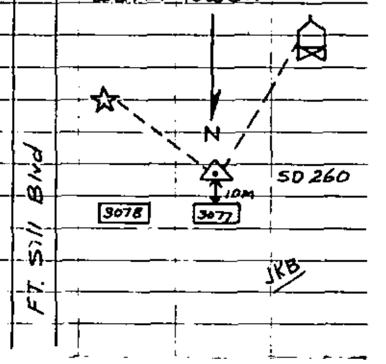



*Figure 120. Recorder's notes for observations on Polaris.*

## Section IV. SELECTION OF STAR AND METHOD OF COMPUTATION

### 303. General

The artillery surveyor must select a star (sun) and method of computation which will give the best results in the time available. In this section an outline of the basic principles to be considered in making the selection is given. The survey officer must be so familiar with these principles that the selection of the best star and method will be automatic.

### 304. Selection of Star

*a.* During daylight hours, the only star visible is the sun and selection of the sun is automatic. At night, when survey operations are conducted north of the equator and south of latitude 60°, the selection of Polaris should be automatic. In the event that Polaris is cloud covered and it becomes necessary to select another star for night observation, more complex methods of selection must be used.

*b.* As the earth rotates on its axis, the apparent path of each star is a circle centered on the pole. The apparent rate of motion of each star along its path is constant. This motion can be divided into horizontal motion, called the change in azimuth per second, and vertical motion called the change in altitude per second. When the star crosses the observer's meridian, its horizontal motion is maximum and there is no vertical motion. When the declination of the star is greater than the observer's latitude, there will be two points on the apparent path of the star where it is a moving tangent to the line of sight, all of the apparent motion is vertical. At all other times, the rate of change of azimuth must be considered against the change in altitude, called rate throughout this paragraph.

*c.* Field use of the concept in *b* above has been simplified. The curves corresponding to rates of motion of 0, 0.5, 1.0, and 3.0 have been computed and drawn on plates for each of the templates of the star identifier (para 306) used by most field units. Appendix V shows these plates to scale. To use the plates, place the template corresponding to the latitude over the plate in the appendix and trace the curve for the working rate on the template. A sharp grease pencil will give a clear curve. The areas between the curves are labeled as shown in (1) through (4) below. The dotted line indicates a rate of zero.

(1) *Area A.* Stars in this area have a rate between 0 and 0.5. They are the best stars for use in observation and should be selected unless this altitude is too high.

(2) *Area B.* Stars in this area have a rate between 0.5 and 1.0. Fourth-order azimuth can be obtained from these stars using reasonable care.

(3) *Area C.* Stars in this area have a rate between 1.0 and 3.0. Fifth-order azimuth can be obtained from these stars using reasonable care.

(4) *Area D.* Stars in this area have very large rates. If it becomes necessary to use a star appearing in this area, the azimuth must be computed by the hour-angle method.

*d.* The area above 60° altitude is blank because stars in this area should not be used.

*e.* It is suggested that only the curves containing the area of immediate interest be traced on the template, since the full set of curves may be confusing. To obtain a fourth-order azimuth, experienced operators may use the area marked "B" and altitudes as high as 1,000 mils (60°). Less experienced operators should choose the area marked "A" and altitude below 800 mils (45°). For fifth-order work, areas marked "A", "B" and "C" may be used.

*f.* When Polaris is blocked by a cloud cover, many of the better stars will also be cloud covered. Select the best star from those visible. Using the template as instructed in *c* above, identify the visible stars and note whether they fall within the area desired. Select the star that is most nearly in the best area. The worst possible star is a star near the meridian on the southern horizon as such a star has a change in azimuth of about 0.25 mil per second. Such a star may be used to obtain a fifth-order azimuth by the hour-angle method. Stars suitable for computation by the altitude method are also the best stars for computation by the hour-angle method.

*g.* When the aiming circle is used in astronomic observations, the vertical angle cannot be measured as accurately as with the theodolite and a similar rate is required to obtain the same accuracy. For example, if the rate is 1.0 and the vertical angle has a probable error (PE) of 1.0 mil, there will be a probable error of 1.0 mil in the azimuth. But if the rate is 0.5, an error of 1.0 mil in the vertical angle will introduce an error of only 0.5 mil in the azimuth. For this reason, unless the star has a very small rate, the hour-angle method must be used with the aiming circle.

## 305. Star Identification With Star Chart

Astronomic observations for azimuth require that the personnel engaged in performing the fieldwork be capable of readily locating and identifying any of the stars listed in the Army Ephemeris. These stars can be identified by using either the star chart or the star identifier or both. The world star chart (fig. 121) shows most of the brighter stars in the heavens. All the stars listed in the Army Ephemeris are shown, as well as many others which aid the observer in locating these stars. The approximate right ascension and declination can be obtained from this chart or can be used as arguments to enter the chart.

*Figure 121. World star chart.*

(Located in back of manual)

*a.* Proficiency in star identification is usually based on a working knowledge of the constellations (star groups) and their relative locations. Starting with such familiar constellations as Orion (a kite-shaped figure on the celestial equator visible during the winter months) or Ursa Major (the Big Dipper), anyone should soon be able to lead himself from constellation to constellation across the sky. If, for example, one follows the arc of the Big Dipper, it will lead him directly to the star Arcturus and eventually to Spica in the constellation Virgo. Also, the end stars in the bucket of the Big Dipper (Dubhe and Merak, fig. 121) will lead the observer directly to Leo. These two stars are often referred to as the *pointers*, since they are the most common means used to locate Polaris, the North Star, when followed in the opposite direction from Leo. Figure 121, however, does not make this apparent because of distortion in the polar areas. Unfortunately, star charts, like maps, must be printed on flat sheets of paper, and the relative positions of some stars are bound to be disturbed on the world star chart. Except for the stars near the celestial equator, the distortions on the world star chart are greater than they would be on a hemisphere star chart, but the world star chart is very useful because the declinations and right ascensions are shown graphically. The star chart indicates the relative positions of the stars as viewed in the sky.

*b.* First efforts should be concentrated on learning a half dozen stars in each 6 hours of the right ascension, which would be useful for observing on or near the prime vertical or as east and west stars. For instance, several stars just east of the constellation Orion form a large pentagon with Canis Minor (Procyon) near the center. The stars are rated in order of brightness from first magnitude to fifth magnitude. Fifth-magnitude stars are the dimmest stars that are ordinarily visible without a telescope. On the star chart, the magnitude is indicated by conventional signs which are also shown in the Army Ephemeris. When the locations of Castor, Pollux, Regulus, Alphard, and Sirius in this part of the heavens are known, it is easy to learn the locations of other stars coming up from the east, as the night or season advances.

## 306. Star Identifier

The star identifier (fig. 122) is issued to all artillery units that are issued a theodolite. It assists in locating stars by providing the approximate true azimuth and altitude to each given star. (It can also be used to identify stars of which the approximate true azimuth and altitude are known.) All stars shown on the star identifier are listed in table 9, Alphabetical Star List, in the Army Ephemeris. The star identifier consists of a base and 10 templates. Nine templates are used in star identification. One template with moon and planet data is not used in artillery survey. A template is furnished for each 10° difference in latitude from 5° through 85°. One side of each template, marked "N," is used for the given latitude in the Northern Hemisphere. The other side, marked "S," is used for the same latitude in the Southern Hemisphere. The template constructed for the latitude nearest the latitude of the observer must be used. To use the star identifier—

*a.* Select the proper template and correctly place it on the appropriate side of the base.

*b.* Determine the orientation angle as follows:

(1) Estimate the watch time at which the observations are to begin.
(2) Determine the orientation angle, using DA Form 6–21.

*c.* Set the arrow on the template over the orientation angle.

*d.* Read the approximate true azimuth and the approximate altitude of any star on the base that is within the observer's field of vision.

*e.* Orient the star identifier so that the pointer on the template is pointing approximately toward true south. The stars will then appear at the approximate altitudes read from the star identifier; the approximate azimuth to the star is as read from the star identifier in the Northern Hemisphere or is equal to the azimuth read from the star identifier minus 180° in the Southern Hemisphere.

*f.* Figure 123 shows the entries made on DA Form 6–21 for determining data in finding and identifying stars. Instructions for the use of the form are contained on the reverse side of the form (fig. 124).

## 307. Selection of Computation Method

There are four methods of computing astro-

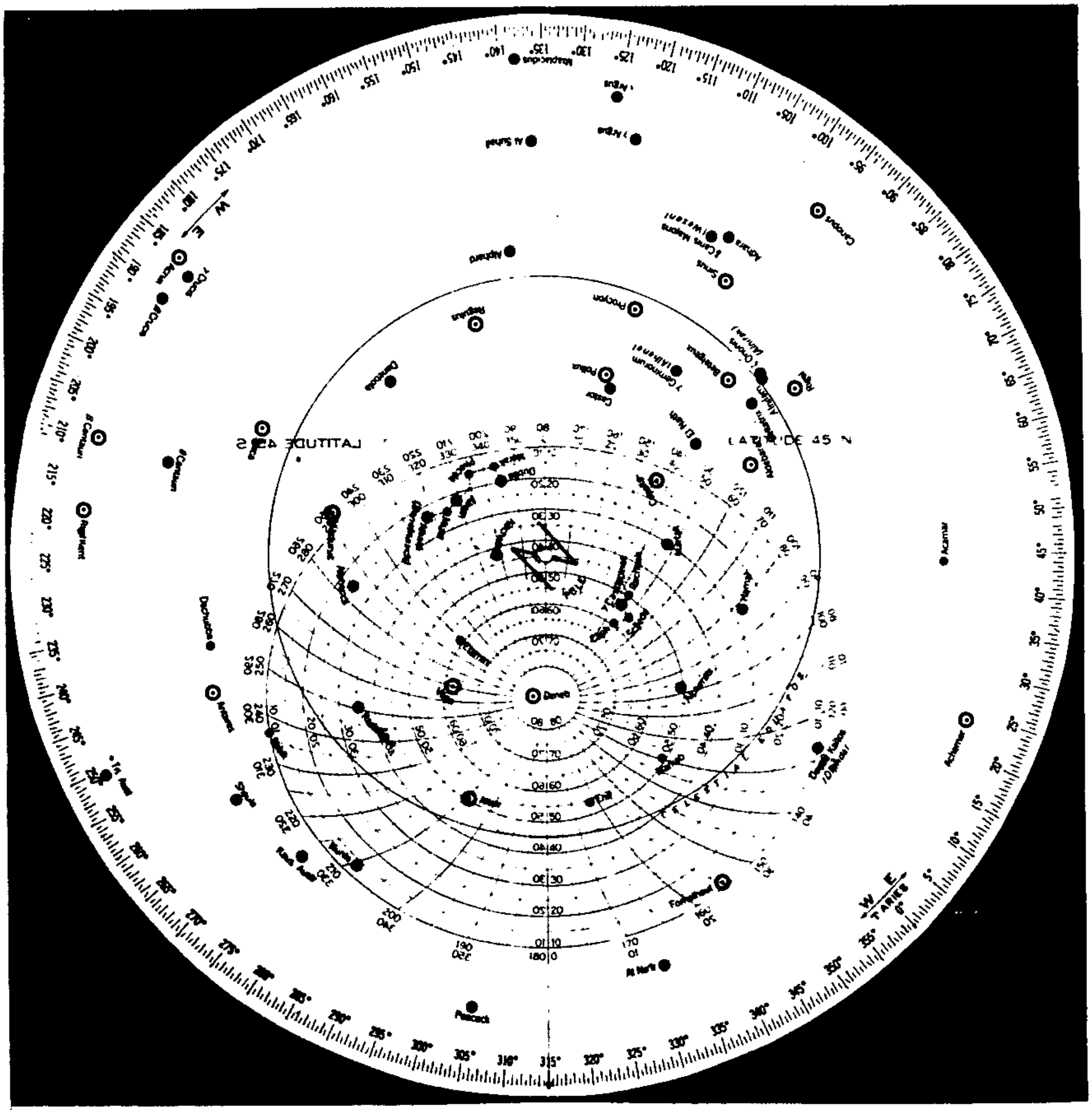


*Figure 122. Star identifier.*

nomic azimuth in the artillery—the Polaris method, the altitude hour-angle method, the altitude method, and the hour-angle method. All involve a solution of the PZS triangle. The Polaris method is an hour-angle method that has been precomputed and is solved by looking up the answer in the Army Ephemeris. It is the fastest method. The altitude hour-angle method involves the law of sines, which is simple and quick, and is the second fastest method. The altitude method involves the law of cosines to solve for a triangle with three known sides. This method is only slightly faster than the hour-angle method. The hour-angle method involves two sides and the included angle of the PZS triangle and is the most time consuming of the methods available.

## COMPUTATION AND INSTRUCTIONS FOR USE WITH STAR IDENTIFIER

(FM 6-120)

| TIME ZONE | LATITUDE OF STATION | LONGITUDE OF STATION | STATION |
|---|---|---|---|
| S | 34° N | 98° W | TS 19 |

| | | SCHEDULE 1 | SCHEDULE 2 | SCHEDULE 3 | SCHEDULE 4 | |
|---|---|---|---|---|---|---|
| 1 | PRESELECTED LOCAL DATE | 16 APR 61 | | | | 1 |
| 2 | PRESELECTED WATCH TIME | 2000 | | | | 2 |
| 3 | LONGITUDE OF STATION (EAST +, WEST −) | − 98° | ± | ± | ± | 3 |
| 4 | LONGITUDE OF CENTRAL MERIDIAN (FROM TABLE I ON REVERSE) (EAST −, WEST +) | + 90° | ± | ± | ± | 4 |
| 5 | ALGEBRAIC SUM (3) AND (4) | − 8° | ± | ± | ± | 5 |
| 6 | SETTING FOR 0h ON LOCAL DATE (FROM TABLE II ON REVERSE) | 204 | | | | 6 |
| 7 | CORRECTION TO (6) FOR WATCH TIME (FROM TABLE III ON REVERSE) | 301 | | | | 7 |
| 8 | (6)+(7) | + 505 | + | + | + | 8 |
| 9 | REPEAT (5) | − 8 | ± | ± | ± | 9 |
| 10 | ALGEBRAIC SUM (8) AND (9) | + 497 | ± | ± | ± | 10 |
| | IF 10 IS: (−) / 0° TO 360° / MORE THAN 360° — (11) IS: 360° (10) / REPEAT (10) / (10) − 360° | 360 | | | | |
| 11 | ORIENTATION ANGLE | 137 | | | | 11 |

**SET POINTER OF APPROPRIATE TEMPLATE ON ORIENTATION ANGLE (*SEE GUIDE ON REVERSE*)**

| | | SCHEDULE 1 | SCHEDULE 2 | SCHEDULE 3 | SCHEDULE 4 | |
|---|---|---|---|---|---|---|
| 12 | NAME OF STAR | ALDEBARAN | | | | 12 |
| 13 | APRX AZIMUTH OF STAR | 272° | ° | ° | ° | 13 |
| 14 | CONVERT (13) TO MILS, IF NECESSARY | m | m | m | m | 14 |
| 15 | APRX ALTITUDE OF STAR | 27° | ° | ° | ° | 15 |
| 16 | CONVERT (15) TO MILS, IF NECESSARY | m | m | m | m | 16 |
| 12 | NAME OF STAR | BELLATRIX | | | | 12 |
| 13 | APRX AZIMUTH OF STAR | 255° | ° | ° | ° | 13 |
| 14 | CONVERT (13) TO MILS, IF NECESSARY | m | m | m | m | 14 |
| 15 | APRX ALTITUDE OF STAR | 32° | ° | ° | ° | 15 |
| 16 | CONVERT (15) TO MILS, IF NECESSARY | m | m | m | m | 16 |
| 12 | NAME OF STAR | BETELGEUX | | | | 12 |
| 13 | APRX AZIMUTH OF STAR | 251° | ° | ° | ° | 13 |
| 14 | CONVERT (13) TO MILS, IF NECESSARY | m | m | m | m | 14 |
| 15 | APRX ALTITUDE OF STAR | 38° | ° | ° | ° | 15 |
| 16 | CONVERT (15) TO MILS, IF NECESSARY | m | m | m | m | 16 |
| 12 | NAME OF STAR | ARCTURUS | | | | 12 |
| 13 | APRX AZIMUTH OF STAR | 81° | ° | ° | ° | 13 |
| 14 | CONVERT (13) TO MILS, IF NECESSARY | m | m | m | m | 14 |
| 15 | APRX ALTITUDE OF STAR | 23° | ° | ° | ° | 15 |
| 16 | CONVERT (15) TO MILS, IF NECESSARY | m | m | m | m | 16 |

| COMPUTER | CHECKER | SHEET / OF / SHEETS |
|---|---|---|
| KLINK | McAFEE | SHEET 1 OF 1 SHEETS |

DA FORM 1 FEB 56 6-21 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

*Figure 123. Entries made on front of DA Form 6–21.*

**TABLE I**

| TIME ZONE | LONG OF MERIDIAN |
|---|---|
| EAST | LONG |
| Z | 0° |
| A | 15 |
| B | 30 |
| C | 45 |
| D | 60 |
| E | 75 |
| F | 90 |
| G | 105 |
| H | 120 |
| I | 135 |
| K | 150 |
| L | 165 |
| M | 180 |
| WEST | LONG |
| Z | 0° |
| N | 15 |
| O | 30 |
| P | 45 |
| Q | 60 |
| R | 75 |
| S | 90 |
| T | 105 |
| U | 120 |
| V | 135 |
| W | 150 |
| X | 165 |
| Y | 180 |

**TABLE II**

| DAY OF MONTH | MONTH | | | | | | | | | | | | DAY OF MONTH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | |
| 1 | 100° | 131° | 158° | 189° | 218° | 249° | 278° | 309° | 340° | 9° | 40° | 69° | 1 |
| 2 | 101 | 132 | 159 | 190 | 219 | 250 | 279 | 310 | 341 | 10 | 41 | 70 | 2 |
| 3 | 102 | 133 | 160 | 191 | 220 | 251 | 280 | 311 | 342 | 11 | 42 | 71 | 3 |
| 4 | 103 | 134 | 161 | 192 | 221 | 252 | 281 | 312 | 343 | 12 | 43 | 72 | 4 |
| 5 | 104 | 135 | 162 | 193 | 222 | 253 | 282 | 313 | 344 | 13 | 44 | 73 | 5 |
| 6 | 105 | 136 | 163 | 194 | 223 | 254 | 283 | 314 | 345 | 14 | 45 | 74 | 6 |
| 7 | 106 | 137 | 164 | 195 | 224 | 255 | 284 | 315 | 346 | 15 | 46 | 75 | 7 |
| 8 | 107 | 137 | 165 | 196 | 225 | 256 | 285 | 316 | 347 | 16 | 47 | 76 | 8 |
| 9 | 108 | 138 | 166 | 197 | 226 | 257 | 286 | 317 | 348 | 17 | 48 | 77 | 9 |
| 10 | 109 | 139 | 167 | 198 | 227 | 258 | 287 | 318 | 349 | 18 | 49 | 78 | 10 |
| 11 | 110 | 140 | 168 | 199 | 228 | 259 | 288 | 319 | 350 | 19 | 50 | 79 | 11 |
| 12 | 111 | 141 | 169 | 200 | 229 | 260 | 289 | 320 | 330 | 20 | 51 | 80 | 12 |
| 13 | 112 | 142 | 170 | 201 | 230 | 261 | 290 | 321 | 351 | 21 | 52 | 81 | 13 |
| 14 | 113 | 143 | 171 | 202 | 231 | 262 | 291 | 322 | 352 | 22 | 53 | 82 | 14 |
| 15 | 114 | 144 | 172 | 203 | 232 | 263 | 292 | 323 | 353 | 23 | 54 | 83 | 15 |
| 16 | 115 | 165 | 173 | 204 | 233 | 264 | 293 | 324 | 354 | 24 | 55 | 84 | 16 |
| 17 | 116 | 144 | 174 | 204 | 234 | 265 | 294 | 325 | 355 | 25 | 56 | 85 | 17 |
| 18 | 117 | 147 | 175 | 205 | 235 | 264 | 295 | 326 | 356 | 26 | 57 | 86 | 18 |
| 19 | 118 | 148 | 176 | 206 | 236 | 267 | 296 | 327 | 357 | 27 | 58 | 87 | 19 |
| 20 | 119 | 149 | 177 | 207 | 237 | 268 | 297 | 328 | 358 | 28 | 59 | 88 | 20 |
| 21 | 120 | 150 | 178 | 208 | 238 | 269 | 298 | 329 | 339 | 29 | 60 | 89 | 21 |
| 22 | 121 | 131 | 179 | 209 | 239 | 270 | 299 | 330 | 0 | 30 | 61 | 90 | 22 |
| 23 | 122 | 152 | 180 | 210 | 240 | 271 | 300 | 331 | 1 | 31 | 62 | 91 | 23 |
| 24 | 123 | 153 | 181 | 211 | 241 | 272 | 301 | 332 | 2 | 32 | 63 | 92 | 24 |
| 25 | 124 | 134 | 182 | 212 | 242 | 273 | 302 | 333 | 3 | 33 | 62 | 93 | 25 |
| 26 | 125 | 155 | 183 | 213 | 243 | 274 | 303 | 334 | 4 | 34 | 64 | 94 | 26 |
| 27 | 126 | 156 | 184 | 214 | 244 | 275 | 304 | 335 | 5 | 35 | 65 | 95 | 27 |
| 28 | 127 | 157 | 185 | 215 | 245 | 276 | 305 | 336 | 6 | 36 | 64 | 96 | 28 |
| 29 | 128 | 158 | 186 | 216 | 246 | 277 | 306 | 337 | 7 | 37 | 67 | 97 | 29 |
| 30 | 129 | | 187 | 217 | 247 | 277 | 307 | 338 | 8 | 38 | 68 | 98 | 30 |
| 31 | 130 | | 188 | | 248 | | 308 | 339 | | 39 | | 99 | 31 |

**TABLE III**

| WATCH TIME | CORR |
|---|---|
| 0h | 0° |
| 1 | 15 |
| 2 | 30 |
| 3 | 45 |
| 4 | 60 |
| 5 | 75 |
| 6 | 90 |
| 7 | 105 |
| 8 | 120 |
| 9 | 135 |
| 10 | 150 |
| 11 | 165 |
| 12 | 181 |
| 13 | 196 |
| 14 | 211 |
| 15 | 226 |
| 16 | 241 |
| 17 | 256 |
| 18 | 271 |
| 19 | 284 |
| 20 | 301 |
| 21 | 316 |
| 22 | 331 |
| 23 | 346 |

GIVEN:

Time zone of area of operation.
Latitude and longitude of station to nearest degree.
Preselected local date of observation.
Preselected watch time of observation to nearest hour.

GUIDE:

When observation is to be made at other than preselected watch time ((2) of computation), increase orientation angle ((11) of computation) 1 degree for each 4 minutes of elapsed time after the hour or decrease orientation angle 1 degree for each 4 minutes of time before the hour.
Select stars between 20 and 45 degrees (60 degrees if a special eyepiece is available) above horizon and within 30 degrees of a 90-degree or 270-degree azimuth (east - west line) to use the altitude method.
Select four stars for each schedule, two in the east and two others in the west.
Read APRX AZIMUTH and APRX ALTITUDE of stars from template of star identifier to nearest degree.
When using a mil-graduated instrument, convert APRX AZIMUTH and APRX ALTITUDE to mils using table III b of TM 6-230.

LIMITATIONS:

The altitude and hour-angle methods should not be used when the star is more than 60 degrees above horizon.

RESULT:

APRX AZIMUTH and APRX ALTITUDE for four schedules of four stars each at preselected watch times.

*Figure 124. Instructions for use of DA Form 6–21.*

*a.* If Polaris is observed, the Polaris method should be used. For any other star (sun), a quick inspection of the field data will determine if the rate of change in azimuth against the rate of change in altitude is suitable for a computation involving altitude. If the rate is 1.0 or less, one of the altitude methods should be used. If the rate is 3.0 or less and a fifth-order azimuth only is desired, an altitude method may still be used. If the vertical angle is suspected to be of poor quality, an altitude method should not be used. If time is accurate to 1 second and the rate is such that an altitude method can be used, the altitude hour-angle method should be used. Avoid the altitude hour-angle method if the approximate azimuth is within 200 mils of due east or west. In all other cases, the hour-angle method must be used. As the rate of change of azimuth against altitude starts to increase, it changes rapidly and the altitude method will fail completely if the rate of change becomes too large. The rate of change in azimuth against the rate of change in time increases more slowly, and a reasonable azimuth can always be obtained by the hour-angle method.

*b.* A rapid computation form (DA Form 2973) is shown in figure 125. The use of this form will be discussed in paragraphs 310 and 311. The form is designed for fifth-order work and combines all four methods of computation. The formulae to be used are shown on the back of the form. When used with the five-place logarithms in the back of the Army Ephemeris, the new form should reduce computation time by about one-half. The principal time-saving feature of the form is that at least three sets of observations are meaned so that only one computation is required. The mean horizontal and vertical angles of the available sets are plotted against the mean time of observation to guard against erroneous field data. The departure from a straight line should not exceed 1.0 mil. If, after plotting the observations, three sets do not form a straight line within the prescribed tolerance, it will be necessary to compute all observed sets individually to determine which are erroneous. DA Forms 6–10, 6–10a, and 6–11 are used for individual computation of three similar sets when the computation of the mean values cannot be used. Use of these forms is discussed in paragraphs 312 and 313.

## 308. Comparison of Methods

Table III summarizes a comparison of the computation methods.

*Table III. Comparison of Computation Methods*

| Element | Polaris method | Altitude-hour-angle method | Altitude method | Hour-angle method |
|---|---|---|---|---|
| Horizontal angle | Required for all methods. Probable error of horizontal angle should be only a small portion of allowed error. | | | |
| Vertical angle | Not required | PE of observed vertical angle plus 1/300th of astronomic refraction correction multiplied by rate of change in azimuth against rate of change in altitude must not exceed 0.08 mil for 4th-order accuracy, 0.15 mil for 5th-order accuracy, or 1.0 mil for 1:500 accuracy. | | Not required |
| Time | ±1 min | ±1 sec | ±5 min (nearest day for stars) | ±1 sec |
| Temperature | Not required | ±10° F | ±10° F | Not required |
| Latitude | ±1° (vertical angle may be used) | Not required | ±15 sec (about 400 m) | ±15 sec (about 400 m) |
| Longitude | ±15 min (about 20 km) | ±15 sec | ±1° (about 80 km) | ±15 sec |

*a.* The accuracy requirements shown in table III for latitude and longitude are based on the accuracy requirements for the astronomic computation. It would be necessary to know the latitude and longitude within about 100 meters or ±2 seconds to compute convergence from geographic coordinates. The UTM coordinates, if known within 100 meters, may be used for computing convergence.

*b.* The statement pertaining to vertical angle applies to both the altitude and the altitude hour-angle methods. The probable error of the observed vertical angle is an estimate of the surveyor based on the instrument used and the experience of the operator. Since the probable error is an estimate, $\frac{1}{300}$th of the vertical refraction need be added only for very small vertical angles. The rate of change in azimuth against the rate of change in altitude may be obtained from the plates in appendix V which show the areas of different rates. Rate of change of 0.5 is used for stars in area A, 1.0 is used for stars in area B, and 3.0 is used for stars in area C. If the observations have already been completed, an inspection of the observed field data will quickly yield a more accurate value for the rate (the change in horizontal angle divided by the change in vertical angle). In most field problems, this inspection will only be of interest in deciding whether it is necessary to improve the azimuth determination by reobserving. The survey officer may quickly select the method of computation from table III which will give the best answer from the data available.

## Section V. ASTRONOMIC COMPUTATIONS

### 309. General

The artillery surveyor may use any one of four methods to compute an azimuth by astronomic observations. The four methods are the Polaris method, the altitude hour-angle method, the altitude method, and the hour-angle method. The four methods are discussed in detail in paragraphs 310 through 313. DA Form 6–11 or DA Form 2973 is used to compute azimuth by the altitude method; DA Form 6–10, DA Form 6–10a, or DA Form 2973, by the hour-angle method. The computations for the Polaris and altitude hour-angle methods can be performed only on DA form 2973. DA Forms 6–10, 6–10a, and 6–11 are used when each set of observations must be computed individually. The advantage of individually computing each set is that a bad set which is not recognized as bad before computation can be detected and rejected. The disadvantage is that individual computations are time consuming. When DA Form 2973 is used, a bad set is detected by plotting the observed horizontal and vertical angles against the times of observations. The computations are then performed on the mean values of all good sets. This reduces the computing time by about one-half.

### 310. The Polaris Method

Table 12 of the Army Ephemeris gives the precomputed azimuth of Polaris for any hour angle. There is no requirement for accurate time, and the star is easy to identify. The formula for using table 12 is given below the table. DA Form 2973 is used for the Polaris method. To compute azimuth by the Polaris method, proceed as follows:

*a.* Fill in the heading and transfer the observed horizontal angle and time of observation for each set from the field notebook to the form. Mean the times of observations and mean the horizontal angles. Apply the watch correction (item 2) and the time zone correction (item 3) and add algebraically to the mean time to obtain the Greenwich mean time (GMT) of observation and enter the GMT in item 4. Obtain the sidereal time of $0^h$ Greenwich from table 2 of the Army Ephemeris and enter it in item 9; obtain the sidereal time correction for the GMT from table 4 of the Army Ephemeris and enter it in item 10. Convert the longitude of time units (hours, minutes, and seconds) by dividing the longitude by 15. Enter this in item 11; use the plus sign (+) if in west longitude and the minus sign (—) if in east longitude. Add items 4, 9, 10, and 11 to obtain the local sidereal time (LST). Enter the LST in item 12.

*b.* Enter table 12 of the Army Ephemeris with the LST and obtain $b_0$, the approximate azimuth of Polaris in minutes of arc. Enter the $b_0$ in item 86. In the same column of table 12 of the Army Ephemeris, obtain $b_1$ and $b_2$, the two small corrections for latitude and the month of the year respectively. Enter $b_1$ and $b_2$ in items 87 and 88, respectively. The negative sign is used in the table to indicate that azimuth is west of north. Enter the sum of $b_0$, $b_1$, and $b_2$ in item 89. Place the log of this sum in item 90. Enter the log of the conversion factor for minutes of arc to mils in item 91. Enter the colog cosine of the latitude in item 92. Enter the sum of the logs in item 93. Enter the antilog of item 93, which is the azimuth of Polaris in mils, in item 94, retaining the sign of item 86. Enter 6,400 mils plus the azimuth of Polaris (item 94) in item 95. Enter the mean horizontal angles in item 96. Subtract the mean horizontal angle from item 95 to obtain the azimuth to the azimuth mark. Enter the azimuth to the azimuth mark in item 97. A sample computation is shown in figure 125.

### 311. The Altitude-Hour Angle Method

This method of computing azimuth is new to the artillery. It is a faster method than either the altitude or the hour-angle method. When using this method, one cannot determine the quadrant in which the star lies, and this method should not be used for observing on due east or due west stars. The approximate azimuth must be accurate enough to determine the quadrant. DA Form 2973 is used for the altitude hour-angle method. To compute azimuth by the altitude hour-angle method, proceed as follows:

*a.* Fill in the heading on the form and transfer the mean observed data for each set from the field notebook to the form. Plot the mean horizontal angles for the sets against the mean times of observations. Reject any set which does not plot within 1.0 mil of a straight line. Plot the vertical angles in the same manner and use the same rejection limit. Mean the remaining sets to obtain one mean time of observation, one mean horizontal angle, and one mean vertical angle. Correct the mean observed vertical angle for parallax and refraction in items 34 and 35. Record the true vertical angle in item 36. Obtain the colog cosine and enter in item 82. Compute the Greenwich mean time, using items 1 through 4. Omit items 19 through 25 as the latitude is not used. The longitude must be converted to mils. Use table 5 in the Army Ephemeris and items 26 through 33 on the form for the conversion. The declination is required in mils. If the sun is observed, use table 2 in the Army Ephemeris and items 37 through 47 for the interpolation. If a star is observed, use table 10b in the Army Ephemeris. Enter the log cosine of the declination in item 81. If the sun is observed, use items 5 through 8 to obtain the Greenwich hour angle (GHA). The 12-hour correction required to change to hour angle is introduced in item 8. To convert the Greenwich hour angle to mils, complete items 13 through 18 by entering table 5 of the Army Ephemeris, using item 8 as an argument. Transfer the longitude in mils from item 33 to item 16 and add items 13 through 16 algebraically to obtain the local hour angle (LHA) in mils. Enter the local hour angle in item 17. The local hour angle in mils is "t" in the formula and should be subtracted from 6,400 if it is greater than 3,200 mils. Enter the final result in item 18. Obtain the log sine of item 18 and enter it in item 80. Figure 126 shows computations by the altitude hour-angle method, using the sun.

*b.* If a star is observed, the procedure for determining the local hour angle is slightly different. Use items 9 through 12 to determine the GHA instead of items 5 through 8. Obtain the sidereal time for $0^h$ of the date in table 2 of the Army Ephemeris and enter it in item 9. Obtain the correction to the mean time interval for the Greenwich time from table 4 of the Army Ephemeris and enter it in item 10. Obtain the right ascension for the star from table 10 of the Army Ephemeris and enter it in item 11. Add item 4 and items 9 through 11 algebraically and enter the sum, which is the GHA for the star, in item 12. The procedure for converting the GHA to mils when a star is observed is the same as that when the sun is observed except that items 13 through 15 are used for a star. Correct the mean observed vertical angle for refraction. Record the true vertical angle in item 36. Obtain the colog cosine and enter it in item 82.

*c.* The altitude hour-angle method block now contains all data necessary for the computation. For fifth-order or lower accuracy, some time

FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION

STAR NAME AND NUMBER: POLARIS 10

| LOCAL DATE | AZIMUTH MARK | APPROX. AZ TO AZ MK | STATION | TEMP |
|---|---|---|---|---|
| 24 JUN 65 | WT | 4291 | SD 260 | 60 °F |

| FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|
| SET NO. 1 | 22 03 02 | 2117 0 | + 616 3 |
| SET NO. 2 | 22 06 04 | 2117 2 | + 616 4 |
| SET NO. 3 | 22 09 06 | 2117 4 | + 616 5 |
| SET NO. | | | |
| SET NO. | | | |
| SET NO. | | | |
| SUM | 66 18 12 | 6351 6 | + 1849 2 |
| 1 MEAN | 22 06 04 | 2117 2 | + 616 4 |


| | | |
|---|---|---|
| 2 | WATCH CORR. SLOW + FAST - | (+) 24 04 28 |
| 3 | TIME ZONE (W LONG+, E LONG-) CORR. | (+) 6 00 00 |
| 4 | (1)+(2)+(3)=GMT* DATE | + 4 10 32 |
| 5 | EQ OF T: AT 0h ON GW DATE (TABLE 2) | |
| 6 | EQ OF T: AT GMT (TABLE 3) | |
| 7 | (4)+(5)+(6) = GAT | |
| 8 | ** = GHA | |
| 9 | SID TIME AT 0h ON GW DATE (TBL 2) | + 18 11 41 |
| 10 | CORRECTION TO (9) (TABLE 4) | + 41 |
| 11 | *** | (-) 6 33 37 |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | (+) 15 49 17 |
| 13 | HRS OF GHA(8) OR (12) IN MILS (TBL 5) | |
| 14 | MIN OF GHA IN MILS | |
| 15 | SEC OF GHA IN MILS | |
| 16 | LONGITUDE EAST + IN MILS(33) WEST - | |
| 17 | (13)+(14)+(15)+(16) = LHA | |
| 18 | **** = t | |

| | | |
|---|---|---|
| | LATITUDE N S | 34 39 48 |
| 19 | MILS IN TENS OF DEGREES | 533 33 |
| 20 | MILS IN UNITS OF DEGREES | 71 11 |
| 21 | MILS IN TENS OF MINUTES | 8 89 |
| 22 | MILS IN UNITS OF MINUTES | 2 67 |
| 23 | MILS IN TENS OF SECONDS | 20 |
| 24 | MILS IN UNITS OF SECONDS | 04 |
| 25 | LAT IN MILS SUM (19) THRU (24) | 616 24 |
| | LONGITUDE E W | 98 24 18 |
| 26 | MILS IN HUNDREDS OF DEGREES | |
| 27 | MILS IN TENS OF DEGREES | |
| 28 | MILS IN UNITS OF DEGREES | |
| 29 | MILS IN TENS OF MINUTES | |
| 30 | MILS IN UNITS OF MINUTES | |
| 31 | MILS IN TENS OF SECONDS | |
| 32 | MILS IN UNITS OF SECONDS | |
| 33 | LONG IN MILS SUM (26) THRU (32) | |

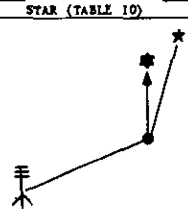
| | | |
|---|---|---|
| 34 | REFRACTION (TABLE 1) | |
| 35 | PARALLAX 0.046 -SUN ONLY or 7 sec | |
| 36 | (1)+(34)+(35)=h | |
| 37 | NO. OF HRS IN GMT (4) x 60 | |
| 38 | NO. OF MIN IN GMT (4) | |
| 39 | (37) + (38) | |
| 40 | DAILY CHANGE IN DECLINATION (TABLE 2) | |
| 41 | LOG (39) | |
| 42 | LOG (40) | |
| 43 | LOG CONSTANT | 6 841638 |
| 44 | (41)+(42)+(43) | |
| 45 | ANTILOG (44) USE SIGN (40) | |
| 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | |
| 47 | (45)+(46)=APP DEC OF SUN OR DEC OF STAR (TABLE 10) | |

* IF (1)+(2)+(3) IS: +24 IS: GW DATE IS:
(+) LESS THAN 24h NOT REQD LOCAL DATE
(+) MORE THAN 24h (-) LOCAL DATE +1
(-) (+) LOCAL DATE -1

** IF (7) IS: (8) IS:
(-) OR (+) AND LESS THAN 12h (7) + 12h
+ AND MORE THAN 12h (7) - 12h

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES ÷ 15 W/SIGN (-) IF LONGITUDE WEST (+) IF EAST

**** IF (17) IS: (18) IS:
(-) OR 0 TO 3200⌀ REPEAT (17)
3200⌀ TO 6400⌀ 6400⌀ - (17) SIGN (-)
MORE THAN 6400⌀ (17)-6400⌀ SIGN (+)



**HOUR ANGLE METHOD**

| | | |
|---|---|---|
| 48 | 1/2 (18) | |
| 49 | 1/2 (25) NORTH + SOUTH - | |
| 50 | 1/2 (47) | |
| 51 | (49) + (50) | |
| 52 | (49) - (50) | |
| 53 | COLOG SIN (51) | |
| 54 | LOG COS (52) | |
| 55 | LOG COT (48) | |
| 56 | (53) + (54) + (55) | |
| 57 | COLOG COS (51) | |
| 58 | LOG SIN (52) | |
| 59 | REPEAT (55) | |
| 60 | (57)+(58)+(59) | |
| 61 | ANTILOG TAN (60) USE SIGN (51) | |
| 62 | ANTILOG TAN (56) USE SIGN (52) | |
| 63 | (61)+(62) = A ENTER IN (95) | |

**ALTITUDE METHOD**

| | | |
|---|---|---|
| 64 | 1600-00 MILS | |
| 65 | (47) W/SIGN REVERSED | |
| 66 | (64) + (65) = P | |
| 67 | REPEAT (36) | |
| 68 | REPEAT (25) NORTH+ SOUTH- | |
| 69 | (66)+(67)+(68) | |
| 70 | 1/2 (69) = S | |
| 71 | (70) - (66) | |
| 72 | COLOG COS (67) | |
| 73 | COLOG COS (68) | |
| 74 | LOG COS (70) | |
| 75 | LOG COS (71) | |
| 76 | (72)+(73)+(74)+(75) | |
| 77 | 1/2 (76) | |
| 78 | ANTILOG COS (77) | |
| 79 | 2 x (78) = A ENTER IN (95) | |

*****(84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A

******
AZ TO STAR = A WHEN STAR IS IN EAST
AZ = 6400 - A WHEN STAR IS IN WEST
ADD 6400 IF (95) IS LESS THAN (96)

**ALTITUDE-HOUR ANGLE METHOD**

| | | |
|---|---|---|
| 80 | LOG SIN (18) | |
| 81 | LOG COS (47) | |
| 82 | COLOG COS (36) | |
| 83 | (80)+(81)+(82) | |
| 84 | ANTILOG SIN (83) = B | |
| 85 | *****A ENTER IN (95) | |

**POLARIS TABULAR METHOD**

| | | |
|---|---|---|
| 86 | $a_0$ VALUES OBTAINED | + 24 2 |
| 87 | $a_1$ FROM TABLE 12 | + 0 2 |
| 88 | $a_2$ USING LST(12) | + 0 5 |
| 89 | (86)+(87)+(88) | 24 9 |
| 90 | LOG (89) | 1 39620 |
| 91 | LOG FACTOR | 9 471 70 |
| 92 | COLOG COS (25) | 0 08486 |
| 93 | (90)+(91)+(92) | 0 95276 |
| 94 | ANTILOG (93) = A ENTER IN (95) | 9 0 |

**AZIMUTH TO AZIMUTH MARK**

| | | |
|---|---|---|
| 95 | A ****** | 6409 0 |
| 96 | MEAN HORIZONTAL ANGLE (1) | 2117 2 |
| 97 | (95)-(96)=AZ TO AZ MK | 4291 8 |

COMPUTER Klein

CHECKER Blair

DA FORM 2973, 1 May 65

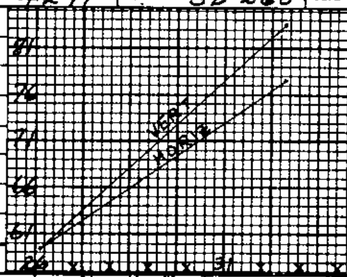
*Figure 125. DA Form 2973 showing computations by the Polaris method.*

FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION

STAR NAME AND NUMBER: Sun

| LOCAL DATE | AZIMUTH MARK | APPROX. AZ TO AZ MK | STATION | TEMP |
|---|---|---|---|---|
| 24 Jun 65 | WT | 4291 | SD 260 | 112 °F |

| FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|
| SET NO. 1 | 09 26 11 | 3759 6 | + 8 79 5 |
| SET NO. 2 | 09 29 16 | 3768 0 | + 8 70 8 |
| SET NO. 3 | 09 32 43 | 3777 6 | + 8 83 3 |
| SET NO. | | | |
| SET NO. | | | |
| SET NO. | | | |
| SUM | 28 28 10 | 11305 2 | 261 2 6 |
| 1 MEAN | 09 29 23 | 3768 4 | + 871 2 |




| | | |
|---|---|---|
| 2 | WATCH CORR (SLOW +, FAST −) | − 24 04 21 |
| 3 | TIME ZONE CORR. (W LONG +, E LONG −) | + 6 00 00 |
| 4 | (1)+(2)+(3)=GMT* DATE 24 JUN 65 | + 15 33 44 |
| 5 | EQ OF T: AT 0h ON GW DATE (TABLE 2) | − 2 09 |
| 6 | EQ OF T: AT GMT (TABLE 3) | − 08 |
| 7 | (4)+(5)+(6) = GAT | + 15 31 27 |
| 8 | ** = GHA | + 3 31 27 |
| 9 | SID TIME AT 0h ON GW DATE (TBL 2) | + |
| 10 | CORRECTION TO (9) (TABLE 4) | + |
| 11 | * * * | + − |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | + − |
| 13 | HRS OF GHA(8) OR (12) IN MILS (TBL 5) | + 800 00 |
| 14 | MIN OF GHA IN MILS | + 137 78 |
| 15 | SEC OF GHA IN MILS | + 2 00 |
| 16 | LONGITUDE EAST +, IN MILS (33) WEST − | − 1749 43 |
| 17 | (13)+(14)+(15)+(16) = LHA | − 809 65 |
| 18 | **** = t | − 809 65 |

| | | |
|---|---|---|
| | LATITUDE (N/S) | 34 39 48 |
| 19 | MILS IN TENS OF DEGREES | 533 33 |
| 20 | MILS IN UNITS OF DEGREES | 71 11 |
| 21 | MILS IN TENS OF MINUTES | 8 89 |
| 22 | MILS IN UNITS OF MINUTES | 2 67 |
| 23 | MILS IN TENS OF SECONDS | 20 |
| 24 | MILS IN UNITS OF SECONDS | 04 |
| 25 | LAT IN MILS SUM (19) THRU (24) | 616 24 |
| | LONGITUDE (E/W) | 98 24 18 |
| 26 | MILS IN HUNDREDS OF DEGREES | |
| 27 | MILS IN TENS OF DEGREES | 1600 00 |
| 28 | MILS IN UNITS OF DEGREES | 142 22 |
| 29 | MILS IN TENS OF MINUTES | 5 93 |
| 30 | MILS IN UNITS OF MINUTES | 1 19 |
| 31 | MILS IN TENS OF SECONDS | 05 |
| 32 | MILS IN UNITS OF SECONDS | 04 |
| 33 | LONG IN MILS SUM (26) THRU (32) | 1749 43 |

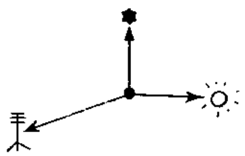
| | | |
|---|---|---|
| 34 | REFRACTION (TABLE 1) | − 22 |
| 35 | PARALLAX 0.04 -SUN ONLY or 7 sec | + 04 |
| 36 | (1)+(34)+(35)=h | + 871 02 |
| 37 | NO. OF HRS IN GMT (4) x 60 | 900 00 |
| 38 | NO. OF MIN IN GMT (4) | 33 00 |
| 39 | (37) + (38) | 933 00 |
| 40 | DAILY CHANGE IN DECLINATION (TABLE 2) | − 35 |
| 41 | LOG (39) | 2 969882 |
| 42 | LOG (40) | 9 544068 |
| 43 | LOG CONSTANT | 6 841638 |
| 44 | (41)+(42)+(43) | 9 355588 |
| 45 | ANTILOG (44) USE SIGN (40) | − 23 |
| 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | + 416 44 |
| 47 | (45)+(46)=APP DEC OF SUN OR 12C OF STAR (TABLE 10) | + 416 21 |

* IF (1)+(2)+(3) IS: +24h IS: GW DATE IS:
(+) & LESS THAN 24h NOT REQD LOCAL DATE
(+) & MORE THAN 24h (−) LOCAL DATE +1
(−) (+) LOCAL DATE −1

** IF (7) IS: (8) IS:
(−) OR (+) AND LESS THAN 12h (7) + 12h
+ AND MORE THAN 12h (7) − 12h

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES + 15 W/SIGN (−) IF LONGITUDE WEST (+) IF EAST

**** IF (17) IS: (18) IS:
(−) OR 0 TO 3200 REPEAT (17)
3200 TO 6400 6400 − (17) SIGN (−)
MORE THAN 6400 (17)−6400 SIGN (+)



## HOUR ANGLE METHOD

| | | |
|---|---|---|
| 48 | 1/2 (18) | |
| 49 | 1/2 (25) NORTH + SOUTH − | |
| 50 | 1/2 (47) | |
| 51 | (49) + (50) | |
| 52 | (49) − (50) | |
| 53 | COLOG SIN (51) | |
| 54 | LOG COS (52) | |
| 55 | LOG COT (48) | |
| 56 | (53) + (54) + (55) | |
| 57 | COLOG COS (51) | |
| 58 | LOG SIN (52) | |
| 59 | REPEAT (55) | |
| 60 | (57)+(58)+(59) | |
| 61 | ANTILOG TAN (60) USE SIGN (51) | |
| 62 | ANTILOG TAN (56) USE SIGN (52) | |
| 63 | (61)+(62) = A ENTER IN (95) | |

## ALTITUDE METHOD

| | | |
|---|---|---|
| 64 | 1600-00 MILS | |
| 65 | (47) W/SIGN REVERSED | |
| 66 | (64) + (65) = P | |
| 67 | REPEAT (36) | |
| 68 | REPEAT (25) NORTH+ SOUTH− | |
| 69 | (66)+(67)+(68) | |
| 70 | 1/2 (69) = S | |
| 71 | (70) − (66) | |
| 72 | COLOG COS (67) | |
| 73 | COLOG COS (68) | |
| 74 | LOG COS (70) | |
| 75 | LOG COS (71) | |
| 76 | (72)+(73)+(74)+(75) | |
| 77 | 1/2 (76) | |
| 78 | ANTILOG COS (77) | |
| 79 | 2 x (78) = A ENTER IN (95) | |

## ALTITUDE-HOUR ANGLE METHOD

| | | |
|---|---|---|
| 80 | LOG SIN (18) | 9 853540 |
| 81 | LOG COS (47) | 9 962690 |
| 82 | COLOG COS (36) | 0 183003 |
| 83 | (80)+(81)+(82) | 9 999233 |
| 84 | ANTILOG SIN (83) = B | 1539 5 |
| 85 | *****A ENTER IN (95) | 1660 5 |

### POLARIS TABULAR METHOD

| | | |
|---|---|---|
| 86 | $b_0$ VALUE; OBTAINED | |
| 87 | $b_1$ FROM TABLE 12 | |
| 88 | $b_2$ USING LST (12) | |
| 89 | (86)+(87)+(88) | |
| 90 | LOG (89) | |
| 91 | LOG FACTOR | 9 471 7 |
| 92 | COLOG COS (25) | |
| 93 | (90)+(91)+(92) | |
| 94 | ANTILOG (93) = A ENTER IN (95) | |

COMPUTER: Klein

CHECKER: Blair

***** (84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A

****** AZ TO STAR = A WHEN STAR IS IN EAST
AZ = 6400 − A WHEN STAR IS IN WEST
ADD 6400 IF (95) IS LESS THAN (96)

### AZIMUTH TO AZIMUTH MARK

| | | |
|---|---|---|
| 95 | A ****** | 8060 5 |
| 96 | MEAN HORIZONTAL ANGLE (1) | 3768 4 |
| 97 | (95)−(96)=AZ TO AZ MK | 4292 1 |

DA FORM 2973, 1 May 65

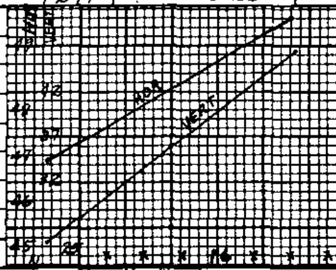
*Figure 126. DA Form 2973 showing computations by the altitude-hour angle method using the sun.*

**FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION**

STAR NAME AND NUMBER: DENEB 68

| LOCAL DATE | AZIMUTH MARK | APPROX. AZ TO AZ MK | STATION | TEMP |
|---|---|---|---|---|
| 24 JUN 65 | WT | 4291 | SD 260 | 83 °F |

| FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|
| SET NO. 1 | 23 11 17 | 3146 8 | + 825 4 |
| SET NO. 2 | 23 14 11 | 3148 2 | + 834 3 |
| SET NO. 3 | 23 18 04 | 3150 0 | + 846 4 |
| SET NO. | | | |
| SET NO. | | | |
| SET NO. | | | |
| SUM | 69 43 32 | 9445 0 | + 2506 1 |
| 1 MEAN | 23 14 31 | 3148 3 | 835 4 |




| | | |
|---|---|---|
| 2 | WATCH CORR. SLOW + FAST - | (+) 24 04 28 |
| 3 | TIME ZONE CORR. W LONG + E LONG - | (+) 6 00 00 |
| 4 | (1)+(2)+(3)=GMT* DATE | + 5 18 59 |
| 5 | EQ OF T: AT 0h ON GW DATE (TABLE 2) | + - |
| 6 | EQ OF T: AT GMT (TABLE 3) | + - |
| 7 | (4)+(5)+(6) = GAT | + - |
| 8 | ** = GHA | + - |
| 9 | SID TIME AT 0h ON GW DATE (TBL 2) | + 18 11 41 |
| 10 | CORRECTION TO (9) (TABLE 4) | + 52 |
| 11 | * * * | (+) 20 40 16 |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | + 2 51 16 |
| 13 | HRS OF GHA (8) OR (12) IN MILS (TBL 5) | (+) 533 33 |
| 14 | MIN OF GHA IN MILS | (+) 226 67 |
| 15 | SEC OF GHA IN MILS | (+) 1 19 |
| 16 | LONGITUDE EAST + IN MILS (33) WEST - | (-) 1749 43 |
| 17 | (13)+(14)+(15)+(16) = LHA | (-) 988 24 |
| 18 | **** = t | (-) 988 24 |

| | | |
|---|---|---|
| | LATITUDE (N) S | 34° 39' 48" |
| 19 | MILS IN TENS OF DEGREES | 533 33 |
| 20 | MILS IN UNITS OF DEGREES | 71 11 |
| 21 | MILS IN TENS OF MINUTES | 8 89 |
| 22 | MILS IN UNITS OF MINUTES | 2 67 |
| 23 | MILS IN TENS OF SECONDS | 20 |
| 24 | MILS IN UNITS OF SECONDS | 04 |
| 25 | LAT IN MILS SUM (19) THRU (24) | 616 24 |
| | LONGITUDE (W) | 98° 24' 18" |
| 26 | MILS IN HUNDREDS OF DEGREES | |
| 27 | MILS IN TENS OF DEGREES | 1600 00 |
| 28 | MILS IN UNITS OF DEGREES | 142 25 |
| 29 | MILS IN TENS OF MINUTES | 5 93 |
| 30 | MILS IN UNITS OF MINUTES | 1 17 |
| 31 | MILS IN TENS OF SECONDS | 05 |
| 32 | MILS IN UNITS OF SECONDS | 04 |
| 33 | LONG IN MILS SUM (26) THRU (32) | 1749 43 |

| | | |
|---|---|---|
| 34 | REFRACTION (TABLE 11) | - 25 |
| 35 | PARALLAX 0.04 -SUN ONLY or 7 sec | + |
| 36 | (1)+(34)+(35)=h | + 835 15 |
| 37 | NO. OF HRS IN GMT (4) x 60 | |
| 38 | NO. OF MIN IN GMT (4) | |
| 39 | (37) + (38) | |
| 40 | DAILY CHANGE IN DECLINATION (TABLE 2) | + - |
| 41 | LOG (39) | |
| 42 | LOG (40) | |
| 43 | LOG CONSTANT | 6 841638 |
| 44 | (41)+(42)+(43) | |
| 45 | ANTILOG (44) USE SIGN (40) | + - |
| 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | + - |
| 47 | (45)+(46)=APP DEC OF SUN OR DEC OF STAR (TABLE 10) | (+) 802 71 |

* IF (1)+(2)+(3) IS: +24h IS: GW DATE IS:
(+)&LESS THAN 24h NOT REQD LOCAL DATE
(+)&MORE THAN 24h (-) LOCAL DATE +1
(-) (+) LOCAL DATE -1

** IF (7) IS: (8) IS:
(-)OR(+) AND LESS THAN 12h (7) + 12h
\+ AND MORE THAN 12h (7) - 12h

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES + 13 W/SIGN(-) IF LONGITUDE WEST(+) IF EAST

**** (IF (17) IS: (18) IS:
(-)OR 0 TO 3200 mils REPEAT (17)
3200 mils TO 6400 mils 6400 mils - (17) SIGN (-)
MORE THAN 6400 mils (17)-6400 mils SIGN (+)

**HOUR ANGLE METHOD**

| | | |
|---|---|---|
| 48 | 1/2 (18) | + - |
| 49 | 1/2 (25) NORTH + SOUTH - | + - |
| 50 | 1/2 (47) | + - |
| 51 | (49) + (50) | + - |
| 52 | (49) - (50) | + - |
| 53 | COLOG SIN (51) | |
| 54 | LOG COS (52) | |
| 55 | LOG COT (48) | |
| 56 | (53) + (54) + (55) | |
| 57 | COLOG COS (51) | |
| 58 | LOG SIN (52) | |
| 59 | REPEAT (55) | |
| 60 | (57)+(58)+(59) | |
| 61 | ANTILOG TAN (60) USE SIGN (51) | + - |
| 62 | ANTILOG TAN (56) USE SIGN (32) | + - |
| 63 | (61)+(62) = A ENTER IN (95) | + |

**ALTITUDE METHOD**

| | | |
|---|---|---|
| 64 | 1600-00 MILS | |
| 65 | (47) W/SIGN REVERSED | + - |
| 66 | (64) + (65) = P | + |
| 67 | REPEAT (36) | |
| 68 | REPEAT (25) NORTH+ SOUTH- | + - |
| 69 | (66)+(67)+(68) | + - |
| 70 | 1/2 (69) = S | + - |
| 71 | (70) - (66) | + |
| 72 | COLOG COS (67) | |
| 73 | COLOG COS (68) | |
| 74 | LOG COS (70) | |
| 75 | LOG COS (71) | |
| 76 | (72)+(73)+(74)+(75) | |
| 77 | 1/2 (76) | |
| 78 | ANTILOG COS (77) | |
| 79 | 2 x (78) = A ENTER IN (95) | |

**ALTITUDE-HOUR ANGLE METHOD**

| | | |
|---|---|---|
| 80 | LOG SIN (18) | 9 916442 |
| 81 | LOG COS (47) | 9 848331 |
| 82 | COLOG COS (36) | 0 166054 |
| 83 | (80)+(81)+(82) | 9 930827 |
| 84 | ANTILOG SIN (83) = B | 1040 2 |
| 85 | ***** ENTER IN (95) | 1040 2 |

**POLARIS TABULAR METHOD**

| | | |
|---|---|---|
| 86 | $P_0$ VALUES OBTAINED | |
| 87 | $P_1$ FROM TABLE 12 | |
| 88 | $P_2$ USING LST (12) | |
| 89 | (86)+(87)+(88) | |
| 90 | LOG (89) | |
| 91 | LOG FACTOR | 9 471 7 |
| 92 | COLOG COS (25) | |
| 93 | (90)+(91)+(92) | |
| 94 | ANTILOG (93) = A ENTER IN (95) | |

COMPUTER: Klein

CHECKER: Blair

***** (84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A

****** AZ TO STAR = A WHEN STAR IS IN EAST
AZ = 6400 - A WHEN STAR IS IN WEST
ADD 6400 IF (95) IS LESS THAN (96)

**AZIMUTH TO AZIMUTH MARK**

| | | |
|---|---|---|
| 95 | A ****** | 7440 2 |
| 96 | MEAN HORIZONTAL ANGLE (1) | 3148 3 |
| 97 | (95)-(96)=AZ TO AZ MK | 4291 9 |

DA FORM 2973, 1 May 65

*Figure 127. DA Form 2973 showing computations by the altitude-hour angle method using the star Deneb.*

will be saved if the five-place logs in table 14 in the Army Ephemeris are used. For fifth-order accuracy, it is better to make a rough interpolation to 0.1 mil. The colog cosine in item 82 is obtained by subtracting the log cosine from 10.0. Each digit is mentally subtracted from 9 and the result is entered in item 82. The sum of the two log sines and the colog cosine is entered in item 83. The angle the sine of which is equal to this sum is the bearing angle and is entered in item 84. The bearing angle is "B" in the formula. The bearing angle may be either east or west from either the north or the south pole. By inspection of the approximate azimuth, the proper quadrant may be determined unless the azimuth is too near due east or west. The bearing angle "B" is then reduced to an azimuth "A" (by subtracting it from or adding it to 3,200 or subtracting if from 6,400, as required) and entered in item 85. Figure 127 shows computations by the altitude hour-angle method, using the star Deneb.

### 312. The Altitude Method

Computations of astronomic azimuth by the altitude method can be performed on either DA Form 6–11 or on the new rapid computation form, DA Form 2973. DA Form 6–11 is used to compute the sets individually and to compare the resulting azimuths to determine if a set contains erroneous data. DA Form 2973 is used to compare the data from all sets graphically to detect erroneous field data; the computations are then made by using the mean data of all remaining sets.

*a.* Instructions for the use of DA Form 6–11 are on the back of the form; the portion labeled "limitations" is obsolete. Several formulas can be used for the solution of a spherical triangle the three sides of which are known; however, the formula selected for artillery survey use is:

$$\text{Cos } \tfrac{1}{2} \text{ A} = \sqrt{\frac{\text{Cos s Cos (s—p)}}{\text{Cos Lat Cos h}}}$$

Where A = astronomic azimuth of the sun (star) measured east or west of the observer's meridian;

s = ½ sum of polar distance, latitude, and true altitude.

p = polar distance of the star (sun);

Lat = latitude of the station;

h = true altitude of the sun (star).

DA Form 6–1 is used to determine the astronomic azimuth of the sun (star) by solving this formula through the use of logarithms. Figure 128 shows computations by the altitude method, using the sun and the sample field notes in figure 118. Figure 129 shows computations by the altitude method, using Deneb, and the sample field notes in figure 119. To solve the formula by use of DA Form 6–11, proceed as follows:

(1) Enter the station data which includes:
- (*a*) Latitude of the station.
- (*b*) Longitude of the station.
- (*c*) Approximate azimuth to the azimuth mark.
- (*d*) Local data.
- (*e*) Name or description of the azimuth mark.
- (*f*) Name of occupied station.
- (*g*) Temperature.
- (*h*) Name of the computer.
- (*i*) Name of the checker.
- (*j*) Notebook reference.
- (*k*) Area name (if available) of the area in which the fieldwork was completed.
- (*l*) A sketch of the survey involved.

(2) From the field notebook, enter the following field data:
- (*a*) *On line 1*, enter the mean watch time of observation.
- (*b*) *On line 2*, enter the watch correction.
- (*c*) *On line 7*, enter the mean vertical angle measured to the sun (star).
- (*d*) *On line 36*, enter the mean horizontal angle measured from the azimuth mark to the sun (star).

(3) *Use lines 1 through 6* to compute the Greenwich mean time of observation. GMT is required as an argument for entering table 2 in the Army Ephemeris to obtain the declination of the sun. This computation may be omitted if the celestial body is a star. The Greenwich date may differ from the local date. Follow the rules at the

**COMPUTATION-ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, SUN OR STAR** — TABLE NRS REFER TO TM 6-300-19 65 — SUN OR STAR NAME AND NR (TABLE 9): SUN

LATITUDE OF STATION: 34° 39' 48" (N) — LONGITUDE OF STATION: 98° 24' 18" (W) — APRX AZ TO AZ MK: 4291 — LOCAL DATE: 24 June 1965 — AZIMUTH MARK: Water Tank — STATION: SD 260

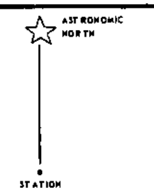
TEMPERATURE: 110 °F

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 1 | MEAN WATCH TIME OF OBSERVATION | 9h 26m 11s | 9h 29m 16s | 9h 32m 43s | 1 |
| 2 | WATCH CORRECTION (SLOW +, FAST −) | + 4 21 | + 4 21 | + 4 21 | 2 |
| 3 | ALGEBRAIC SUM (1) AND (2) | + 9 30 32 | + 9 33 37 | + 9 37 04 | 3 |
| 4 | TIME ZONE CORRECTION (W LONG +, E LONG −) | + 6 | + 6 | + 6 | 4 |
| 5 | ALGEBRAIC SUM (3) AND (4) | + 15 30 32 | + 15 33 37 | + 15 37 04 | 5 |
| | GREENWICH DATE* ____ 19__ | 24 00 00 | 24 00 00 | 24 00 00 | |
| 6 | GREENWICH MEAN TIME (GMT)* | 15 30 32 | 15 33 37 | 15 37 04 | 6 |
| 7 | OBSERVED ALTITUDE OF SUN OR STAR | 8 59 50 | 8 70 77 | 8 83 27 | 7 |
| 8 | PARALLAX (SUN ONLY) + 07 SECONDS OR + 0.04 MILS | + 04 | + 04 | + 04 | 8 |
| 9 | FOR SUN: (7) + (8) FOR STAR: REPEAT (7) | 8 59 54 | 8 70 81 | 8 83 31 | 9 |
| 10 | REFRACTION (TABLE 7 OR 1-MILS) | 23 | 22 | 22 | 10 |
| 11 | (9) − (10) TRUE ALTITUDE (h) | 8 59 31 | 8 70 59 | 8 83 09 | 11 |
| 12 | APPARENT DECLINATION: SUN, (14) OF AUX COMP ON REVERSE; STAR ON DATE IN (6) (TABLE 10 OR 10-MILS) | + 4 16 21 | + 4 16 21 | + 4 16 21 | 12 |
| 13 | 90°00'00" OR 1600.00 mils | + 16 00 00 | + 16 00 00 | + 16 00 00 | 13 |
| 14 | REPEAT (12) WITH SIGN REVERSED | − 4 16 21 | − 4 16 21 | − 4 16 21 | 14 |
| 15 | ALGEBRAIC SUM (13) AND (14) | + 11 83 79 | + 11 83 79 | + 11 83 79 | 15 |
| 16 | REPEAT (11) | + 8 59 31 | + 8 70 59 | + 8 83 09 | 16 |
| 17 | (15) + (16) | + 20 43 10 | + 20 54 38 | + 20 66 88 | 17 |
| 18 | LATITUDE (17) OF CONVERSION TO MILS COMP ON REVERSE IF USING MILS (NORTH +, SOUTH −) | + 6 16 24 | + 6 16 24 | + 6 16 24 | 18 |
| 19 | ALGEBRAIC SUM (17) AND (18) | 26 59 34 | 26 70 62 | 26 83 12 | 19 |
| 20 | 1/2 OF (19) | 13 29 67 | 13 35 31 | 13 41 56 | 20 |
| 21 | REPEAT (15) | 11 83 79 | 11 83 79 | 11 83 79 | 21 |
| 22 | SUBTRACT SMALLER, (20) OR (21), FROM LARGER, (21) OR (20). SIGN ALWAYS PLUS | + 1 45 88 | + 1 51 62 | + 1 57 77 | 22 |

* SF (5) IS: (+) AND LESS THAN 24 HRS; (+) AND MORE THAN 24 HRS; (−) — GREENWICH DATE (6) IS: LOCAL DATE; LOCAL DATE + 1 DAY; LOCAL DATE − 1 DAY — AND GMT (6) IS: SAME AS (5); (5) − 24 HRS; 24 HRS − (5)

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 23 | LOG COS (18) | 9.915 1394 | 9.915 1394 | 9.915 1394 | 23 |
| 24 | LOG COS (11) | 9.822 6640 | 9.817 1984 | 9.810 9971 | 24 |
| 25 | (23) + (24) | 9.737 8034 | 9.732 3378 | 9.726 1365 | 25 |
| 26 | LOG COS (20) | 9.418 7839 | 9.409 8386 | 9.399 6899 | 26 |
| 27 | LOG COS (22) | 9.995 5307 | 9.995 1708 | 9.994 7695 | 27 |
| 28 | (26) + (27) | 9.414 3146 | 9.405 0094 | 9.394 4594 | 28 |
| 29 | REPEAT (25) | 9.737 8034 | 9.732 3378 | 9.726 1365 | 29 |
| 30 | (28) − (29) | 9.676 5112 | 9.672 6716 | 9.668 3229 | 30 |
| 31 | (30) + 10.000 0000 | 19.676 5112 | 19.672 6716 | 19.668 3229 | 31 |
| 32 | 1/2 OF (31) | 9.838 2556 | 9.836 3358 | 9.834 1614 | 32 |
| 33 | ANGLE HAVING LOG COS (32) | 8 25 68 | 8 29 94 | 8 34 73 | 33 |
| 34 | 2 X (33) | 16 51 36 | 16 59 88 | 16 69 46 | 34 |
| 35 | WHEN SUN (STAR) IS EAST AND (34) IS: LESS THAN (34), GREATER THAN (34); WHEN SUN (STAR) IS WEST AND (360° / 6400 mils) − (34) IS: LESS THAN (34), GREATER THAN (34) — (35) IS: (34) + (180° / 3200 mils); REPEAT (34); (35) IS: (360° / 6400 mils) − (34); (540° / 9600 mils) − (34) | 80 51 36 | 80 59 88 | 80 69 46 | 35 |
| 36 | MEAN HORIZONTAL ANGLE | 37 59 59 | 37 67 96 | 37 77 58 | 36 |
| 37 | (35) − (36) = ASTRONOMIC AZIMUTH TO MARK | 42 91 77 | 42 91 92 | 42 91 88 | 37 |

SKETCH:




COMPUTER — CHECKER — SHEET __ OF __ SHEETS — DATE — AREA — NOTEBOOK REFERENCE

DA FORM 6-11, 1 DEC 55 — REPLACES EDITION OF 1 SEP 53, WHICH IS OBSOLETE

*Figure 128. DA Form 6–11 showing computations by the altitude method, using the sun.*

## AUXILIARY COMPUTATION FOR APPARENT DECLINATION OF SUN AT GREENWICH DATE AND GMT

| No. | Item | Set Nr 1 | Set Nr 2 | Set Nr 3 | No. |
|---|---|---|---|---|---|
| 1 | Greenwich date [(6) of computation] | 24 June 65 | 24 June 65 | 24 June 65 | 1 |
| 2 | GMT [hours and minutes in (6) of computation] | Hrs 15, Min 31 | Hrs 15, Min 34 | Hrs 15, Min 37 | 2 |
| | | X60 | X60 | X60 | |
| 3 | Numbers of hours in (2) x 60 | 900 | 900 | 900 | 3 |
| 4 | Number of minutes in (2) | 31 | 34 | 37 | 4 |
| 5 | (3)+(4) | 931 | 934 | 937 | 5 |
| 6 | Daily change in declination (Table 2) | − 0.35 | − 0.35 | − 0.35 | 6 |
| 7 | Log of (5) | 2.968 9497 | 2.970 3469 | 2.971 7396 | 7 |
| 8 | Log of (6) | 9.544 0680 | 9.544 0680 | 9.544 0680 | 8 |
| 9 | Log of constant | 6.841 6375 | 6.841 6375 | 6.841 6375 | 9 |
| 10 | (7)+(8)+(9) | 9.354 6552 | 9.355 0524 | 9.357 4451 | 10 |
| 11 | Number having log (10) = seconds or mils of change | .23 | .23 | .23 | 11 |
| 12 | Apparent declination at 0<sup></sup>h on Greenwich date (Table 2) | + 4 16 44 | + 4 16 44 | + 4 16 44 | 12 |
| 13 | (11) converted to minutes and seconds or (11) in mils [use sign of (6)] | − 23 | − 23 | − 23 | 13 |
| 14 | Algebraic sum (12) and (13) enter in (12) on front | + 4 16 21 | + 4 16 21 | + 4 16 21 | 14 |

## CONVERSION TO MILS COMPUTATION *(USE TABLE III b OF TM 6-230)*

| | | | | | |
|---|---|---|---|---|---|
| 1 | Longitude [from front of form] | 98° 24' 18" | 10 | Latitude [from front of form] | 34° 39' 48" |
| 2 | ⋔ in hundreds of degrees of (1) | | 11 | ⋔ in tens of degrees of (10) | 5 33.33 |
| 3 | ⋔ in tens of degrees of (1) | 16 00.00 | 12 | ⋔ in units of degrees of (10) | 71.11 |
| 4 | ⋔ in units of degrees of (1) | 1 42.22 | 13 | ⋔ in tens of minutes of (10) | 8.89 |
| 5 | ⋔ in tens of minutes of (1) | 5.93 | 14 | ⋔ in units of minutes of (10) | 2.67 |
| 6 | ⋔ in units of minutes of (1) | 1.19 | 15 | ⋔ in tens of seconds of (10) | .20 |
| 7 | ⋔ in tens of seconds of (1) | .5 | 16 | ⋔ in units of seconds of (10) | .4 |
| 8 | ⋔ in units of seconds of (1) | .4 | | Sum of (11) through (16) | 6 16.24 |
| 9 | Sum of (2) through (8) [enter on DA Form 4-20] | 17 49.43 | 17 | [Enter in (18) on front and on DA Form 6-20] | |

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GIVEN:
Time zone of area of operation.

FIELD DATA:
Latitude and longitude of station.
Approximate azimuth to azimuth mark and to sun or star (sketch).
Sun or name(s) and number(s) of selected star(s).
Local date of observation.
Temperature at time of observation.
Mean watch time of observation and watch correction.
Horizontal clockwise angle from azimuth mark to sun.
Observed altitude of (vertical angle to) sun or star.

GUIDE:
Enter observed field data in block marked, ▭
When using a mil-graduated instrument,--
a. (7) through (22) of computation are computed using hundredth-mil values.
b. (6) through (14) of AUXILIARY COMPUTATION are computed using hundredth-mil values.
c. (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.
d. (23) through (37) of computation are computed using tenth-mil values.
Value in (37) should be about equal to approximate azimuth to azimuth mark.
Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:
This form should not be used when accuracies greater than fourth-order are required.
The altitude method should not be used when the sun or star is--
a. Less than 20 degrees or more than 60 degrees above horizon.
b. More than 30 degrees from a 90-degree or 270-degree azimuth (east-west line).

RESULTS:
A value of astronomic azimuth for each set of observations.

FORMULA:

$$\text{Cos } 1/2\, A = \sqrt{\frac{\text{Cos } s \text{ Cos } (s-p)}{\text{Cos Lat Cos } h}}$$

A = astronomic azimuth of sun or star measured east or west of meridian.

s = 1/2 sum of polar distance, latitude, and true altitude.

p = polar distance of celestial body.

Lat = latitude of station.

h = true altitude of celestial body.

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*Figure 128*—Continued.

COMPUTATION-ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, SUN OR STAR

TABLE NRS REFER TO TM 6-300-19____

SUN OR STAR NAME AND NR (TABLE 9): Deneb 68

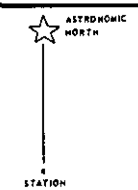
| | | | | | |
|---|---|---|---|---|---|
| LATITUDE OF STATION: 34° 39' 48" N | LONGITUDE OF STATION: 98° 24' 18" W | APRX AZ TO AZ MK: 4291 | LOCAL DATE: 24 June 1965 | AZIMUTH MARK: Water Tank | STATION: SD 260 |
| TEMPERATURE: 83 °F | | | | | |

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 1 | MEAN WATCH TIME OF OBSERVATION | 23h 11m 17s | 23h 14m 11s | 23h 18m 04s | 1 |
| 2 | WATCH CORRECTION (SLOW +, FAST −) | + 4 28 | + 4 28 | + 4 28 | 2 |
| 3 | ALGEBRAIC SUM (1) AND (2) | + 23 15 45 | + 23 18 39 | + 23 22 32 | 3 |
| 4 | TIME ZONE CORRECTION (W LONG +, E LONG −) | + 6 | + 6 | + 6 | 4 |
| 5 | ALGEBRAIC SUM (3) AND (4) | + 29 15 45 | + 29 18 39 | + 29 22 32 | 5 |
| | GREENWICH DATE *25 June 19 65 | 24 00 00 | 24 00 00 | 24 00 00 | |
| 6 | GREENWICH MEAN TIME (GMT) * | 5 15 45 | 5 18 39 | 5 22 32 | 6 |
| 7 | OBSERVED ALTITUDE OF SUN OR STAR | 8 25 38 | 8 34 31 | 8 46 44 | 7 |
| 8 | PARALLAX (SUN ONLY) + 07 SECONDS OR + 0.04 MILS | + | + | + | 8 |
| 9 | FOR SUN: (7) + (8) FOR STAR: REPEAT (7) | 8 25 38 | 8 34 31 | 8 46 44 | 9 |
| 10 | REFRACTION (TABLE 7 OR 7-MILS) | 25 | 25 | 24 | 10 |
| 11 | (9)−(10) TRUE ALTITUDE (h) | 8 25 13 | 8 34 06 | 8 46 20 | 11 |
| 12 | APPARENT DECLINATION: SUN, (14) OF AUX COMP ON REVERSE; STAR ON DATE IN (4)(TABLE 10 OR 10-MILS) | + 8 02 71 | + 8 02 71 | + 8 02 71 | 12 |
| 13 | 90°00'00" OR 1600.00 mils | + 16 00 00 | + 16 00 00 | + 16 00 00 | 13 |
| 14 | REPEAT (12) WITH SIGN REVERSED | ± 8 02 71 | ± 8 02 71 | ± 8 02 71 | 14 |
| 15 | ALGEBRAIC SUM (13) AND (14) | + 7 97 29 | + 7 97 29 | + 7 97 29 | 15 |
| 16 | REPEAT (11) | + 8 25 13 | + 8 34 06 | + 8 46 20 | 16 |
| 17 | (15) + (16) | + 16 22 42 | + 16 31 35 | + 16 43 49 | 17 |
| 18 | LATITUDE [(17) OF CONVERSION TO MILS COMP ON REVERSE IF USING MILS] (NORTH +, SOUTH −) | + 6 16 24 | + 6 16 24 | + 6 16 24 | 18 |
| 19 | ALGEBRAIC SUM (17) AND (18) | 22 38 66 | 22 47 59 | 22 59 73 | 19 |
| 20 | 1/2 OF (19) | 11 19 33 | 11 23 80 | 11 29 86 | 20 |
| 21 | REPEAT (15) | 7 97 29 | 7 97 29 | 7 97 29 | 21 |
| 22 | SUBTRACT SMALLER, (20) OR (21), FROM LARGER, (21) OR (20), SIGN ALWAYS PLUS | + 3 22 04 | + 3 26 51 | + 3 32 57 | 22 |

* IF (3) IS: (+) AND LESS THAN 24 HRS; (+) AND MORE THAN 24 HRS; (−) — GREENWICH DATE (A) IS: LOCAL DATE; LOCAL DATE + 1 DAY; LOCAL DATE − 1 DAY — AND GMT (6) IS: SAME AS (5); (5) − 24 HRS; 24 HRS − (5)

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 23 | LOG COS (18) | 9.915 1394 | 9.915 1394 | 9.915 1394 | 23 |
| 24 | LOG COS (11) | 9.838 5016 | 9.834 4661 | 9.828 8651 | 24 |
| 25 | (23) + (24) | 9.753 6410 | 9.749 6055 | 9.744 0045 | 25 |
| 26 | LOG COS (20) | 9.657 6070 | 9.653 8522 | 9.648 6960 | 26 |
| 27 | LOG COS (22) | 9.977 9228 | 9.977 2946 | 9.976 4283 | 27 |
| 28 | (26) + (27) | 9.635 5298 | 9.631 1468 | 9.625 1243 | 28 |
| 29 | REPEAT (25) | 9.753 6410 | 9.749 6055 | 9.744 0045 | 29 |
| 30 | (28) − (29) | 9.881 8888 | 9.881 5413 | 9.881 1198 | 30 |
| 31 | (30) + 10.000 0000 | 19.881 8888 | 19.881 5413 | 19.881 1198 | 31 |
| 32 | 1/2 OF (31) | 9.940 9444 | 9.940 7706 | 9.940 5599 | 32 |
| 33 | ANGLE HAVING LOG COS (32) | 5 19 24 | 5 19 97 | 5 20 85 | 33 |
| 34 | 2 x (33) | 10 38 48 | 10 39 94 | 10 41 70 | 34 |
| 35 | WHEN SUN (STAR) IS EAST AND (34) IS: LESS THAN (34), GREATER THAN (36); WHEN SUN (STAR) IS WEST AND (34) IS: LESS THAN (36), GREATER THAN (36) — (35) IS: (34) + (180° / 3200 mils); REPEAT (34); (35) IS: (360° / 6400 mils) − (34); (180° / 3200 mils) − (34) | 74 38 48 | 74 39 94 | 74 41 70 | 35 |
| 36 | MEAN HORIZONTAL ANGLE | 31 46 84 | 31 48 25 | 31 49 97 | 36 |
| 37 | (35) − (36) = ASTRONOMIC AZIMUTH TO MARK | 42 91 64 | 42 91 69 | 42 91 73 | 37 |

SKETCH:




COMPUTER | CHECKER | SHEET OF SHEETS

DATE | AREA | NOTEBOOK REFERENCE

DA FORM 1 DEC 55 6-11 REPLACES EDITION OF 1 SEP 53, WHICH IS OBSOLETE

*Figure 129. DA Form 6–11 showing computations by the altitude method, using the star Deneb.*

## AUXILIARY COMPUTATION FOR APPARENT DECLINATION OF SUN AT GREENWICH DATE AND GMT

| | | SET HR ____ | | SET HR ____ | | SET HR ____ | | |
|---|---|---|---|---|---|---|---|---|
| 1 | GREENWICH DATE [(4) OF COMPUTATION] | | | | | | | 1 |
| 2 | GMT [HOURS AND MINUTES IN (6) OF COMPUTATION] | HRS | MIN | HRS | MIN | HRS | MIN | 2 |
| | | X60 | | X60 | | X60 | | |
| 3 | NUMBERS OF HOURS IN (2) X 60 | | | | | | | 3 |
| 4 | NUMBER OF MINUTES IN (2) | | | | | | | 4 |
| 5 | (3)+(4) | | | | | | | 5 |
| 6 | DAILY CHANGE IN DECLINATION (TABLE 2) | ± | | ± | | ± | | 6 |
| 7 | LOG OF (5) | | | | | | | 7 |
| 8 | LOG OF (6) | | | | | | | 8 |
| 9 | LOG OF CONSTANT | 6.841 | 6375 | 6.841 | 6375 | 6.841 | 6375 | 9 |
| 10 | (7)+(8)+(9) | | | | | | | 10 |
| 11 | NUMBER HAVING LOG (10) = SECONDS OR MILS OF CHANGE | | | | | | | 11 |
| 12 | APPARENT DECLINATION AT 0h ON GREENWICH DATE (TABLE 2) | ± | | ± | | ± | | 12 |
| 13 | (11) CONVERTED TO MINUTES AND SECONDS OR (11) IN MILS [USE SIGN OF (6)] | ± | | ± | | ± | | 13 |
| 14 | ALGEBRAIC SUM (12) AND (13) ENTER IN (12) ON FRONT | ± | | ± | | ± | | 14 |

## CONVERSION TO MILS COMPUTATION (USE TABLE III b OF TM 6-230)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | LONGITUDE [FROM FRONT OF FORM] | 98° | 24' | 18" | 10 | LATITUDE [FROM FRONT OF FORM] | 34° | 39' | 48" |
| 2 | m IN HUNDREDS OF DEGREES OF (1) | | | | 11 | m IN TENS OF DEGREES OF (10) | 5 | 33 | 33 |
| 3 | m IN TENS OF DEGREES OF (1) | 16 | 00 | 00 | 12 | m IN UNITS OF DEGREES OF (10) | | 71 | 11 |
| 4 | m IN UNITS OF DEGREES OF (1) | 1 | 42 | 22 | 13 | m IN TENS OF MINUTES OF (10) | | 8 | 89 |
| 5 | m IN TENS OF MINUTES OF (1) | | 5 | 93 | 14 | m IN UNITS OF MINUTES OF (10) | | 2 | 67 |
| 6 | m IN UNITS OF MINUTES OF (1) | | 1 | 19 | 15 | m IN TENS OF SECONDS OF (10) | | | 20 |
| 7 | m IN TENS OF SECONDS OF (1) | | | 05 | 16 | m IN UNITS OF SECONDS OF (10) | | | 04 |
| 8 | m IN UNITS OF SECONDS OF (1) | | | 04 | 17 | SUM OF (11) THROUGH (16) [ENTER IN (18) ON FRONT AND ON DA FORM 6-28] | 6 | 16 | 24 |
| 9 | SUM OF (2) THROUGH (8) [ENTER ON DA FORM 6-20] | 17 | 49 | 43 | | | | | |

GIVEN:
Time zone of area of operation.

FIELD DATA:
Latitude and longitude of station.
Approximate azimuth to azimuth mark and to sun or star (sketch).
Sun or name(s) and number(s) of selected star(s).
Local date of observation.
Temperature at time of observation.
Mean watch time of observation and watch correction.
Horizontal clockwise angle from azimuth mark to sun.
Observed altitude of (vertical angle to) sun or star.

GUIDE:
Enter observed field data in block marked.
When using a mil-graduated instrument,--
a. (7) through (22) of computation are computed using hundredth-mil values.
b. (6) through (14) of AUXILIARY COMPUTATION are computed using hundredth-mil values.
c. (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.
d. (23) through (37) of computation are computed using tenth-mil values.
Value in (37) should be about equal to approximate azimuth to azimuth mark.
Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:
This form should not be used when accuracies greater than fourth-order are required.
The altitude method should not be used when the sun or star is--
a. Less than 20 degrees or more than 60 degrees above horizon.
b. More than 30 degrees from a 90-degree or 270-degree azimuth (east-west line).

RESULTS:
A value of astronomic azimuth for each set of observations.

FORMULA:

$$\text{Cos } 1/2\ A = \sqrt{\frac{\text{Cos s Cos (s-p)}}{\text{Cos Lat Cos h}}}$$

A = astronomic azimuth of sun or star measured east or west of meridian.

s = 1/2 sum of polar distance, latitude, and true altitude.

p = polar distance of celestial body.

Lat = latitude of station.

h = true altitude of celestial body.

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*Figure 129*—Continued.

bottom of the form. The time zone correction (line 4) may be determined from table 1 in paragraph 287 or computed as discussed in paragraph 287.

(4) *Use lines 7 through 11* to compute the value of "h," or the true altitude of the sun (star). Correct the observed vertical angle for refraction. Correct for parallax only if the sun is observed.

(5) *Use lines 12 through 15* to compute the value of "p," or the polar distance, by subtracting the declination of the celestial body from 1,600 mils (90°). If the sun is observed, perform an auxiliary computation on the back of the form to determine the apparent declination. If a star is observed, obtain the apparent declination from the Army Ephemeris in mils or degrees, depending on how "h" is expressed.

(6) *On lines 16 and 17*, add the values of "h" and "p" as part of the value of "s."

(7) *On line 18*, enter the latitude of the occupied station. Latitude is ordinarily expressed in degrees, minutes, and seconds. If the true altitude (h) is in degrees, this latitude may be entered on line 18 without change. If the true altitude is in mils, an auxiliary computation must be performed on the back of the form to convert the latitude to mils. Use the conversion table in TM's 6–230 and 6–231 or table 5 in the Army Ephemeris.

(8) *Use lines 19 and 20* to compute the value of s by adding lines 17 (h + p) and 18 (Lat) and dividing the sum by 2.

(9) *Use lines 21 and 22* to compute the value of s − p.

(10) *On lines 23 through 24*, solve, with the use of logarithms, the value of A. Use TM 6–230 (six-place logarithms) or TM 6–231 (seven-place logarithms) for three computations. "A" is the angle measured from the north pole to the sun (star). If this angle is measured to the east, the value of the angle is the azimuth of the sun (star). If this angle is measured to the west, its value must be subtracted from 6,400 mils (360°) to determine the azimuth of the sun (star).

(11) *On lines 35 through 37*, determine the astronomic azimuth from the occupied station to the azimuth mark by subtracting the measured mean horizontal angle from the azimuth of the sun (star).

*b*. The same formula is used to compute azimuth by the altitude method, on DA Form 2973 as is used on DA Form 6–11. Table 14 (five-place logarithms) in the Army Ephemeris may be used instead of TM 6–230 or TM 6–231 to increase the speed of computations but with some sacrifice in accuracy. When DA Form 2973 is used, field data are plotted on the form and erroneous data is rejected prior to computation. If possible, the validity of the data should be determined before the instrument is taken down in case another set may be required. All remaining sets are meaned prior to computation, and only the mean values are used. This reduces computation time by about one-half of that required for DA Form 6–11. Figure 130 shows computations by the altitude method, using the sun and the field data in figure 118. Figure 131 shows computations by the altitude method, using the star Deneb, and the field data in figure 119. To solve the formula by use of DA Form 2973, proceed as follows:

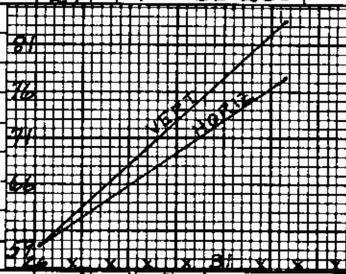
(1) Enter the station data which includes:
- (*a*) Local date.
- (*b*) Name or description of the azimuth mark.
- (*c*) Approximate azimuth to the azimuth mark.
- (*d*) Name of occupied station.
- (*e*) Temperature.
- (*f*) Latitude of the station (above item 19).
- (*g*) Longitude of the station (above item 26).
- (*h*) A sketch of the survey.

FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION

STAR NAME AND NUMBER: SUN

| LOCAL DATE | AZIMUTH MARK | APPROX. AZ TO AZ MK | STATION | TEMP |
|---|---|---|---|---|
| 24 Jun 65 | WT | 4291 | SD 260 | 110 °F |

| | FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|---|
| | SET NO. 1 | 09 26 11 | 3759 6 | + 859 5 |
| | SET NO. 2 | 09 29 16 | 3768 0 | + 870 8 |
| | SET NO. 3 | 09 32 43 | 3777 6 | + 883 3 |
| | SET NO. | | | |
| | SET NO. | | | |
| | SET NO. | | | |
| | SUM | 28 28 10 | 11305 2 | 2613 6 |
| 1 | MEAN | 09 29 23 | 3768 4 | + 871 2 |




| | | | |
|---|---|---|---|
| 2 | WATCH CORR. SLOW + FAST - | + - 24 | 04 21 |
| 3 | TIME ZONE W LONG+ CORR. E LONG- | + - | 6 00 00 |
| 4 | (1)+(2)+(3)=GMT* DATE | + | 15 33 44 |
| 5 | EQ OF T: AT 0h ON GW DATE (TABLE 2) | + - | |
| 6 | EQ OF T: AT GMT (TABLE 3) | + - | |
| 7 | (4)+(5)+(6) = GAT | + - | |
| 8 | ** = GHA | + - | |
| 9 | SID TIME AT 0h ON GW DATE (TBL 2) | + | |
| 10 | CORRECTION TO (9) (TABLE 4) | + | |
| 11 | * * * | + - | |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | + - | |
| 13 | HRS OF GHA (8) OR (12) IN MILS (TBL 5) | + - | |
| 14 | MIN OF GHA IN MILS | + - | |
| 15 | SEC OF GHA IN MILS | + - | |
| 16 | LONGITUDE EAST + IN MILS (33) WEST - | + - | |
| 17 | (13)+(14)+(15)+(16) = LHA | + - | |
| 18 | **** = t | + - | |

| | | |
|---|---|---|
| | LATITUDE N S | 34° 39' 48" |
| 19 | MILS IN TENS OF DEGREES | 533 33 |
| 20 | MILS IN UNITS OF DEGREES | 71 11 |
| 21 | MILS IN TENS OF MINUTES | 8 89 |
| 22 | MILS IN UNITS OF MINUTES | 2 67 |
| 23 | MILS IN TENS OF SECONDS | 20 |
| 24 | MILS IN UNITS OF SECONDS | 04 |
| 25 | LAT IN MILS SUM (19) THRU (24) | 616 24 |
| | LONGITUDE E W | 98° 24' 18" |
| 26 | MILS IN HUNDREDS OF DEGREES | |
| 27 | MILS IN TENS OF DEGREES | 1600 00 |
| 28 | MILS IN UNITS OF DEGREES | 142 22 |
| 29 | MILS IN TENS OF MINUTES | 5 93 |
| 30 | MILS IN UNITS OF MINUTES | 1 19 |
| 31 | MILS IN TENS OF SECONDS | 0 05 |
| 32 | MILS IN UNITS OF SECONDS | 04 |
| 33 | LONG IN MILS SUM (26) THRU (32) | 1749 43 |

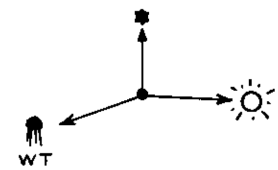
| | | | |
|---|---|---|---|
| 34 | REFRACTION (TABLE 1) | - | 22 |
| 35 | PARALLAX 0.04₥ -SUN ONLY or 7 sec | + | 0 04 |
| 36 | (1)+(34)+(35)=h | + | 871 02 |
| 37 | NO. OF HRS IN GMT (4) x 60 | | 900 00 |
| 38 | NO. OF MIN IN GMT (4) | | 33 00 |
| 39 | (37) + (38) | | 933 00 |
| 40 | DAILY CHANGE IN DECLINATION (TABLE 2) | + - | 35 |
| 41 | LOG (39) | | 2 969882 |
| 42 | LOG (40) | | 9 544068 |
| 43 | LOG CONSTANT | | 6 841638 |
| 44 | (41)+(42)+(43) | | 9 355588 |
| 45 | ANTILOG (44) USE SIGN (40) | + - | 23 |
| 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | + - | 416 44 |
| 47 | (45)+(46)=APP DEC OF SUN OR DEC OF STAR (TABLE 10) | + - | 416 21 |

* IF (1)+(2)+(3) IS: +24 IS: GW DATE IS:
(+) & LESS THAN 24h NOT REQD LOCAL DATE
(+) & MORE THAN 24h (-) LOCAL DATE +1
(-) (+) LOCAL DATE -1

** IF (7) IS: (8) IS:
(-) OR (+) AND LESS THAN 12h (7) + 12h
+ AND MORE THAN 12h (7) - 12h

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES ÷ 15 W/SIGN (-) IF LONGITUDE WEST (+) IF EAST

**** (IF (17) IS: (18) IS:
(-) OR 0 TO 3200₥ REPEAT (17)
3200₥ TO 6400₥ 6400₥ - (17) SIGN (-)
MORE THAN 6400₥ (17)-6400₥ SIGN (+)




HOUR ANGLE METHOD

| | | | |
|---|---|---|---|
| 48 | 1/2 (18) | + - | |
| 49 | 1/2 (25) NORTH + SOUTH - | + - | |
| 50 | 1/2 (47) | + - | |
| 51 | (49) + (50) | + - | |
| 52 | (49) - (50) | + - | |
| 53 | COLOG SIN (51) | | |
| 54 | LOG COS (52) | | |
| 55 | LOG COT (48) | | |
| 56 | (53) + (54) + (55) | | |
| 57 | COLOG COS (51) | | |
| 58 | LOG SIN (52) | | |
| 59 | REPEAT (55) | | |
| 60 | (57)+(58)+(59) | | |
| 61 | ANTILOG TAN (60) USE SIGN (51) | + - | |
| 62 | ANTILOG TAN (56) USE SIGN (52) | + - | |
| 63 | (61)+(62) = A ENTER IN (95) | + | |

ALTITUDE METHOD

| | | | |
|---|---|---|---|
| 64 | 1600.00 MILS | | 1600 00 |
| 65 | (47) W/SIGN REVERSED | + - | 416 21 |
| 66 | (64) + (65) = P | + | 1183 79 |
| 67 | REPEAT (36) | + | 871 02 |
| 68 | REPEAT (25) NORTH+ SOUTH- | + - | 616 24 |
| 69 | (66)+(67)+(68) | - | 2671 05 |
| 70 | 1/2 (69) = s | + | 1335 52 |
| 71 | (70) - (66) | + | 151 73 |
| 72 | COLOG COS (67) | | 0 183003 |
| 73 | COLOG COS (68) | | 0 084849 |
| 74 | LOG COS (70) | | 9 409534 |
| 75 | LOG COS (71) | | 9 995166 |
| 76 | (72)+(73)+(74)+(75) | | 19 672552 |
| 77 | 1/2 (76) | | 9 836276 |
| 78 | ANTILOG COS (77) | | 830 1 |
| 79 | 2 x (78) = A ENTER IN (95) | | 1660 2 |

ALTITUDE-HOUR ANGLE METHOD

| | | |
|---|---|---|
| 80 | LOG SIN (18) | |
| 81 | LOG COS (47) | |
| 82 | COLOG COS (36) | |
| 83 | (80)+(81)+(82) | |
| 84 | ANTILOG SIN (83) = B | |
| 85 | *****A ENTER IN (95) | |

POLARIS TABULAR METHOD

| | | |
|---|---|---|
| 86 | b0 VALUES OBTAINED | |
| 87 | b1 FROM TABLE 12 | |
| 88 | b2 USING LST (12) | |
| 89 | (86)+(87)+(88) | |
| 90 | LOG (89) | |
| 91 | LOG FACTOR | 9 471 7 |
| 92 | COLOG COS (25) | |
| 93 | (90)+(91)+(92) | |
| 94 | ANTILOG (93) = A ENTER IN (95) | |

COMPUTER Klein

CHECKER Blair

*****(84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A

****** AZ TO STAR = A WHEN STAR IS IN EAST
AZ = 6400 - A WHEN STAR IS IN WEST
ADD 6400 IF (95) IS LESS THAN (96)

AZIMUTH TO AZIMUTH MARK

| | | |
|---|---|---|
| 95 | A ****** | 1660 2 |
| 96 | MEAN HORIZONTAL ANGLE (1) | 3768 4 |
| 97 | AZ TO (95)-(96)=AZ MK | 4291 8 |

DA FORM 2973, 1 May 65

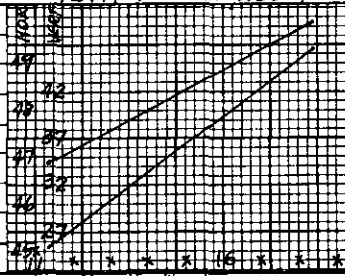
*Figure 130. DA Form 2973 showing computations by the altitude method, using the sun.*

FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION

STAR NAME AND NUMBER: DENEB 68

| LOCAL DATE | AZIMUTH MARK | APPROX. AZ TO AZ MK | STATION | TEMP |
|---|---|---|---|---|
| 24 JUN 65 | WT | 4291 | SD 260 | 83 °F |

| FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|
| SET NO. 1 | 23 11 17 | 3146 8 | +825 4 |
| SET NO. 2 | 23 14 11 | 3148 2 | +834 3 |
| SET NO. 3 | 23 08 04 | 3150 0 | +846 4 |
| SET NO. | | | |
| SET NO. | | | |
| SET NO. | | | |
| SUM | 69 43 32 | 9445 0 | 2506 1 |
| 1 MEAN | 23 14 31 | 3148 3 | 835 4 |




| | | | |
|---|---|---|---|
| 2 | WATCH CORR. SLOW + FAST - | + | 24 04 28 |
| 3 | TIME ZONE CORR. W LONG+ E LONG- | + | 6 00 00 |
| 4 | (1)+(2)+(3)=GMT* DATE 25 JUN 65 | + | 5 18 59 |
| 5 | EQ OF T: AT 0h ON GW DATE (TABLE 2) | ± | |
| 6 | EQ OF T: AT GMT (TABLE 3) | ± | |
| 7 | (4)+(5)+(6) = GAT | ± | |
| 8 | ** = GHA | ± | |
| 9 | SID TIME AT 0h ON GW DATE (TBL 2) | + | |
| 10 | CORRECTION TO (9) (TABLE 4) | + | |
| 11 | * * * | ± | |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | ± | |
| 13 | HRS OF GHA(8) OR (12) IN MILS (TBL 5) | ± | |
| 14 | MIN OF GHA IN MILS | ± | |
| 15 | SEC OF GHA IN MILS | ± | |
| 16 | LONGITUDE EAST + IN MILS (33) WEST - | ± | |
| 17 | (13)+(14)+(15)+(16) = LHA | ± | |
| 18 | **** = t | ± | |

| | | |
|---|---|---|
| | LATITUDE N S | 34 39 48 |
| 19 | MILS IN TENS OF DEGREES | 533 33 |
| 20 | MILS IN UNITS OF DEGREES | 71 11 |
| 21 | MILS IN TENS OF MINUTES | 8 89 |
| 22 | MILS IN UNITS OF MINUTES | 2 67 |
| 23 | MILS IN TENS OF SECONDS | 20 |
| 24 | MILS IN UNITS OF SECONDS | 04 |
| 25 | LAT IN MILS SUM (19) THRU (24) | 616 24 |
| | LONGITUDE W | 98 24 18 |
| 26 | MILS IN HUNDREDS OF DEGREES | |
| 27 | MILS IN TENS OF DEGREES | 1600 00 |
| 28 | MILS IN UNITS OF DEGREES | 142 22 |
| 29 | MILS IN TENS OF MINUTES | 5 93 |
| 30 | MILS IN UNITS OF MINUTES | 1 19 |
| 31 | MILS IN TENS OF SECONDS | 05 |
| 32 | MILS IN UNITS OF SECONDS | 04 |
| 33 | LONG IN MILS SUM (26) THRU (32) | 1749 43 |

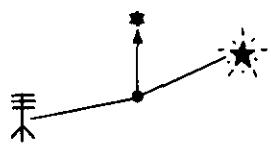
| | | | |
|---|---|---|---|
| 34 | REFRACTION (TABLE 1) | - | 25 |
| 35 | PARALLAX 0.04 -SUN ONLY or 7 sec | + | |
| 36 | (1)+(34)+(35)=h | + | 835 15 |
| 37 | NO. OF HRS IN GMT (4) x 60 | | |
| 38 | NO. OF MIN IN GMT (4) | | |
| 39 | (37) + (38) | | |
| 40 | DAILY CHANGE IN DECLINATION (TABLE 2) | ± | |
| 41 | LOG (39) | | |
| 42 | LOG (40) | | |
| 43 | LOG CONSTANT | | 6 841638 |
| 44 | (41)+(42)+(43) | | |
| 45 | ANTILOG (44) USE SIGN (40) | ± | |
| 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | ± | |
| 47 | (45)+(46)=APP DEC OF SUN OR DEC OF STAR (TABLE 10) | + | 802 71 |

* IF (1)+(2)+(3) IS: +24 IS: GW DATE IS:
(+) LESS THAN 24h NOT REQD LOCAL DATE
(+) MORE THAN 24h (-) LOCAL DATE +1
(-) (+) LOCAL DATE -1

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES ÷ 15 W/SIGN (-) IF LONGITUDE WEST (+) IF EAST

** IF (7) IS: (8) IS:
(-) OR (+) AND LESS THAN 12h (7) + 12h
+ AND MORE THAN 12h (7) - 12h

**** (IF (17) IS: (18) IS:
(-) OR 0 TO 3200 REPEAT (17)
3200 TO 6400 6400 - (17) SIGN (-)
MORE THAN 6400 (17)-6400 SIGN (+)



**HOUR ANGLE METHOD**

| | | |
|---|---|---|
| 48 | 1/2 (18) | |
| 49 | 1/2 (25) NORTH + SOUTH - | |
| 50 | 1/2 (47) | |
| 51 | (49) + (50) | |
| 52 | (49) - (50) | |
| 53 | COLOG SIN (51) | |
| 54 | LOG COS (52) | |
| 55 | LOG COT (48) | |
| 56 | (53) + (54) + (55) | |
| 57 | COLOG COS (51) | |
| 58 | LOG SIN (52) | |
| 59 | REPEAT (55) | |
| 60 | (57)+(58)+(59) | |
| 61 | ANTILOG TAN (60) USE SIGN (51) | |
| 62 | ANTILOG TAN (56) USE SIGN (52) | |
| 63 | (61)+(62) = A ENTER IN (95) | |

**ALTITUDE METHOD**

| | | | |
|---|---|---|---|
| 64 | 1600.00 MILS | | 1600 00 |
| 65 | (47) W/SIGN REVERSED | - | 802 71 |
| 66 | (64) + (65) = P | + | 797 29 |
| 67 | REPEAT (36) | + | 835 15 |
| 68 | REPEAT (25) NORTH+ SOUTH- | + | 616 24 |
| 69 | (66)+(67)+(68) | + | 2248 68 |
| 70 | 1/2 (69) = S | + | 1124 34 |
| 71 | (70) - (66) | + | 327 05 |
| 72 | COLOG COS (67) | | 0 166054 |
| 73 | COLOG COS (68) | | 0 084849 |
| 74 | LOG COS (70) | | 9 653429 |
| 75 | LOG COS (71) | | 9 977225 |
| 76 | (72)+(73)+(74)+(75) | | 19 881557 |
| 77 | 1/2 (76) | | 9 940778 |
| 78 | ANTILOG COS (77) | | 519 9 |
| 79 | 2 x (78) = A ENTER IN (95) | | 1039 8 |

**ALTITUDE-HOUR ANGLE METHOD**

| | | |
|---|---|---|
| 80 | LOG SIN (18) | |
| 81 | LOG COS (47) | |
| 82 | COLOG COS (36) | |
| 83 | (80)+(81)+(82) | |
| 84 | ANTILOG SIN (83) = B | |
| 85 | *****A ENTER IN (95) | |

**POLARIS TABULAR METHOD**

| | | |
|---|---|---|
| 86 | b0 VALUES OBTAINED | |
| 87 | b1 FROM TABLE 12 | |
| 88 | b2 USING LST(12) | |
| 89 | (86)+(87)+(88) | |
| 90 | LOG (89) | |
| 91 | LOG FACTOR | 9 471 7 |
| 92 | COLOG COS (25) | |
| 93 | (90)+(91)+(92) | |
| 94 | ANTILOG (93) = A ENTER IN (95) | |

**AZIMUTH TO AZIMUTH MARK**

| | | |
|---|---|---|
| 95 | A ****** | 7439 8 |
| 96 | MEAN HORIZONTAL ANGLE (1) | 3148 3 |
| 97 | (95)-(96)=AZ TO AZ MK | 4291 5 |

***** (84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A

****** AZ TO STAR = A WHEN STAR IS IN EAST
AZ = 6400 - A WHEN STAR IS IN WEST
ADD 6400 IF (95) IS LESS THAN (96)

COMPUTER Klein

CHECKER Blair

DA FORM 2973, 1 May 65

*Figure 131. DA Form 2973 showing computations by the altitude method, using the star Deneb.*

(2) From the field notebook, enter the following field data for each set:

(*a*) Mean watch time of observation.

(*b*) Mean horizontal angle.

(*c*) Mean vertical angle.

(3) Add the mean values of the sets, divide the sum by the number of sets used, and enter the mean of each value in *item 1*.

(4) *Use items 1 through 4* to compute the GMT and Greenwich date. GMT is not required when observing a star.

(5) *Ignore or cross out items 5 through 18*, as they are not required when computing by the altitude method.

(6) *In items 19 through 25*, convert the latitude from degrees, minutes, and seconds to mils.

(7) *Ignore or cross out items 26 through 33*, as they are not required when computing by the altitude method.

(8) *In items 34 through 36*, determine the value of h.

(9) *In items 37 through 47*, determine the apparent declination of the sun. These items are used only when observing the sun and may be ignored or crossed out when observing a star.

(10) *Use items 64 through 79* to compute the value of A. Note that cologs, as well as logarithms, are used. Cologs are determined by subtracting the logarithms from 10.0.

(11) *Use items 95 through 97* to compute the final azimuth from the occupied station to the azimuth mark by subtracting the mean horizontal angle from the azimuth of the sun or star.

## 313. The Hour-Angle Method

Computations of astronomic azimuth by the hour-angle method can be performed on DA Form 6–10 when the sun is observed, DA Form 6–10a when a star is observed, or DA Form 2973 when either the sun or a star is observed.

*a*. Instructions for the use of DA Forms 6–10 and 6–10a are on the back of the forms. The formulas used on these forms for the solution of a spherical triangle when two sides and the included angle are known are:

$$\tan \tfrac{1}{2}(A+q) = \frac{\cos \tfrac{1}{2}(\text{Lat}-\text{Dec}) \cot \tfrac{1}{2} t}{\sin \tfrac{1}{2}(\text{Lat}+\text{Dec})}$$

$$\tan \tfrac{1}{2}(A-q) = \frac{\sin \tfrac{1}{2}(\text{Lat}-\text{Dec}) \cot \tfrac{1}{2} t}{\cos \tfrac{1}{2}(\text{Lat}+\text{Dec})}$$

where A = astronomic azimuth of the sun (star) measured east or west of the observer's meridian;

q = parallactic angle (cancels out in computations);

Lat — latitude of the station;

Dec = declination of the star or apparent declination of the sun;

t = hour angle (less than $12^h$) of the sun (star).

Figure 132 shows a computation on DA Form 6–10 by the hour-angle method, using the sun and the sample field notes in figure 118. Figure 133 shows computations on DA Form 6–10a, using the star Deneb and the sample field notes in figure 119. To solve the formulas by use of DA Forms 6–10 and 6–10a, proceed as follows:

(1) Enter the station data. The same information is required as on DA Form 6–11 (para 312*a*(1)) except that the temperature is not required.

(2) From the field notebook, enter the following field data:

(*a*) *On line 1*, enter the mean watch time of observation.

(*b*) *On line 2*, enter the watch correction.

(*c*) *On line 40*, enter the mean horizontal angle measured from the azimuth mark to the sun (star).

(3) *Use lines 1 through 6* to compute the Greenwich mean time of observation. Use the same procedures as discussed in paragraph 312*a*(3). Note the value of line 5 and follow the rules at the bottom of the form. The Greenwich date is used to enter table 2 or table 10 of the Army Ephemeris.

(4) *Use lines 6 through 16* to determine the value of ½ t, or the hour angle of the sun (star). The procedure for

**COMPUTATION - ASTRONOMIC AZIMUTH BY HOUR - ANGLE METHOD, SUN** — TABLE NRS REFER TO TM 6-300-1965 — SUN

| LATITUDE OF STATION | LONGITUDE OF STATION | APRX AZ TO AZ MK | LOCAL DATE | AZIMUTH MARK | STATION |
|---|---|---|---|---|---|
| 34° 39′ 48″ N | 98° 24′ 18″ W | 4291 | 24 June 1965 | Water Tank | SD 260 |

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 1 | MEAN WATCH TIME OF OBSERVATION | 9h 26m 11s | 9h 29m 16s | 9h 32m 43s | 1 |
| 2 | WATCH CORRECTION (SLOW +, FAST −) | + 4 21 | + 4 21 | + 4 21 | 2 |
| 3 | ALGEBRAIC SUM (1) AND (2) | + 9 30 32 | + 9 33 37 | + 9 37 04 | 3 |
| 4 | TIME ZONE CORRECTION (W LONG +, E LONG −) | + 6 | + 6 | + 6 | 4 |
| 5 | ALGEBRAIC SUM (3) AND (4) | + 15 30 32 | + 15 33 37 | + 15 37 04 | 5 |
| | GREENWICH DATE* ______ 19__ | 24 00 00 | 24 00 00 | 24 00 00 | |
| 6 | GREENWICH MEAN TIME (GMT)* | 15 30 32 | 15 33 37 | 15 37 04 | 6 |
| 7 | EQUATION OF TIME AT 0h ON GREENWICH DATE (TABLE 3) | − 2 09 | − 2 09 | − 2 09 | 7 |
| 8 | ALGEBRAIC SUM (6) AND (7) | + 15 28 23 | + 15 31 28 | + 15 34 55 | 8 |
| 9 | EQUATION OF TIME AT GMT (TABLE 3) | − 08 | − 08 | − 08 | 9 |
| 10 | ALGEBRAIC SUM (8) AND (9) | + 15 28 15 | + 15 31 20 | + 15 34 47 | 10 |
| | IF (10) IS: (+) AND LESS THAN 12h: (11) IS (10) + 12h; (+) AND MORE THAN 12h: (10) − 12h; (−) | 12 00 00 | 12 00 00 | 12 00 00 | |
| 11 | ALGEBRAIC SUM (10) AND 12h | + 3 28 15 | + 3 31 20 | + 3 34 47 | 11 |
| 12 | (11) CONVERTED TO ARC [(5) OF CONV COMP ON REVERSE] | + 925 55 | + 939 26 | + 954 59 | 12 |
| 13 | LONGITUDE [(9) OF CONVERSION TO MILS COMP ON REVERSE IF USING MILS] (EAST +, WEST −) | − 1 749 43 | − 1 749 43 | − 1 749 43 | 13 |
| 14 | ALGEBRAIC SUM (12) AND (13) | − 823 88 | − 810 17 | − 794 84 | 14 |
| 15 | IF (14) IS: (−); 0° TO +180°; +180° TO 360°; MORE THAN 360° — (15) IS: REPEAT (14); REPEAT (14); 360° − (14), SIGN (−); (14) − 360°, SIGN (+) | − 823 88 | − 810 17 | − 794 84 | 15 |
| 16 | 1/2 OF (15) | − 411 94 | − 405 08 | − 397 42 | 16 |
| 17 | LATITUDE [(17) OF CONVERSION TO MILS COMP ON REVERSE IF USING MILS] (NORTH +, SOUTH −) | + 616 24 | + 616 24 | + 616 24 | 17 |
| 18 | APPARENT DECLINATION OF SUN [(14) OF AUX COMP ON REVERSE] | + 416 21 | + 416 21 | + 416 21 | 18 |
| 19 | ALGEBRAIC SUM (17) AND (18) | + 1 032 45 | + 1 032 45 | + 1 032 45 | 19 |
| 20 | 1/2 OF (19) | + 516 22 | + 516 22 | + 516 22 | 20 |

* IF (5) IS: (+) AND LESS THAN 24 HRS; (+) AND MORE THAN 24 HRS; (−) — GREENWICH DATE (6) IS: LOCAL DATE; LOCAL DATE + 1 DAY; LOCAL DATE − 1 DAY — AND GMT (6) IS: SAME AS (5); (5) − 24 HRS; 24 HRS − (5)

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 21 | REPEAT (17) | + 616 24 | + 616 24 | + 616 24 | 21 |
| 22 | REPEAT (18) WITH OPPOSITE SIGN | − 416 21 | − 416 21 | − 416 21 | 22 |
| 23 | ALGEBRAIC SUM (21) AND (22) | + 200 03 | + 200 03 | + 200 03 | 23 |
| 24 | 1/2 OF (23) | + 100 02 | + 100 02 | + 100 02 | 24 |
| 25 | LOG COS (24) | 9.997 9029 | 9.997 9029 | 9.997 9029 | 25 |
| 26 | LOG COT (16) | .368 5416 | .376 6797 | .385 9850 | 26 |
| 27 | (25) + (26) | 0.366 4445 | 0.374 5826 | 0.383 7979 | 27 |
| 28 | LOG SIN (20) | 9.686 0819 | 9.686 0819 | 9.686 0819 | 28 |
| 29 | (27) − (28) | 0.680 3626 | 0.688 5007 | 0.697 7160 | 29 |
| 30 | ANGLE HAVING LOG TAN (29) | 1 390 37 | 1 394 16 | 1 398 37 | 30 |
| 31 | LOG SIN (24) | 8.991 3886 | 8.991 3886 | 8.991 3886 | 31 |
| 32 | REPEAT (26) | .368 5416 | .376 6797 | .385 8950 | 32 |
| 33 | (31) + (32) | 9.359 9302 | 9.368 0683 | 9.377 2836 | 33 |
| 34 | LOG COS (20) | 9.941 6621 | 9.941 6621 | 9.941 6621 | 34 |
| 35 | (33) − (34) | 9.418 2681 | 9.426 4062 | 9.435 6215 | 35 |
| 36 | ANGLE HAVING LOG TAN (35) | 260 99 | 265 70 | 271 14 | 36 |
| 37 | REPEAT (30) | 1 390 37 | 1 394 16 | 1 398 37 | 37 |
| 38 | IF (20) AND (24) HAVE SAME SIGNS, USE (36) + (37); IF (20) AND (24) HAVE OPPOSITE SIGNS, SUBTRACT SMALLER (36) OR (37), FROM LARGER, (37) OR (36) | 1 651 36 | 1 659 86 | 1 669 51 | 38 |
| | WHEN STATION IS IN NORTH LATITUDE: IF (11) IS (+): 360° (6400 mils) − (38); (−): REPEAT (38). SOUTH LATITUDE: IF (11) IS (+): 180° (3200 mils) + (38); (−): 180° (3200 mils) − (38) | 6 400 00 | 6 400 00 | 6 400 00 | |
| 39 | | 8 051 36 | 8 059 86 | 8 069 51 | 39 |
| 40 | MEAN HORIZONTAL ANGLE | 3 759 59 | 3 767 96 | 3 777 58 | 40 |
| 41 | (39) − (40) = ASTRONOMIC AZIMUTH TO MARK | 4 291 77 | 4 291 90 | 4 291 93 | 41 |

DATE — AREA — NOTEBOOK REFERENCE

COMPUTER — CHECKER — SHEET ___ OF ___ SHEETS

DA FORM 6-10, 1 JAN 56 — PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

*Figure 132. DA Form 6–10 showing computations by the hour-angle method, using the sun.*

## CONVERSION COMPUTATION (TABLE 5)

HOURS, MINUTES AND SECONDS (TIME) TO DEGREES, MINUTES AND SECONDS OR MILS (ARC)

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 1 | (1) OF COMPUTATION | 3 h 28 m 15 s | 3 h 31 m 20 s | 3 h 34 m 47 s | 1 |
| 2 | DEGREES OR MILS IN HOURS OF (1) | 800 00 | 800 00 | 800 00 | 2 |
| 3 | DEGREES AND MINUTES OR MILS IN MINUTES OF (1) | 124 44 | 137 78 | 151 11 | 3 |
| 4 | MINUTES AND SECONDS OR MILS IN SECONDS OF (1) | 1 11 | 1 48 | 3 48 | 4 |
| 5 | (2)+(3)+(4) [ENTER IN (12) ON FRONT] | 925 55 | 939 26 | 954 59 | 5 |

## CONVERSION TO MILS COMPUTATION (USE TABLE III b OF TM 6-230)

| | | | | | |
|---|---|---|---|---|---|
| 1 | LONGITUDE [FROM FRONT OF FORM] | 98° 24′ 18″ | 10 | LATITUDE [FROM FRONT OF FORM] | 34° 39′ 48″ |
| 2 | ₥ IN HUNDREDS OF DEGREES OF (1) | . | 11 | ₥ IN TENS OF DEGREES OF (10) | 5 33 . 33 |
| 3 | ₥ IN TENS OF DEGREES OF (1) | 16 00 . 00 | 12 | ₥ IN UNITS OF DEGREES OF (10) | 71 . 11 |
| 4 | ₥ IN UNITS OF DEGREES OF (1) | 1 42 . 22 | 13 | ₥ IN TENS OF MINUTES OF (10) | 8 . 89 |
| 5 | ₥ IN TENS OF MINUTES OF (1) | 5 . 93 | 14 | ₥ IN UNITS OF MINUTES OF (10) | 2 . 67 |
| 6 | ₥ IN UNITS OF MINUTES OF (1) | 1 . 19 | 15 | ₥ IN TENS OF SECONDS OF (10) | . 20 |
| 7 | ₥ IN TENS OF SECONDS OF (1) | . 5 | 16 | ₥ IN UNITS OF SECONDS OF (10) | . 4 |
| 8 | ₥ IN UNITS OF SECONDS OF (1) | . 4 | 17 | SUM OF (11) THROUGH (16) [ENTER IN (17) ON FRONT AND ON DA FORM 6-20] | 6 16 . 24 |
| 9 | SUM OF (2) THROUGH (8) [ENTER IN (12) ON FRONT AND ON DA FORM 6-20] | 17 49 . 43 | | | |

## AUXILIARY COMPUTATION FOR APPARENT DECLINATION OF SUN AT GREENWICH DATE AND GMT

| | | SET NR 1 | | SET NR 2 | | SET NR 3 | | |
|---|---|---|---|---|---|---|---|---|
| 1 | GREENWICH DATE [(6) OF COMPUTATION] | 24 June 64 | | 24 June 65 | | 24 June 65 | | 1 |
| | | HRS | MIN | HRS | MIN | HRS | MIN | |
| 2 | GMT [HOURS AND MINUTES IN (4) OF COMPUTATION] | 15 | 31 | 15 | 34 | 15 | 37 | 2 |
| | | X60 | | X60 | | X60 | | |
| 3 | NUMBERS OF HOURS IN (2) X 60 | 900 | | 900 | | 900 | | 3 |
| 4 | NUMBER OF MINUTES IN (2) | 31 | | 34 | | 37 | | 4 |
| 5 | (3)+(4) | 931 | | 934 | | 937 | | 5 |
| 6 | DAILY CHANGE IN DECLINATION (TABLE 2) | − 0 . 35 | | − 0 . 35 | | − 0 . 35 | | 6 |
| 7 | LOG OF (5) | 2.968 | 9497 | 2.970 | 3469 | 2.971 | 7396 | 7 |
| 8 | LOG OF (6) | 9.544 | 0680 | 9.544 | 0680 | 9.544 | 0680 | 8 |
| 9 | LOG OF CONSTANT | 6.841 | 6375 | 6.841 | 6375 | 6.841 | 6375 | 9 |
| 10 | (7)+(8)+(9) | 9.354 | 6552 | 9.355 | 0524 | 9.357 | 4451 | 10 |
| 11 | NUMBER HAVING LOG (10) = SECONDS OR MILS OF CHANGE | . 23 | | . 23 | | . 23 | | 11 |
| 12 | APPARENT DECLINATION AT 0h ON GREENWICH DATE (TABLE 2) | + 4 16 44 | | + 4 16 44 | | + 4 16 44 | | 12 |
| 13 | (11) CONVERTED TO MINUTES AND SECONDS OR (11) IN MILS [USE SIGN OF (6)] | − 23 | | − 23 | | − 23 | | 13 |
| 14 | ALGEBRAIC SUM (12) AND (13) ENTER IN (18) ON FRONT | + 4 16 21 | | + 4 16 21 | | + 4 16 21 | | 14 |

GIVEN:
Time zone of area of operation.

FIELD DATA:
Latitude and longitude of station.
Approximate azimuth to azimuth mark.
Local date of observation.
Mean watch time of observation and watch correction to nearest second.
Horizontal clockwise angle from azimuth mark to sun.

GUIDE:
Enter observed field data in block marked.
When using a mil-graduated instrument, --

a. (2) through (5) of CONVERSION COMPUTATION are computed using hundredth-mil values.
b. (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.
c. (12) through (24) of computation are computed using hundredth-mil values.
d. (6) through (14) of AUXILIARY COMPUTATION are computed using hundredth-mil values.
e. (25) through (41) of computation are computed using tenth-mil values.

Value in (41) should be about equal to approximate azimuth to azimuth mark.
Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:
This form is not to be used when accuracies greater than fourth-order are required.
The hour-angle method should not be used when the sun is more than 60 degrees above horizon.

RESULTS:
A value of astronomic azimuth for each set of observations.

FORMULAS:

$$\tan 1/2\,(A+q) = \frac{\cos 1/2\,(\text{Lat}-\text{Dec})}{\sin 1/2\,(\text{Lat}+\text{Dec})}\ \cot 1/2\ t$$

$$\tan 1/2\,(A-q) = \frac{\sin 1/2\,(\text{Lat}-\text{Dec})}{\cos 1/2\,(\text{Lat}+\text{Dec})}\ \cot 1/2\ t$$

A = astonomic azimuth of sun measured east or west of meridian.

q = parallactic angle (cancels in computations).

Lat = latitude of station.

Dec = apparent declination of sun.

t = hour angle (less than $12^h$) of sun.

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*Figure 132*—Continued.

## CONVERSION COMPUTATION (TABLE 5)

### HOURS, MINUTES AND SECONDS (TIME) TO DEGREES, MINUTES AND SECONDS OR MILS (ARC)

| | | SET NR 1 | SET NR 2 | SET NR 3 | |
|---|---|---|---|---|---|
| 1 | (11) OF COMPUTATION | 2 h 48 m 02 s | 2 h 50 m 56 s | 2 h 54 m 49 s | 1 |
| 2 | DEGREES OR MILS IN HOURS OF (1) | 533 33 | 533 33 | 533 33 | 2 |
| 3 | DEGREES AND MINUTES OR MILS IN MINUTES OF (1) | 213 33 | 222 22 | 240 00 | 3 |
| 4 | MINUTES AND SECONDS OR MILS IN SECONDS OF (1) | 15 | 4 15 | 3 63 | 4 |
| 5 | (2)+(3)+(4) [ENTER IN (12) ON FRONT] | 746 81 | 759 70 | 776 96 | 5 |

### CONVERSION TO MILS COMPUTATION (USE TABLE III b OF TM 6-230)

| | | | | | |
|---|---|---|---|---|---|
| 1 | LONGITUDE [FROM FRONT OF FORM] | 98° 24′ 18″ | 10 | LATITUDE [FROM FRONT OF FORM] | 34° 39′ 48″ |
| 2 | m̸ IN HUNDREDS OF DEGREES OF (1) | . | 11 | m̸ IN TENS OF DEGREES OF (10) | 5 33 . 33 |
| 3 | m̸ IN TENS OF DEGREES OF (1) | 16 00 .00 | 12 | m̸ IN UNITS OF DEGREES OF (10) | 71 . 11 |
| 4 | m̸ IN UNITS OF DEGREES OF (1) | 1 42 .22 | 13 | m̸ IN TENS OF MINUTES OF (10) | 8 . 89 |
| 5 | m̸ IN TENS OF MINUTES OF (1) | 5 .93 | 14 | m̸ IN UNITS OF MINUTES OF (10) | 2 . 67 |
| 6 | m̸ IN UNITS OF MINUTES OF (1) | 1 .19 | 15 | m̸ IN TENS OF SECONDS OF (10) | . 20 |
| 7 | m̸ IN TENS OF SECONDS OF (1) | .05 | 16 | m̸ IN UNITS OF SECONDS OF (10) | . 04 |
| 8 | m̸ IN UNITS OF SECONDS OF (1) | .04 | 17 | SUM OF (11) THROUGH (16) [ENTER IN (17) ON FRONT AND ON DA FORM 6-20] | 6 16 . 24 |
| 9 | SUM OF (2) THROUGH (8) [ENTER IN (13) ON FRONT AND ON DA FORM 6-20] | 17 49 .43 | | | |

GIVEN:
Time zone of area of operation.

FIELD DATA:
Latitude and longitude of station.
Approximate azimuth to azimuth mark.
Name(s) and number(s) of selected star(s).
Local date of observation.
Mean watch time of observation and watch correction to nearest second.
Horizontal clockwise angle from azimuth mark to star.

GUIDE:
Enter observed field data in block marked. [ ]
When using a mil-graduated instrument,--

a. (2) through (5) of CONVERSION COMPUTATION are computed using hundredth-mil values.
b. (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.
c. (12) through (24) of computation are computed using hundredth-mil values.
d. (25) through (41) of computation are computed using tenth-mil values.

Value in (41) should be about equal to approximate azimuth to azimuth mark.
Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:
This form should not be used when accuracies greater than fourth-order are required.
The hour-angle method should not be used when the star is more than 60 degrees above horizon.

RESULTS:
A value of astronomic azimuth for each set of observations.

FORMULAS:

$$\tan 1/2\,(A+q) = \frac{\cos 1/2\,(Lat-Dec)}{\sin 1/2\,(Lat+Dec)} \cot 1/2\,t$$

$$\tan 1/2\,(A-q) = \frac{\sin 1/2\,(Lat-Dec)}{\cos 1/2\,(Lat+Dec)} \cot 1/2\,t$$

A = astronomic azimuth of star measured east or west of meridian.

q = parallactic angle (cancels in computations).

Lat = latitude of station.

Dec = declination of star.

t = hour angle (less than $12^h$) of star.

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*Figure 133. DA Form 6–10a showing computations by the hour-angle method, using the star Deneb.*

COMPUTATION - ASTRONOMIC AZIMUTH BY HOUR - ANGLE METHOD, STAR — TABLE NRS REFER TO TM 6-300 - 19 65

STAR NAME AND NR (TABLE 9): Deneb 68

LATITUDE OF STATION: 34° 39' 48" N | LONGITUDE OF STATION: 98° 24' 18" W | APRX AZ TO AZ MK: 4291 | LOCAL DATE: 24 June 1965 | AZIMUTH MARK: Water Tank | STATION: SD 260

| Nr | | SET NR 1 | SET NR 2 | SET NR 3 | Nr |
|---|---|---|---|---|---|
| 1 | MEAN WATCH TIME OF OBSERVATION | 23h 11m 17s | 23 14 11 | 23 18 04 | 1 |
| 2 | WATCH CORRECTION (SLOW +, FAST −) | + 4 28 | + 4 28 | + 4 28 | 2 |
| 3 | ALGEBRAIC SUM (1) AND (2) | + 23 15 45 | + 23 18 39 | + 23 22 32 | 3 |
| 4 | TIME ZONE CORRECTION (W LONG +) | + 6 | + 6 | + 6 | 4 |
| 5 | ALGEBRAIC SUM (3) AND (4) | + 29 15 45 | + 29 18 39 | + 29 22 32 | 5 |
| | GREENWICH DATE* 25 June 1965 | 24 00 00 | 24 00 00 | 24 00 00 | |
| 6 | GREENWICH MEAN TIME (GMT)* | 5 15 45 | 5 18 39 | 5 22 32 | 6 |
| 7 | SIDEREAL TIME AT 0h ON GREENWICH DATE (TABLE 3) | 18 11 41 | 18 11 41 | 18 11 41 | 7 |
| 8 | CORRECTION TO (7) (TABLE 4) | 52 | 52 | 52 | 8 |
| | (6)+(7)+(8) [IF LESS THAN (10), ADD 24 HRS] | 23 28 18 | 23 31 12 | 23 35 05 | |
| | | 24 00 00 | 24 00 00 | 24 00 00 | |
| 9 | | 23 28 18 | 23 31 12 | 23 35 05 | 9 |
| 10 | RIGHT ASCENSION OF STAR (TABLE 10, 10-MILS, OR 11) | 20 40 16 | 20 40 16 | 20 40 16 | 10 |
| 11 | (9) − (10) | 2 48 02 | 2 50 56 | 2 54 49 | 11 |
| 12 | (11) CONVERTED TO ARC [(S) OF CONV COMP ON REVERSE] | 746 81 | 759 70 | 776 96 | 12 |
| 13 | LONGITUDE (P) OF CONVERSION TO MILS, COMP ON REVERSE IF USING MILS (EAST +, WEST −) | − 1 749 43 | − 1 749 43 | − 1 749 43 | 13 |
| 14 | ALGEBRAIC SUM (12) AND (13) | − 1 002 62 | − 989 73 | − 972 47 | 14 |
| | IF (14) IS: (−); 0° TO +180°; +180° TO 360°; MORE THAN 360° — (15) IS: REPEAT (14); REPEAT (14); 360° − (14), SIGN (−); (14) − 360°, SIGN (+) | | | | |
| 15 | | − 1 002 62 | − 989 73 | − 972 47 | 15 |
| 16 | 1/2 OF (15) | − 501 31 | − 494 86 | − 486 24 | 16 |
| 17 | LATITUDE (17) OF CONVERSION TO MILS, COMP ON REVERSE IF USING MILS (NORTH +, SOUTH −) | + 616 24 | + 616 24 | + 616 24 | 17 |
| 18 | DECLINATION OF STAR ON GREENWICH DATE (TABLE 10, 10-MILS, OR 11) | + 802 71 | + 802 71 | + 802 71 | 18 |
| 19 | ALGEBRAIC SUM (17) AND (18) | + 1 418 95 | + 1 418 95 | + 1 418 95 | 19 |
| 20 | 1/2 OF (19) | + 709 48 | + 709 48 | + 709 48 | 20 |

* IF (5) IS: (+) AND LESS THAN 24 HRS; (+) AND MORE THAN 24 HRS; (−) — GREENWICH DATE (6) IS: LOCAL DATE; LOCAL DATE +1 DAY; LOCAL DATE −1 DAY — AND GMT (6) IS: SAME AS (5); (5) − 24 HRS; 24 HRS − (5)

| Nr | | SET NR 1 | SET NR 2 | SET NR 3 | Nr |
|---|---|---|---|---|---|
| 21 | REPEAT (17) | + 616 24 | + 616 24 | + 616 24 | 21 |
| 22 | REPEAT (18) WITH OPPOSITE SIGN | − 802 71 | − 802 71 | − 802 71 | 22 |
| 23 | ALGEBRAIC SUM (21) AND (22) | − 186 47 | − 186 47 | − 186 47 | 23 |
| 24 | 1/2 OF (23) | − 93 24 | − 93 24 | − 93 24 | 24 |
| 25 | LOG COS (24) | 9.998 1779 | 9.998 1779 | 9.998 1779 | 25 |
| 26 | LOG COT (16) | 270 7009 | 277 3326 | 286 2859 | 26 |
| 27 | (25)+(26) | 0.268 8788 | 0.275 5105 | 0.284 4638 | 27 |
| 28 | LOG SIN (20) | 9.807 2373 | 9.807 2373 | 9.807 2373 | 28 |
| 29 | (27)−(28) | 0.461 6415 | 0.468 2732 | 0.477 2265 | 29 |
| 30 | ANGLE HAVING LOG TAN (29) | 1 261 22 | 1 265 99 | 1 272 34 | 30 |
| 31 | LOG SIN (24) | 8.960 9955 | 8.960 9955 | 8.960 9955 | 31 |
| 32 | REPEAT (26) | 270 7009 | 277 3326 | 286 2859 | 32 |
| 33 | (31)+(32) | 9.231 6964 | 9.238 3281 | 9.247 2814 | 33 |
| 34 | LOG COS (20) | 9.884 8366 | 9.884 8366 | 9.884 8366 | 34 |
| 35 | (33)−(34) | 9.346 8598 | 9.353 4915 | 9.362 4448 | 35 |
| 36 | ANGLE HAVING LOG TAN (35) | 222 77 | 226 09 | 230 64 | 36 |
| 37 | REPEAT (30) | 1 261 22 | 1 265 99 | 1 272 34 | 37 |
| | IF (20) AND (24) HAVE SAME SIGNS, USE (36)+(37) | 222 77 | 226 09 | 230 64 | |
| 38 | IF (20) AND (24) HAVE OPPOSITE SIGNS, SUBTRACT SMALLER, (36) OR (37), FROM LARGER, (37) OR (36) | 1 038 45 | 1 039 90 | 1 041 70 | 38 |
| | WHEN STATION IS IN NORTH LATITUDE: IF (15) IS (+), (M) IS (360° or 6400 mils) − (38); (−), REPEAT (38). SOUTH LATITUDE: IF (15) IS (+), (M) IS (180° or 3200 mils) + (38); (−), (180° or 3200 mils) − (38) | | | | |
| 39 | | 7 438 45 | 7 439 90 | 7 441 70 | 39 |
| 40 | MEAN HORIZONTAL ANGLE | 3 146 84 | 3 148 25 | 3 149 97 | 40 |
| 41 | (39) − (40) = ASTRONOMIC AZIMUTH TO MARK | 4 291 61 | 4 291 65 | 4 291 73 | 41 |

COMPUTER | CHECKER | SHEET OF SHEETS | NOTEBOOK REFERENCE | DATE | AREA

DA FORM 6-10a, 1 JAN 56 — REPLACES EDITION OF 1 SEP 53, WHICH IS OBSOLETE

Figure 133—Continued.

determining this value depends on the celestial body observed, hence the differences in DA Form 6–10 and DA Form 6–10a. The procedure on both forms starts with the value of GMT and evolves to the local hour angle (LHA).

(*a*) To determine the hour angle of the sun on DA Form 6–10, proceed as follows:

*1. On line 7*, enter the equation of time at $0^h$ which is extracted from the Army Ephemeris by using the Greenwich date (line 6).

*2. On line 8*, algebraically add lines 6 and 7.

*3. On line 9*, enter the correction to the equation of time at GMT. The correction is read from table 2, using the daily change from table 2 and the GMT.

*4. On line 10*, algebraically add lines 8 and 9. This value is the Greenwich apparent time (GAT).

*5. On line 11*, change GAT to Greenwich hour angle (GHA) by adding or subtracting 12 hours. The final total must be less than 12 hours after the longitude correction is applied.

*6. On line 12*, convert GHA to mils of arc. Perform the conversion computation on the back of the form.

*7. On line 13*, convert longitude which is expressed in degrees, to mils. Perform the conversion computation on the back of the form.

*8. On line 14*, algebraically add lines 12 and 13. This value is the local hour angle of the sun. It must be less than 3,200 mils.

(*b*) To determine the hour angle of a star on DA Form 6–10a, proceed as follows:

*1. On line 7*, enter the sidereal time value for $0^h$ which is extracted from table 2 of the Army Ephemeris by using the Greenwich date (line 6).

*2. On line 8*, enter the correction to the sidereal time for a partial day. The correction is extracted from table 4 of the Army Ephemeris using GMT as an argument.

*3. On line 9*, add lines 6, 7, and 8. This value is Greenwich sidereal time.

*4. On line 10*, enter the right ascension which is extracted from table 10 or 11 of the Army Ephemeris, using the star number and Greenwich date.

*5. On line 11*, subtract line 10 from line 9. This value is the Greenwich hour angle.

*6. On line 12*, convert GHA to mils of arc. Perform the computation on the back of the form.

*7. On line 13*, convert longitude to mils. Perform the computation on the back of the form.

*8. On line 14*, algebraically add lines 12 and 13. This value is the local hour angle of the star. It must be less than 3,200 mils.

(5) *On line 17*, enter the value of the latitude of the station in mils. To convert the latitude from degrees to mils, perform an auxiliary computation on the back of the form.

(6) *On line 18*, enter the value of the declination of the star or sun. Declination of a star is extracted from table 10 or 11 in the Army Ephemeris. Apparent declination of the sun is computed on the back of DA Form 6–10 by using table 2 in the Army Ephemeris.

(7) *Use lines 19 and 20* to determine the value of ½ (Lat+Dec) by adding lines 17 and 18 and dividing the sum by 2.

(8) *Use lines 21 through 24* to determine the value of ½ (Lat—Dec) by subtracting line 22 from line 21 and dividing the result by 2.

(9) *Use lines 25 through 30* to solve, with the use of logarithms, the value of the angle ½ (A+q).

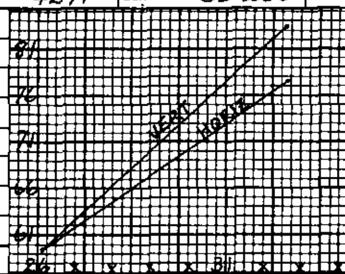
(10) *Use lines 31 through 36* to solve, with the use of logarithms, the value of the angle ½ (A—q).

FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION

STAR NAME AND NUMBER: SUN

| LOCAL DATE | AZIMUTH MARK | APPROX. AZ TO AZ MK | STATION | TEMP |
|---|---|---|---|---|
| 24 JUN 65 | WT | 4291 | SD 260 | 110 °F |

| FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|
| SET NO. 1 | 09 26 11 | 3759 6 | + 859 5 |
| SET NO. 2 | 09 29 16 | 3768 0 | + 870 8 |
| SET NO. 3 | 09 32 43 | 3777 6 | + 883 3 |
| SET NO. | | | |
| SET NO. | | | |
| SET NO. | | | |
| SUM | 28 28 10 | 11305 2 | 2613 6 |
| 1 MEAN | 09 29 23 | 3768 4 | 871 2 |



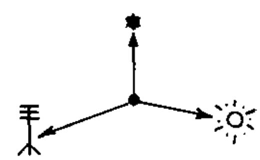

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | WATCH CORR. SLOW + FAST - | + 24 4 21 | | LATTITUDE N S | 34° 39' 48" | 34 | REFRACTION (TABLE 1) | − |
| 3 | TIME ZONE CORR. W LONG + E LONG - | + 6 00 00 | 19 | MILS IN TENS OF DEGREES | 533 33 | 35 | PARALLAX 0.04₥ -SUN ONLY or 7 sec | + |
| 4 | (1)+(2)+(3)=GMT* DATE 24 JUN | + 15 33 44 | 20 | MILS IN UNITS OF DEGREES | 71 11 | 36 | (1)+(34)+(35)=h | |
| 5 | EQ OF T: AT 0h ON GW DATE (TABLE 2) | − 2 09 | 21 | MILS IN TENS OF MINUTES | 8 89 | 37 | NO. OF HRS IN GMT (4) x 60 | 900 00 |
| 6 | EQ OF T: AT GMT (TABLE 3) | − 8 | 22 | MILS IN UNITS OF MINUTES | 2 67 | 38 | NO. OF MIN IN GMT (4) | 33 00 |
| 7 | (4)+(5)+(6) = GAT | + 15 31 27 | 23 | MILS IN TENS OF SECONDS | 20 | 39 | (37) + (38) | 933 00 |
| 8 | ** = GHA | + 3 31 27 | 24 | MILS IN UNITS OF SECONDS | 04 | 40 | DAILY CHANGE IN DECLINATION (TABLE 2) | − 35 |
| 9 | SID TIME AT 0h ON GW DATE (TBL 2) | + | 25 | LAT IN MILS SUM (19) THRU (24) | 616 24 | 41 | LOG (39) | 2 969882 |
| 10 | CORRECTION TO (9) (TABLE 4) | + | | LONGITUDE E W | 98° 24' 18" | 42 | LOG (40) | 9 544068 |
| 11 | * * * | + - | 26 | MILS IN HUNDREDS OF DEGREES | | 43 | LOG CONSTANT | 6 841638 |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | + - | 27 | MILS IN TENS OF DEGREES | 1600 00 | 44 | (41)+(42)+(43) | 9 355588 |
| 13 | HRS OF GHA(8) OR (12) IN MILS (TBL 5) | + 800 00 | 28 | MILS IN UNITS OF DEGREES | 142 22 | 45 | ANTILOG (44) USE SIGN (40) | − 23 |
| 14 | MIN OF GHA IN MILS | + 137 78 | 29 | MILS IN TENS OF MINUTES | 5 93 | 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | + 416 44 |
| 15 | SEC OF GHA IN MILS | + 2 00 | 30 | MILS IN UNITS OF MINUTES | 1 19 | 47 | (45)+(46)=APP DEC OF SUN OR DEC OF STAR (TABLE 10) | + 416 21 |
| 16 | LONGITUDE EAST + IN MILS (33) WEST - | − 1749 43 | 31 | MILS IN TENS OF SECONDS | 05 | | | |
| 17 | (13)+(14)+(15)+(16) = LHA | − 809 65 | 32 | MILS IN UNITS OF SECONDS | 04 | | | |
| 18 | **** = t | − 809 65 | 33 | LONG IN MILS SUM (26) THRU (32) | 1749 43 | | | |

| IF (1)+(2)+(3) IS: | +24 IS: | GW DATE IS: |
|---|---|---|
| (+) & LESS THAN 24h | NOT REQD | LOCAL DATE |
| (+) & MORE THAN 24h | (-) | LOCAL DATE +1 |
| (-) | (+) | LOCAL DATE -1 |

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES ÷ 15 W/SIGN (-) IF LONGITUDE WEST (+) IF EAST

| ** IF (7) IS: | (8) IS: |
|---|---|
| (-) OR (+) AND LESS THAN 12h | (7) + 12h |
| + AND MORE THAN 12h | (7) - 12h |

| **** (IF (17) IS: | (18) IS: |
|---|---|
| (-) OR 0 TO 3200₥ | REPEAT (17) |
| 3200₥ TO 6400₥ | 6400₥ - (17) SIGN (-) |
| MORE THAN 6400₥ | (17)-6400₥ SIGN (+) |



## HOUR ANGLE METHOD

| | | |
|---|---|---|
| 48 | 1/2 (18) | − 404 82 |
| 49 | 1/2 (25) NORTH + SOUTH - | + 308 12 |
| 50 | 1/2 (47) | + 208 10 |
| 51 | (49) + (50) | + 516 22 |
| 52 | (49) - (50) | + 100 02 |
| 53 | COLOG SIN (51) | 0 313934 |
| 54 | LOG COS (52) | 9 997904 |
| 55 | LOG COT (48) | 0 377014 |
| 56 | (53) + (54) + (55) | 0 688852 |
| 57 | COLOG COS (51) | 0 058333 |
| 58 | LOG SIN (52) | 8 991302 |
| 59 | REPEAT (55) | 0 377014 |
| 60 | (57)+(58)+(59) | 9 426649 |
| 61 | ANTILOG TAN (60) USE SIGN (51) | + 265 8 |
| 62 | ANTILOG TAN (56) USE SIGN (52) | + 1394 3 |
| 63 | (61)+(62) = A ENTER IN (95) | + 1660 1 |

## ALTITUDE METHOD

| | | |
|---|---|---|
| 64 | 1600-00 MILS | |
| 65 | (47) W/SIGN REVERSED | + - |
| 66 | (64) + (65) = P | + |
| 67 | REPEAT (36) | |
| 68 | REPEAT (25) NORTH+ SOUTH- | + - |
| 69 | (66)+(67)+(68) | + - |
| 70 | 1/2 (69) = S | + - |
| 71 | (70) - (66) | + |
| 72 | COLOG COS (67) | |
| 73 | COLOG COS (68) | |
| 74 | LOG COS (70) | |
| 75 | LOG COS (71) | |
| 76 | (72)+(73)+(74)+(75) | |
| 77 | 1/2 (76) | |
| 78 | ANTILOG COS (77) | |
| 79 | 2 x (78) = A ENTER IN (95) | |

## ALTITUDE-HOUR ANGLE METHOD

| | | |
|---|---|---|
| 80 | LOG SIN (18) | |
| 81 | LOG COS (47) | |
| 82 | COLOG COS (36) | |
| 83 | (80)+(81)+(82) | |
| 84 | ANTILOG SIN (83) = B | |
| 85 | *****A ENTER IN (95) | |

POLARIS TABULAR METHOD

| | | |
|---|---|---|
| 86 | $P_0$ VALUES OBTAINED | |
| 87 | $P_1$ FROM TABLE 12 | |
| 88 | $P_2$ USING LST(12) | |
| 89 | (86)+(87)+(88) | |
| 90 | LOG (89) | |
| 91 | LOG FACTOR | 9 471 7 |
| 92 | COLOG COS (25) | |
| 93 | (90)+(91)+(92) | |
| 94 | ANTILOG (93) = A ENTER IN (95) | |

COMPUTER: Klein

CHECKER: Blair

***** (84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A

******
AZ TO STAR = A WHEN STAR IS IN EAST
AZ = 6400 - A WHEN STAR IS IN WEST
ADD 6400 IF (95) IS LESS THAN (96)

AZIMUTH TO AZIMUTH MARK

| | | |
|---|---|---|
| 95 | A ****** | 8060 1 |
| 96 | MEAN HORIZONTAL ANGLE (1) | 3768 4 |
| 97 | (95)-(96)=AZ TO AZ MK | 4291 7 |

DA FORM 2973, 1 May 65

*Figure 134. DA Form 2973 showing computations by the hour-angle method, using the sun.*

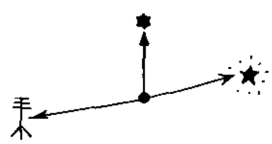
FIFTH ORDER ASTRONOMIC AZIMUTH COMPUTATION

STAR NAME DENEB AND NUMBER 68

| LOCAL DATE 24 JUN 65 | AZIMUTH MARK WT | APPROX. AZ TO AZ MK 4291 | STATION SD 260 | TEMP 83 °F |
|---|---|---|---|---|

| FIELD DATA | WATCH TIME OF OBSERV | HORIZONTAL ANGLE | VERTICAL ANGLE |
|---|---|---|---|
| SET NO. 1 | 23 11 17 | 3146 8 | + 825 4 |
| SET NO. 2 | 23 14 11 | 3148 2 | + 834 3 |
| SET NO. 3 | 23 18 04 | 3150 0 | + 846 4 |
| SET NO. | | | |
| SET NO. | | | |
| SET NO. | | | |
| SUM | 69 43 32 | 9445 0 | 2506 1 |
| 1 MEAN | 23 14 31 | 3148 3 | 835 4 |


| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | WATCH CORR. SLOW + FAST - | ⊕ 24 04 28 | | LATITUDE (N) S | 34 39 48 | 34 | REFRACTION (TABLE 1) | - | |
| 3 | TIME ZONE CORR. W LONG+ E LONG- | ⊕ 6 00 00 | 19 | MILS IN TENS OF DEGREES | 533 33 | 35 | PARALLAX 0.04 - SUN ONLY or 7 sec | + | |
| 4 | (1)+(2)+(3)=GMT* DATE 25 JUN 65 | + 5 18 59 | 20 | MILS IN UNITS OF DEGREES | 71 11 | 36 | (1)+(34)+(35)=h | | |
| 5 | EQ OF T: AT 0h ON GW DATE(TABLE 2) | + - | 21 | MILS IN TENS OF MINUTES | 8 89 | 37 | NO. OF HRS IN GMT (4) x 60 | | |
| 6 | EQ OF T: AT GMT (TABLE 3) | + - | 22 | MILS IN UNITS OF MINUTES | 2 67 | 38 | NO. OF MIN IN GMT (4) | | |
| 7 | (4)+(5)+(6) = GAT | + - | 23 | MILS IN TENS OF SECONDS | 20 | 39 | (37) + (38) | | |
| 8 | ** = GHA | + - | 24 | MILS IN UNITS OF SECONDS | 04 | 40 | DAILY CHANGE IN DECLINATION(TABLE 2) | + - | |
| 9 | SID TIME AT 0h ON GW DATE(TBL 2) | ⊕ 18 11 41 | 25 | LAT IN MILS SUM (19) THRU(24) | 616 24 | 41 | LOG (39) | | |
| 10 | CORRECTION TO (9) (TABLE 4) | + 52 | | LONGITUDE (W) E | 98 24 18 | 42 | LOG (40) | | |
| 11 | * * * | ⊕ 20 40 16 | 26 | MILS IN HUNDREDS OF DEGREES | | 43 | LOG CONSTANT | 6 | 841638 |
| 12 | (4)+(9)+(10)+(11) = GHA OR LST | ⊕ 2 51 16 | 27 | MILS IN TENS OF DEGREES | 1600 00 | 44 | (41)+(42)+(43) | | |
| 13 | HRS OF GHA(8)OR (12)IN MILS(TBL 5) | ⊕ 533 33 | 28 | MILS IN UNITS OF DEGREES | 142 22 | 45 | ANTILOG (44) USE SIGN (40) | + - | |
| 14 | MIN OF GHA IN MILS | ⊕ 226 67 | 29 | MILS IN TENS OF MINUTES | 5 93 | 46 | APP DEC AT 0h ON GW DATE (TABLE 2) | + - | |
| 15 | SEC OF GHA IN MILS | ⊕ 1 19 | 30 | MILS IN UNITS OF MINUTES | 1 19 | 47 | (45)+(46)=APP DEC OF SUN OR DEC OF STAR (TABLE 10) | ⊕ | 802 71 |
| 16 | LONGITUDE EAST + IN MILS(33)WEST - | ⊖ 1749 43 | 31 | MILS IN TENS OF SECONDS | 05 | | | | |
| 17 | (13)+(14)+(15)+(16) = LHA | ⊖ 988 24 | 32 | MILS IN UNITS OF SECONDS | 04 | | | | |
| 18 | **** = t | ⊖ 988 24 | 33 | LONG IN MILS SUM (26) THRU (32) | 1749 43 | | | | |



* IF (1)+(2)+(3) IS: +24 IS: GW DATE IS: (+)LESS THAN 24h NOT REQD LOCAL DATE (+)MORE THAN 24h (-) LOCAL DATE +1 (-) (+) LOCAL DATE -1

*** FOR HOUR ANGLE METHOD USE RIGHT ASCENSION W/SIGN REVERSED. FOR POLARIS TABULAR METHOD USE LONGITUDE IN DEGREES ÷ 15 W/SIGN(-)IF LONGITUDE WEST(+) IF EAST

** IF (7) IS: (8) IS: (-)OR(+) AND LESS THAN 12h (7) + 12h; + AND MORE THAN 12h (7) - 12h

**** (IF (17) IS: (18) IS: (-)OR 0 TO 3200 REPEAT (17); 3200 TO 6400 6400 - (17) SIGN (-); MORE THAN 6400 (17)-6400 SIGN (+)

| HOUR ANGLE METHOD | | | ALTITUDE METHOD | | | ALTITUDE-HOUR ANGLE METHOD | | |
|---|---|---|---|---|---|---|---|---|
| 48 | 1/2 (18) | ⊖ 494 12 | 64 | 1600-00 MILS | | 80 | LOG SIN (18) | |
| 49 | 1/2 (25) NORTH + SOUTH - | ⊕ 308 12 | 65 | (47) W/SIGN REVERSED | + - | 81 | LOG COS (47) | |
| 50 | 1/2 (47) | ⊕ 401 36 | 66 | (64) + (65) = P | + | 82 | COLOG COS (36) | |
| 51 | (49) + (50) | ⊕ 709 48 | 67 | REPEAT (36) | | 83 | (80)+(81)+(82) | |
| 52 | (49) - (50) | ⊖ 93 24 | 68 | REPEAT(25) NORTH+ SOUTH- | + - | 84 | ANTILOG SIN (83)= B | |
| 53 | COLOG SIN (51) | 0 192753 | 69 | (66)+(67)+(68) | + | 85 | *****A ENTER IN (95) | |
| 54 | LOG COS (52) | 9 998179 | 70 | 1/2 (69) = S | + | | POLARIS TABULAR METHOD | |
| 55 | LOG COT (48) | 0 278118 | 71 | (70) - (66) | + | 86 | $P_0$ VALUES OBTAINED | |
| 56 | (53) + (54) + (55) | 0 469050 | 72 | COLOG COS (67) | | 87 | $P_1$ FROM TABLE 12 | |
| 57 | COLOG COS (51) | 0 115170 | 73 | COLOG COS (68) | | 88 | $P_2$ USING LST(12) | |
| 58 | LOG SIN (52) | 8 960809 | 74 | LOG COS (70) | | 89 | (86)+(87)+(88) | |
| 59 | REPEAT (55) | 0 278118 | 75 | LOG COS (71) | | 90 | LOG (89) | |
| 60 | (57)+(58)+(59) | 9 354097 | 76 | (72)+(73)+(74)+(75) | | 91 | LOG FACTOR | 9 471 7 |
| 61 | ANTILOG TAN (60) USE SIGN (51) | ⊕ 226 4 | 77 | 1/2 (76) | | 92 | COLOG COS (25) | |
| 62 | ANTILOG TAN (56) USE SIGN (52) | ⊖ 1266 5 | 78 | ANTILOG COS (77) | | 93 | (90)+(91)+(92) | |
| 63 | (61)+(62) = A ENTER IN (95) | + 1040 1 | 79 | 2 x (78) = A ENTER IN (95) | | 94 | ANTILOG (93) = A ENTER IN (95) | |

| | | |
|---|---|---|
| COMPUTER Klein | *****(84) IS BEARING ANGLE USE APPROX AZ TO DETERMINE VALUE OF A | AZIMUTH TO AZIMUTH MARK |
| | | 95 A ****** 7040 1 |
| CHECKER Blair | ****** AZ TO STAR = A WHEN STAR IS IN EAST AZ = 6400 - A WHEN STAR IS IN WEST ADD 6400 IF (95) IS LESS THAN (96) | 96 MEAN HORIZONTAL ANGLE (1) 3148 3 |
| | | 97 (95)-(96)=AZ TO AZ MK 4291 8 |

DA FORM 2973, 1 May 65

*Figure 135. DA Form 2973 showing computations by the hour-angle method, using the star Deneb.*

(11) *Use lines 36 through 38* to solve the value of "A" by adding algebraically lines 36 and 37. Note that the value "q" cancels out here. "A" is the angle measured east or west from the north pole to the sun (star).

(12) *Use lines 39 through 41* to compute the astronomic azimuth from the occupied station to the azimuth mark. Follow the instructions contained in line 39. Subtract line 40 from line 39 to obtain the astronomic azimuth to the azimuth mark.

*b.* The formulas used when computing astronomic azimuth by the hour-angle method on DA Form 2973 are the same as those used on DA Forms 6–10 and 6–10a. Figure 134 shows computations on DA Form 2973 by the hour-angle method, using the sun and the field data in figure 118. Figure 135 shows computations on DA Form 2973 by the hour-angle method, using the star Deneb and the field data in figure 119. To solve the formulas by use of DA Form 2973, proceed as follows:

(1) Enter the station data and the mean values of each set and determine the mean of all sets as discussed in paragraph 312*b*(1), (2), and (3).

(2) *Use items 1 through 4* to compute the GMT and Greenwich date. Item 4 is the algebraic sum of the mean observed time (item 1), the watch correction (item 2), and the time zone correction (item 3) plus or minus 24 hours if required to make the total positive and less than 24 hours. The 24 hours, if used, represent 1 day borrowed or added to the local date to obtain the Greenwich time.

(3) *Use items 5 through 8* to compute the GHA of the sun. If observing a star, ignore or cross out these lines. The equation of time for $0^h$ is obtained from table 2 of the Army Ephemeris, and the interpolation for GMT is obtained from table 3.

(4) *Use items 9 through 12* to compute the GHA of a star. If observing the the sun, ignore or cross out these lines. The sidereal time at $0^h$ (item 9) is obtained from table 2 of the Army Ephemeris for the Greenwich date. The sidereal correction to the Greenwich mean time (item 10) is obtained from table 4. The right ascension is obtained from table 10 and is entered in item 11 with a negative sign. The sum of items 4, 9, 10, and 11 is entered as item 12 and is the GHA of the star.

(5) *Use items 13 through 18* to compute the value of "t" in mils by using the GHA in item 8 or 12. Use table 5 of Army Ephemeris and enter the value in mils for the hours, minutes, and seconds of GHA. The longitude is converted to mils in items 26 through 33 and is entered in item 16.

(6) *In items 19 through 25*, convert the latitude from degrees, minutes, and seconds to mils.

(7) *In items 26 through 33*, convert the longitude from degrees, minutes, and seconds to mils.

(8) *Ignore or cross out items 34 through 36*, as they are not required in the hour-angle method.

(9) *In items 37 through 47*, determine the apparent declination of the sun. These items are used only when observing the sun and may be ignored or crossed out when observing a star. GMT is converted to minutes in items 37 through 39. The daily change is obtained from table 2 of the Army Ephemeris and is entered in item 40. The logarithms of items 39 and 40 are added to the logarithm of the number of minutes in a day (which appears in the form of a constant). The antilog of the resulting sum is added to the declination for the date to obtain the declination at the time of observation.

(10) *Use items 48 through 63* to compute the value of "A." Note that cologs,

as well as logarithms, are used. Cologs are determined by subtracting the logarithms from 10.0.

(11) Use items 95 through 97 to determine the final azimuth from the occupied station to the azimuth mark.

# CHAPTER 14

# GYRO AZIMUTH SURVEYING INSTRUMENT

## Section I. GENERAL

### 314. Introduction

*a.* The artillery gyro azimuth surveying instrument (fig. 136) (azimuth gyro) is a portable gyrocompass used to determine a true direction. With this instrument, a direction can be determined under conditions of poor visibility without lengthy computations and with an accuracy that is comparable to that of astronomic observations. Direction is determined by observing the effect of the rotation of the earth on the gyroscope and applying appropriate corrections to the instrument. This instrument is for use in latitudes between 60° north and 60° south of the equator.

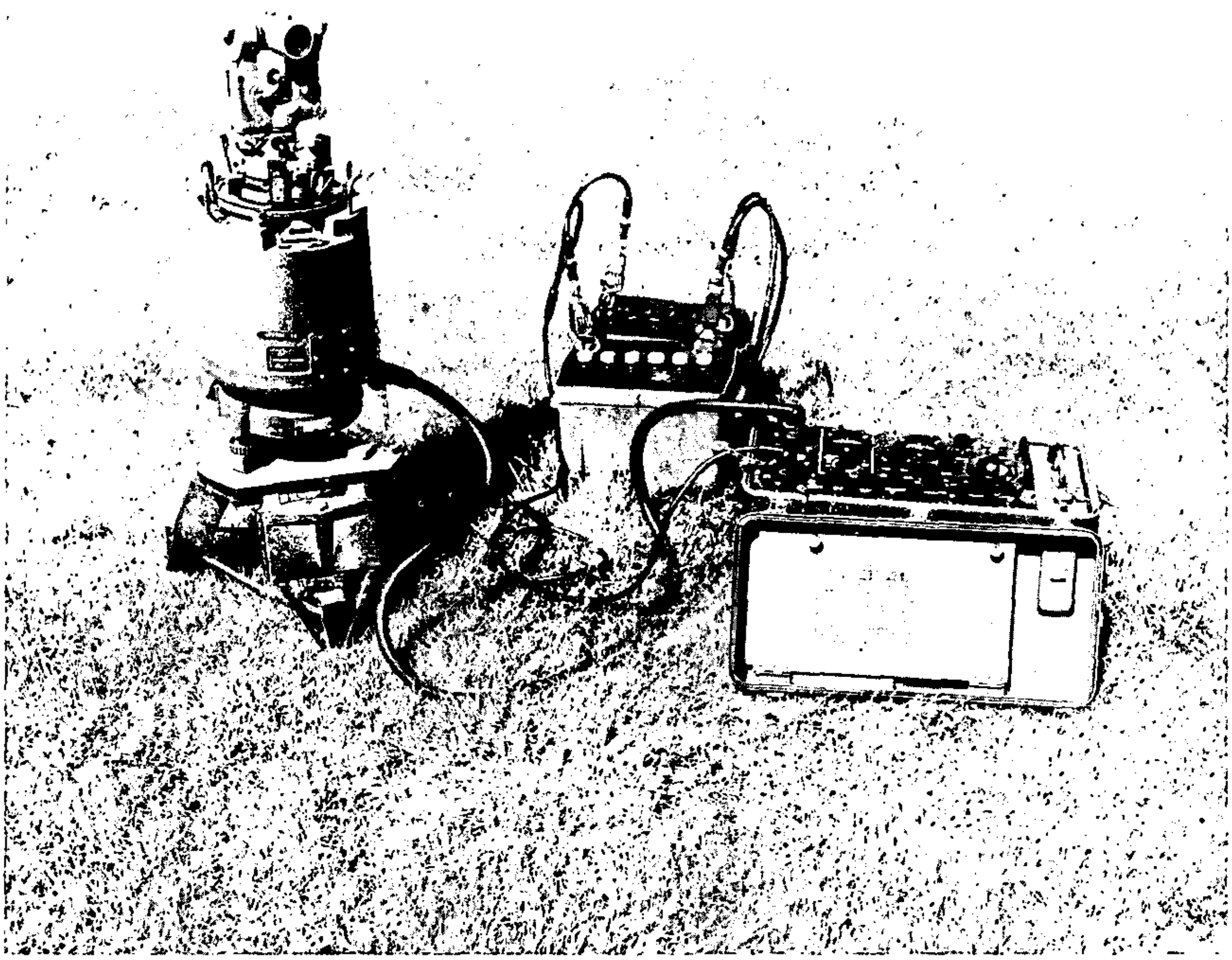


*Figure 136. The artillery gyro azimuth surveying instrument.*

*b.* The instrument is authorized for field artillery howitzer, gun, and missile battalions; for the survey element in the headquarters battery of division artillery; and for the batteries of the target acquisition battalion.

## 315. Description of Components

The components of the artillery azimuth gyro are as follows:

*a. Sensing Element.* The sensing element consists of the gyroscope case and the mil-graduated T2 theodolite mounted on top of the case.

(1) The gyroscope case contains a highly sensitive single axis rate gyroscope. On the outside of the case are the leveling screws, leveling bubbles, an azimuth lock and vernier, and a digital counter to measure increments of sensing element azimuth changes.

(2) The 0.002-mil T2 theodolite differs from the standard theodolite in that it is equipped with a special mounting device and the circle-setting knob is locked in position. When the theodolite is installed in the special mounting device, the horizontal circle of the theodolite is mechanically coupled to the gyroscope so that the line from 0 to 3,200 mils on the horizontal circle is in coincidence with the spin axis of the gyroscope.

*b. Control Indicator.* The control indicator is an electronic package which provides power to the gyro rotor, the heating elements, and the signals for measuring the amount and direc-

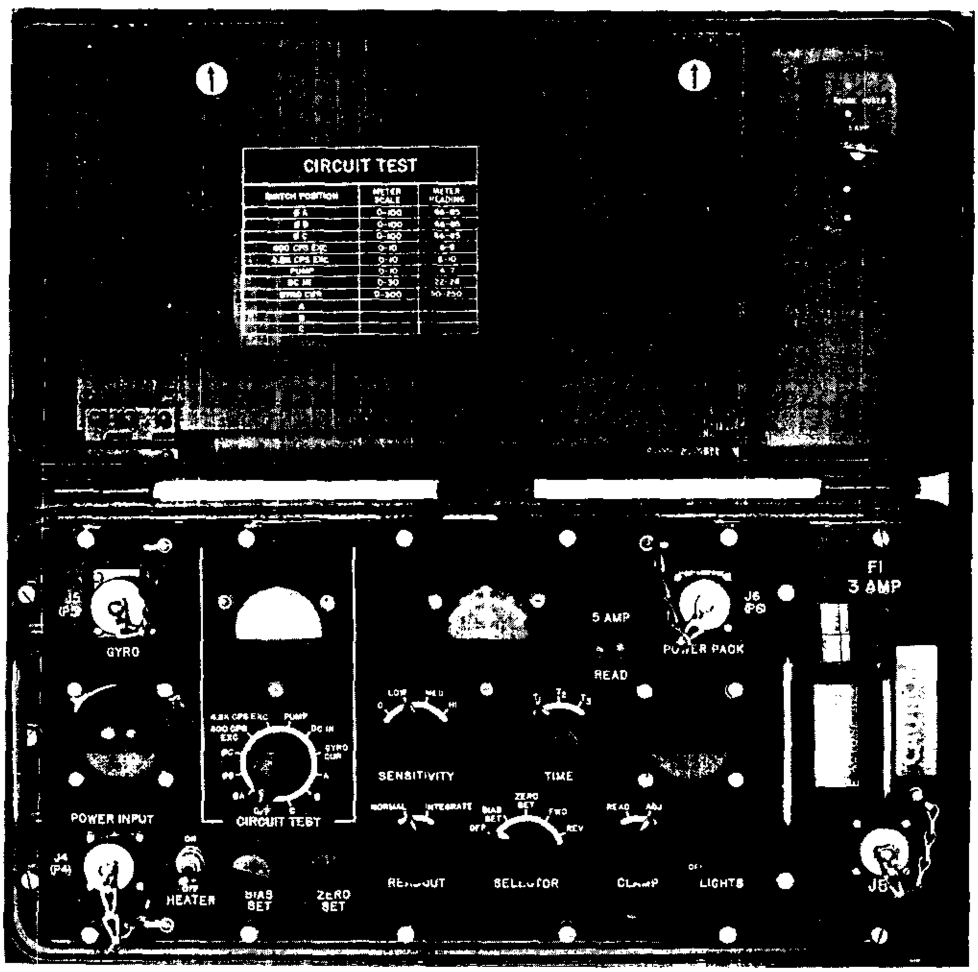



*Figure 137. Control indicator panel.*

tion of the gyro misalinement. The control indicator panel (fig. 137) provides the controls and indicators necessary for the operation and the directional alinement of the instrument. Receptacles are provided for cabling the control indicator to the power supply and to the sensing element. Located on the control panel are the following controls and indicators.

(1) *CIRCUIT TEST section.* THE CIRCUIT TEST section is provided for checking the circuits and for troubleshooting. Before the system is operated, all the electrical circuits are tested to insure that electrical conditions are correct.

(2) *READ lamp.* The indicator READ lamp is located in the upper right part of the control panel. When lit, the READ lamp indicates that the CLAMP switch has been turned from the ADJ position to the READ position and that readings can be taken from the null meter. Brightness of the lamp can be controlled by rotating the button on the lampholder.

(3) *HEATER switch.* A two-position toggle switch is located in the lower left part of the control panel to actuate the heating elements contained within the sensing element.

(4) *BIAS SET control.* The BIAS SET control permits the adjustment of bias to the gyro output axis and thereby returns the null meter to a zero reading. The SELECTOR switch must be in the BIAS SET position while the adjustment is made.

(5) *ZERO SET control.* The ZERO SET control permits adjustment of the readout amplifier drift to zero. The SELECTOR switch must be in the ZERO SET position while the adjustment is made.

(6) *LIGHTS switch.* A rheostat-type switch is located in the lower right corner to turn the panel lights on or off and to control their intensity.

(7) *SELECTOR switch.* The SELECTOR switch is a five-position switch containing positions labeled OFF, BIAS SET, ZERO SET, FWD, and REV. The forward and reverse positions refer to the direction of rotation of the gyro rotor.

(8) *CLAMP switch.* A two-position switch is provided for the read and adjust modes. The CLAMP switch must be in the READ position when zero set or bias set adjustments are being made or when the null meter is to be read. When the orientation of the sensing element is to be changed or when the direction of rotation of the rotor in the gyro is to be changed, the CLAMP switch must be in the ADJ position.

(9) *READOUT switch.* The two positions of the READOUT switch are NORMAL and INTEGRATE. When the switch is in the NORMAL position, a direct indication of the amount and direction of gyro misalinement is reflected on the null meter; when the switch is in the INTEGRATE position, the integral of this value is reflected.

(10) *SENSITIVITY switch.* The null meter pointer can be made more sensitive, or reactive, to electrical signals by moving the SENSITIVITY switch from LOW to MED or from MED to HI until the desired sensitivity is reached. The sensitivity changes by a factor of 2 from low to medium, and from medium to high. The C, or coarse, position is a very low sensitivity position which is used for making initial azimuth adjustments of the sensing element.

(11) *TIME switch.* The TIME switch provides three times—T1, T2, and T3—with periods of 30, 60, and 120 seconds, respectively, for null meter filter time (READOUT switch in NORMAL) or integration time (READOUT switch in INTEGRATE).

(12) *Null meter.* The null meter is a dial-type meter which indicates, when centered, that the spin axis of the sensing

element is accurately alined with the true north-south line.

*c. Tripod.* The tripod issued with the equipment is used with the sensing element and consists of three major parts — the tripod head with the housing for the tripod legs, a set of three wooden tripod legs, and a set of three short metal tripod legs. The two sets of tripod legs are interchangeable, and either set may be used with the tripod head. Each leg is retained in the housing by a single bolt. The short metal legs are recommended for greater rigidity and stability. The safety chain around the feet of the tripod legs must be secure each time the tripod is set up.

*d. Carrying Case and Accessories.* The carrying case is a heavy-gage drum-type container which affords protection against exterior abuse and provides maximum environmental protection for the sensing element during transit or storage. Six hook-type clamps secure the cover to the case, and a rubber gasket forms an airtight seal. A pressure relief valve facilitates removal of the airtight cover when internal and external pressures are unequal. An external electrical receptacle is provided on the side of the container for either 24-volt DC or 115-volt AC current that is used for heating the sensing element during movement or storage. Accessory equipment consists of three power cables, two adapters, two clips, the sensing element insulation cover, and technical manuals.

### 316. Principles of Operation

The gyroscope of the azimuth gyro detects the earth's rotation. A bias instrument is made to insure that the only torque (force) exerted on the gyroscope is the rotation of the earth. Through an electrical system, a signal is provided on the null meter that is proportional to the amount and direction of the misalinement of the gyro input axis with respect to the direction of the earth's rotation. The gyroscope is repositioned in azimuth until a null position on the meter is reached. When the gyro is so positioned with respect to the earth that the component of the earth's rotation rate on the input axis is zero, the null meter registers a null and the spin axis is alined in a true north-south direction. Since the line from 0 to 3200 mils on the horizontal circle of the theodolite is mechanically coupled to the spin axis of the gyroscope, the horizontal circle is oriented on true north. For any pointing now made with the theodolite, the horizontal circle reading is a direct readout of the *true* direction from the instrument to the sighted point. This true direction is then converted to a grid direction by applying the grid convergence.

## Section II. OPERATION OF THE AZIMUTH GYRO

### 317. Selecting an Operating Site

Precautions must be taken to select a station on firm ground away from large trees and pedestrian or vehicular traffic. If both ends of a line for which the direction is to be established can be occupied, the equipment should be set up at the end with the least activity in the general area. For best results, the system should always be protected from weather by a plywood shelter. Wind gusts will be sensed by the gyro and will cause erratic operation. Tree roots will carry the effect of wind into the ground near trees. Direct sun rays will cause erratic operation due to the unequal contraction and expansion of the various parts of the unit. The sensing element, the control indicator, and the 24-volt power supply must be shaded from the sun during operation when the ambient temperature is in excess of 75°.

### 318. Setting Up the Instrument

*a. Tripod.* Open the legs until the tripod head is at the desired operating height and adjust the chain to secure the legs with a minimum of slack in the chain. Center the tripod over the station, and use foot pressure of at least 100 pounds to firmly embed the tripod legs in the ground. The bubble in the circular level vial should be approximately centered at the completion of this operation. For setups on reasonably flat terrain, detents in the hinges permit the legs to be positioned at identical angles.

**Caution:** The chain must be secure on the legs to prevent inadvertent collapse of the tripod and severe damage to the sensing element.

*b. Sensing Element.*

**Caution:** Use extreme care when handling this delicate and sensitive equipment. Do not attempt to shift or move the tripod when the sensing element is attached. For safety in handling, the sensing element should be lifted by two people. Always lift the sensing element by the two handles provided to prevent damage or misalinement. Do not attempt to lift the sensing element by grasping the theodolite.

To prepare the sensing element for operation—

(1) Release the holddown clamps and remove the theodolite, still attached to the carrying plate. Set the theodolite in a safe place.

(2) Check to see that the mating surface of the sensing element and the tripod head are clean. Place the sensing element with its leveling screws over the corners of the tripod, and position the tripod fixing screw so that it can be screwed into the base plate of the sensing element. Tighten the fixing screw to secure the sensing element to the tripod.

(3) Install the plumb bob on the hook of the fixing screw, and plumb the instrument exactly over the station.

(4) Remove the dust cap from the electrical connector.

(5) Wipe the mating surfaces of the theodolite and sensing element.

(6) Remove the theodolite from its carrying plate and attach it to the sensing element.

*c. Leveling the Sensing Element.* To level the sensing element—

(1) Release the azimuth lock by turning the spanner counterclockwise (no more than one turn) so that the sensing element may be rotated freely by hand.

(2) Place one hand on each side of the sensing element, or one hand on each handle, and gently rotate the sensing element in azimuth until one of the index marks at the bottom of the sensing element lines up with an index mark on the base.

(3) Two leveling screws and a pivot point are located on the base of the sensing element in a tribrach arrangement. When the index marks are in alinement ((2) above), the axis of one level bubble is parallel to the line through the pivot point and one leveling screw, while the axis of the second level bubble is parallel to the line from the pivot point through the second leveling screws. Adjust the leveling screws until the level bubbles are centered.

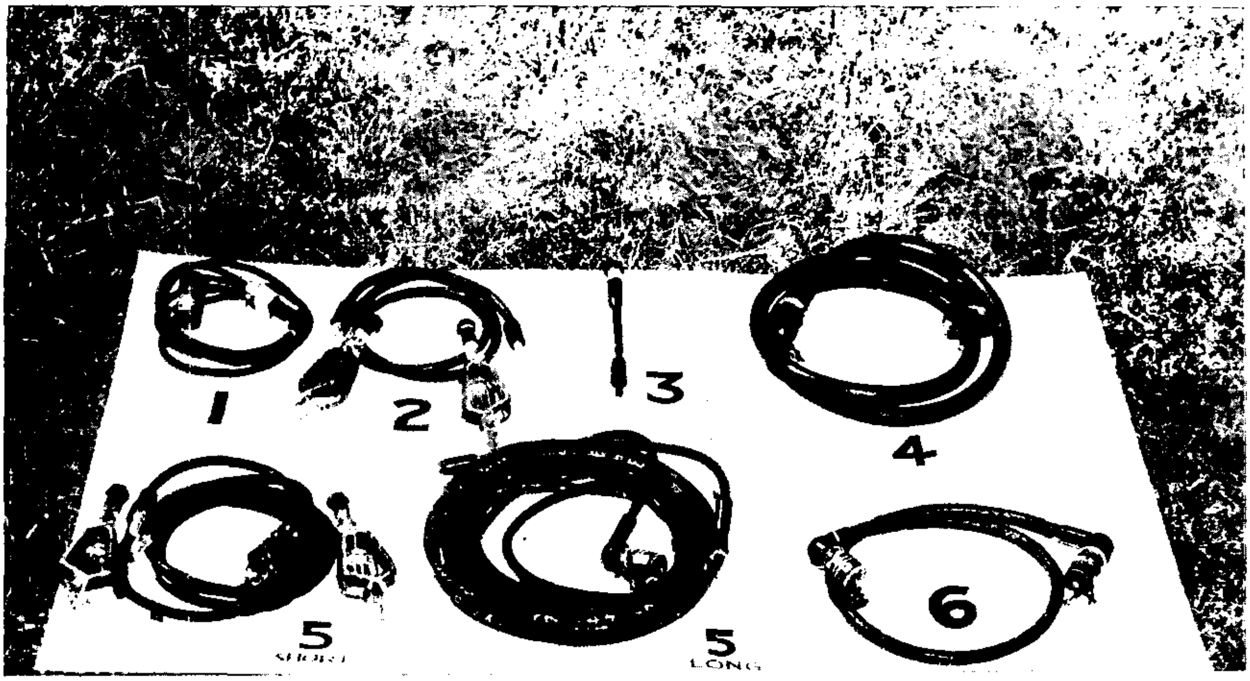
(4) Rotate the sensing element 3,200 mils in azimuth until the index marks again line up. If the level bubbles are in correct adjustment, a level condition will still be indicated. If a level condition is not indicated, the appropriate leveling screws must be adjusted to correct for one-half the indicated misalinement.

(5) Rotate the sensing element to the first index position. The level bubbles should read the same as in (4) above.

(6) Repeat the leveling procedure ((2) through (5) above), using the split bubble levels.

(7) Tighten the azimuth lock on the sensing element.

(8) Loosen the horizontal circle clamp on the T2 theodolite, and rotate the alidade until the axis of the plate level vial is parallel to an imaginary line formed by one of the leveling screws on the theodolite mounting bracket and the bracket pivot point. Note the position of the plate level bubble. Rotate the alidade 3,200 mils, and again note the position of the bubble. Repeat this operation, using the second leveling screw. If the various positions of the bubble are the same within plus or minus one-half division, the theodolite and sensing axis are parallel; if not, the theodolite must be leveled, using the same procedure as for the sensing element. A special tool is available in the carrying case for ro-




| CABLE NUMBER | LENGTH | USE |
|---|---|---|
| 1 | 6-FT | AC POWER INPUT, CONTROL PANEL TO AC POWER SOURCE. |
| 2 | 4-FT | PROVIDED FOR SERIES CONNECTION OF TWO 12V BATTERIES. |
| 3 | 6-IN | ADAPTER FOR RECEPTACLE OF DC POWER SOURCE OTHER THAN BATTERY. |
| 4 | 6-FT | CONNECTOR BETWEEN CONTROL PANEL AND SENSING ELEMENT. |
| 5 SHORT | 6-FT | DC POWER INPUT, CONTROL PANEL TO DC POWER SOURCE. |
| 5 LONG | 25-FT | |
| 6 | 3-FT | CONNECTOR BETWEEN CONTROL PANEL AND POWER PACK (FOR AC USE). |

*Figure 138. Power cables.*

tating the leveling screws on the mounting bracket.

(9) Release the sensing element azimuth lock, and rotate the sensing element until the mirror window points generally west.

(10) Secure the sensing element azimuth lock, and leave the theodolite horizontal circle clamp free.

*d. Connecting the Power Cables.* Before connecting the power cables (fig. 138) for operation of the equipment, set the switches on the control indicator panel to the following positions:

| *Switch* | *Position* |
|---|---|
| CIRCUIT TEST | OFF |
| HEATER | OFF |
| SELECTOR | OFF |
| SENSITIVITY | HI |
| READOUT | NORMAL |
| TIME | T1 |
| CLAMP | ADJ |

(1) To connect the cables for DC operation—

(*a*) *Remove the dust caps, and attach* the connector marked P5 of the 6-foot cable (number 4) to the receptacle marked GYRO on the control indicator panel and the connector marked P7 to the sensing element receptacle.

(*b*) For a DC source other than a battery, select either the 6-foot cable or the 25-foot branched cable (number 5). Remove the dust caps, and attach the connector marked P4 to the

POWER INPUT receptacle on the control indicator panel. The 25-foot cable (number 5) permits operations at a greater distance from the power supply. The 6-inch cable (number 3) serves as an adapter between the 25-foot cable and a power receptacle.

(*c*) Observe the polarity, and attach the branched ends of the cable (P2-black and P3-red) to the power source.

(*d*) For a DC battery source, follow the instructions in (*a*) through (*c*) above with one exception. In connecting the 25-foot cable to the power source, use the two adapters and color-coded clips to complete the connections to the battery terminals. The 4-foot cable (number 2) is marked for polarity to provide a series connection in the event the two 12-volt batteries are used as a power source.

(2) To connect the cables for AC operation—

(*a*) Remove the 24-volt DC powerpack from the control indicator. In use, this powerpack heats, and it must be removed to avoid unequal heating of elements in the control indicator.

(*b*) Attach the 4-foot cable as in (1) (*a*) above.

(*c*) Remove the dust caps, and attach the connector marked P8 of the 3-foot cable (number 6) to the 24-volt power supply receptacle marked J8. Attach the connector marked P6 of the same cable to the control indicator receptacle marked POWER PACK.

(*d*) Remove the dust caps, and attach the connector marked P4 of the 6-foot cable (number 1) to the control indicator receptacle marked POWER INPUT. Attach the connector marked P1 to the AC power source.

## Section III. USE, CARE, AND MAINTENANCE OF THE AZIMUTH GYRO

### 319. Azimuth Measurement Procedures

To measure an azimuth, after the azimuth gyro has been set up and connected to a power source as described in paragraph 318, perform the following steps in the sequence shown:

*a. Circuit Testing.*

(1) Turn the SELECTOR switch to BIAS SET.

(2) Check to see whether the fan is circulating air by placing a hand over the air exhaust duct located above the CLAMP switch. If air is not circulating, turn the SELECTOR switch to OFF and recheck all connections. If the connections are good and air still does not circulate, turn the system in for repairs.

(3) Turn the LIGHTS switch to ON (night operation only).

(4) Turn the CIRCUIT TEST switch through positions ØA, ØB, ØC, 400 CPS EXC, 4.8K CPS EXC, PUMP, and DC IN, noting the reading on the appropriate scale of the circuit test meter. For AC operation, the readings must lie in the range shown on the circuit test panel on the inside cover of the control indicator. When batteries are used, the readings should be the same as for AC operation except that the reading for the pump should be 5–8.

(5) Place the CIRCUIT TEST switch in the GYRO CUR position. The reading will be zero.

(6) Turn HEATER switch to ON if the ambient temperature is less than $+50°$ F.

*b. Bias Set Adjustment.*

(1) Turn the CLAMP switch to READ. Check to insure that the READ lamp comes on.

(2) Observe the position of the indicator on the null meter. Turn the BIAS SET control until the indicator is at zero.

(3) Turn the CLAMP switch to ADJ.

*c. Zero Set Adjustment.*

(1) Turn the SELECTOR switch to ZERO SET.

(2) Turn the CLAMP switch to READ.

(3) Observe the position of the indicator on the null meter. Turn the ZERO SET control until the indicator is at zero.

(4) Turn the CLAMP switch to ADJ.

(5) Turn the READOUT switch to INTEGRATE.

(6) Turn the CLAMP switch to READ.

(7) Observe the position of the indicator on the null meter when the READ lamp comes on (about 30 seconds). The indicator should be within 0.25 unit of zero. If it is not, repeat (1) through (7) above.

(8) Turn the CLAMP switch to ADJ.

*d. Final Bias Adjustment.*

(1) Turn the READOUT switch to NORMAL.

(2) Turn the SELECTOR switch to BIAS SET.

(3) Turn the CLAMP switch to READ.

(4) Observe the position of the indicator on the null meter when the READ lamp comes on. The indicator should be within 0.5 unit of zero. If it is not, adjust the indicator to within 0.5 unit of zero by turning the BIAS SET control.

*Note.* If an adjustment is made, repeat *b*, *c*, and *d* (1) through (4) above.

(5) Turn the CLAMP switch to ADJ.

*e. Alinement Procedure.*

*Note.* During the alinement process, keep pedestrian traffic at least 3 meters and vehicle traffic at least 30 meters away from the sensing element.

(1) Release the fast motion azimuth lock on the sensing element.

(2) Rotate the sensing element gently by hand until the mirror window of the sensing element points generally west or until the reading on the theodolite is the approximate azimuth to the azimuth mark.

(3) Set the digital counter of the azimuth slow motion on the sensing element to 5000 (center of 4000-6000 counter units).

(4) Turn the SELECTOR switch to REV.

(5) Wait 90 seconds for the gyroscope to reach synchronous speed. Synchronous speed is indicated by an abrupt drop in the gyro current on the circuit test meter.

(6) Check the gyro current on the circuit test meter.

(7) Turn the SENSITIVITY switch to C.

(8) Turn the CLAMP switch to READ. After a pause, turn the CLAMP switch to ADJ and then to READ. Observe the direction and reading on the null meter. If the indicator rests at a position more than one unit from zero, turn the CLAMP switch to ADJ and slowly turn the sensing element in small increments in the appropriate direction, using the two handles.

(9) Repeat (8) above until the null meter indicator is within one unit of zero.

(10) Turn the CLAMP switch to ADJ.

(11) Lock the fast motion azimuth lock on sensing element.

(12) Turn the SENSITIVITY switch to LOW.

(13) Turn the CLAMP switch to READ and observe the direction and reading on the null meter.

(14) Turn the CLAMP switch to ADJ and turn the digital counter knob in the appropriate direction for the proper amount which is determined as follows: One unit on the null meter is equal to a change of 30 units on the digital counter. For example, if the indicator on the null meter reads four units to the left of zero, the digital counter knob must be turned to the right to bring the indicator to zero.

In this case, the product of 30 x 4 is subtracted from the digital counter reading of 5000, making the digital counter read 4880. Repeat this step until the indicator on the null meter lies within one unit of zero.

*Note.* If an azimuth correct to 1 mil is desired, achieve null, skip (15) through (21) below, and proceed with (22) below.

(15) Turn the CLAMP switch to ADJ.

(16) Turn the SENSITIVITY switch to MED.

(17) Turn the CLAMP switch to READ and observe the direction and reading on the null meter. If the reading is not zero, turn the CLAMP switch to ADJ and turn the sensing element in the appropriate direction for the proper amount. At this sensitivity setting, 1 unit on the null meter is equal to 15 units on the digital counter. Turn the CLAMP switch to READ; if the reading on the null meter is not zero, repeat this step. When the reading is zero, proceed.

*Note.* If an azimuth correct to 0.3 mil is desired, skip (18) through (21) below, and proceed with (22) below. For azimuth correct to 0.1 mil or 0.15 mil, proceed with (18) below.

(18) Turn the CLAMP switch to ADJ.

(19) Turn the SENSITIVITY switch to HI.

(20) Turn the CLAMP switch to READ and observe the direction and reading on the null meter. If the reading is not zero, turn the CLAMP switch to ADJ and turn the sensing element in the appropriate direction for the proper amount. At this sensitivity setting, one unit on the null meter is equal to a change of seven units on the digital counter. Turn the CLAMP switch to READ; if the reading on the null meter is not zero, repeat this step. When the reading is zero, proceed.

(21) Turn the CLAMP switch to ADJ.

(22) Turn the SELECTOR switch to REV.

(23) Observe the azimuth mark with the theodolite in the direct position and then with the theodolite in the reverse position. Record and mean the readings (para 320).

(24) Turn the SENSITIVITY switch to LOW.

(25) Wait 5 minutes after gyro has gone into synchronization.

(26) Turn the CLAMP switch to READ.

(27) Repeat (13) through (23); (13) through (27) comprise one set of readings for azimuth determination.

*f. Turning System Off.*

(1) Turn the CLAMP switch to ADJ.

(2) Turn the SELECTOR switch to FWD. Wait 45 seconds.

(3) Turn the SELECTOR switch to OFF.

(4) Turn the CIRCUIT TEST switch to OFF.

(5) Disconnect all cables. Disconnect the power source cable first.

(6) Do not remove the sensing element from the tripod until the gyro has completely stopped. Listen with an ear on the sensing element case to detect when the gyro has stopped.

## 320. Recording

*a.* After the azimuth gyro has been oriented (para 319*e*(23)), readout of direction is accomplished by taking one position with the theodolite to a desired mark or reference point. These readings are recorded in the field notebook and meaned, giving a direction to the reference point with the gyro rotating in one direction. The SELECTOR swith is then turned to the REV position and the instrument is again oriented (para 319*e*(24)–(27)). Readout of direction is again accomplished by taking one position with the theodolite to the same reference point. These readings are recorded and meaned, giving a direction to the reference point with the gyro rotating in the opposite direction. The mean of the directions determined with the gyro in forward and reverse rotation completes *one set* of readings.

*Example:*

FWD reading: D 6011.111
R 2811.121

Difference 0.010

Mean FWD reading = (0.010 ÷ 2) + 6011.111 = 6011.116

REV reading: D 6011.333
R 2811.347

Difference 0.014

Mean REV reading = (0.014 ÷ 2) + 6011.333 = 6011.340

Mean REV reading = 6011.340
Mean FWD reading = 6011.116

Difference 0.224

Mean azimuth = (0.224 ÷ 2) + 6011.116 = 6011.2228 mils

*b.* The mean true azimuth determined in *a* above is then converted to a grid azimuth by applying the grid convergence.

*c.* The following specifications must be met to determine an azimuth to the required accuracy with the azimuth gyro:

(1) For 1-mill accuracy, take two sets of readings with the SENSITIVITY switch in the LOW position. The sets must agree within 2 mils.

(2) For 0.3 mil accuracy (fifth-order astronomic), take three sets of readings with the SENSITIVITY switch in the MED position. The sets must agree within 0.8 mil of the mean. At least two sets of readings must be used to determine the final mean azimuth.

(3) For fourth-order or higher accuracy azimuths, the effect of latitude cannot be ignored. To determine the number of sets required to obtain a 95 percent assurance of a particular accuracy, use the table in figure 139. Enter the appropriate latitude column, move down the column to the desired accuracy, and read the number of required sets from the column marked "N." For example, to obtain a 95 percent assurance of an accuracy of 0.15 mil at Fort Sill (latitude 35°), enter the column, move down the column to 0.146, and read the number of re-

ACCURACY FIGURES IN MILS FOR THE MEAN OF N AZIMUTH SETS
BASED ON 95 PERCENT ASSURANCE

LATITUDE IN DEGREES

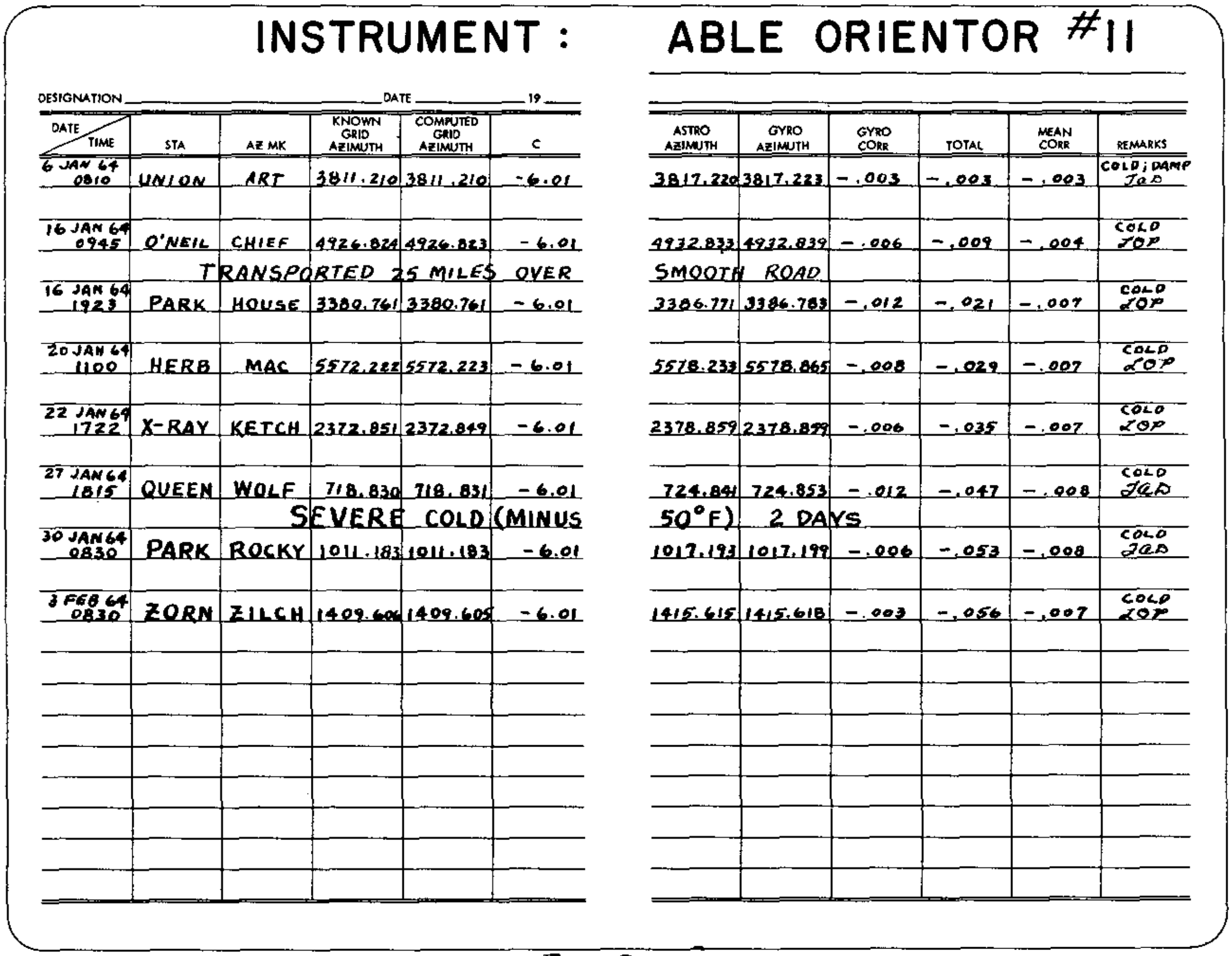
| N | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.279 | 0.280 | 0.284 | 0.292 | 0.302 | 0.315 | 0.332 | 0.355 | 0.384 | 0.420 | 0.467 | 0.530 | 0.613 |
| 2 | 0.200 | 0.202 | 0.204 | 0.209 | 0.216 | 0.226 | 0.239 | 0.255 | 0.275 | 0.301 | 0.335 | 0.378 | 0.438 |
| 3 | 0.166 | 0.167 | 0.169 | 0.173 | 0.179 | 0.188 | 0.198 | 0.212 | 0.228 | 0.249 | 0.277 | 0.313 | 0.362 |
| 4 | 0.146 | 0.147 | 0.149 | 0.152 | 0.158 | 0.164 | 0.174 | 0.185 | 0.200 | 0.218 | 0.243 | 0.275 | 0.318 |
| 5 | 0.132 | 0.133 | 0.135 | 0.139 | 0.143 | 0.149 | 0.158 | 0.168 | 0.181 | 0.198 | 0.220 | 0.249 | 0.287 |
| 6 | 0.122 | 0.123 | 0.125 | 0.128 | 0.133 | 0.138 | 0.146 | 0.155 | 0.168 | 0.183 | 0.204 | 0.230 | 0.266 |
| 7 | 0.115 | 0.116 | 0.117 | 0.120 | 0.124 | 0.130 | 0.137 | 0.146 | 0.157 | 0.172 | 0.191 | 0.216 | 0.249 |
| 8 | 0.108 | 0.109 | 0.110 | 0.112 | 0.116 | 0.121 | 0.128 | 0.136 | 0.147 | 0.161 | 0.178 | 0.202 | 0.233 |
| 9 | 0.101 | 0.102 | 0.103 | 0.105 | 0.109 | 0.114 | 0.120 | 0.128 | 0.138 | 0.150 | 0.167 | 0.188 | 0.217 |
| 10 | 0.096 | 0.096 | 0.097 | 0.099 | 0.103 | 0.107 | 0.113 | 0.121 | 0.130 | 0.142 | 0.157 | 0.178 | 0.206 |
| 12 | 0.088 | 0.088 | 0.089 | 0.091 | 0.094 | 0.098 | 0.103 | 0.110 | 0.119 | 0.130 | 0.144 | 0.162 | 0.187 |
| 14 | 0.082 | 0.082 | 0.083 | 0.085 | 0.088 | 0.092 | 0.097 | 0.102 | 0.110 | 0.121 | 0.134 | 0.151 | 0.173 |
| 16 | 0.077 | 0.077 | 0.078 | 0.080 | 0.083 | 0.086 | 0.091 | 0.097 | 0.104 | 0.114 | 0.126 | 0.142 | 0.164 |
| 18 | 0.073 | 0.074 | 0.075 | 0.076 | 0.079 | 0.082 | 0.087 | 0.092 | 0.100 | 0.108 | 0.120 | 0.135 | 0.156 |
| 20 | 0.071 | 0.071 | 0.072 | 0.073 | 0.076 | 0.079 | 0.083 | 0.089 | 0.095 | 0.104 | 0.115 | 0.130 | 0.150 |
| 30 | 0.062 | 0.062 | 0.063 | 0.064 | 0.066 | 0.069 | 0.072 | 0.077 | 0.082 | 0.090 | 0.100 | 0.112 | 0.130 |
| 40 | 0.057 | 0.057 | 0.058 | 0.059 | 0.061 | 0.063 | 0.067 | 0.071 | 0.076 | 0.083 | 0.092 | 0.103 | 0.119 |
| Rejection Limit | 0.42 | 0.42 | 0.43 | 0.44 | 0.45 | 0.47 | 0.50 | 0.53 | 0.58 | 0.63 | 0.70 | 0.79 | 0.92 |

EXAMPLE: For a desired accuracy of 0.12 mils at 35 degrees latitude, it is necessary to take a minimum of ten azimuth sets. The rejection limit for 35 degree latitude would be 0.53 mils.

*Figure 139. Azimuth gyro accuracy table.*

quired sets from column N. The number of required sets in this case is seven. To obtain the same accuracy in Maine (altitude 45°) enter the 45° column, move down the column to 0.150, and read the number of required sets from column N. In this case, the number is nine. It should be noted that the figures in the table represent 95 percent assurance, which allows for about three probable errors. If a lower assurance can be tolerated, a fewer number of sets will be required. Each set used must agree with the mean of all sets within some amount (called the rejection limit) which varies with the latitude. The rejection limit is listed on the bottom of the table for each latitude. After the obviously bad sets are rejected, a first mean is taken and those sets which differ from this mean by more than the rejection limit are discarded. A final mean is taken of the remaining sets. The 95 percent assured accuracy of this mean is the value opposite "N" equal to the required sets in the column corresponding to the latitude of the station.

*d.* Units that are issued an azimuth gyro should operate the instrument at least once each month. After an azimuth gyro is obtained, an astronomic azimuth should be observed with the theodolite mounted on the azimuth gyro orienter. An initial set of 10 gyro and astro-



INSTRUMENT : ABLE ORIENTOR #11

DESIGNATION ________ DATE ________ 19 ___

| DATE / TIME | STA | AZ MK | KNOWN GRID AZIMUTH | COMPUTED GRID AZIMUTH | C | ASTRO AZIMUTH | GYRO AZIMUTH | GYRO CORR | TOTAL | MEAN CORR | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 JAN 64 0810 | UNION | ART | 3811.210 | 3811.210 | -6.01 | 3817.220 | 3817.223 | -.003 | -.003 | -.003 | COLD; DAMP JAD |
| 16 JAN 64 0945 | O'NEIL | CHIEF | 4926.824 | 4926.823 | -6.01 | 4932.833 | 4932.839 | -.006 | -.009 | -.004 | COLD LOP |
| | | TRANSPORTED | 25 MILES | OVER | | SMOOTH ROAD | | | | | |
| 16 JAN 64 1923 | PARK | HOUSE | 3380.761 | 3380.761 | -6.01 | 3386.771 | 3386.783 | -.012 | -.021 | -.007 | COLD LOP |
| 20 JAN 64 1100 | HERB | MAC | 5572.222 | 5572.223 | -6.01 | 5578.233 | 5578.865 | -.008 | -.029 | -.007 | COLD LOP |
| 22 JAN 64 1722 | X-RAY | KETCH | 2372.851 | 2372.849 | -6.01 | 2378.859 | 2378.899 | -.006 | -.035 | -.007 | COLD LOP |
| 27 JAN 64 1815 | QUEEN | WOLF | 718.830 | 718.831 | -6.01 | 724.841 | 724.853 | -.012 | -.047 | -.008 | COLD JAD |
| | | | SEVERE COLD | | (MINUS | 50°F) | 2 DAYS | | | | |
| 30 JAN 64 0830 | PARK | ROCKY | 1011.183 | 1011.183 | -6.01 | 1017.193 | 1017.199 | -.006 | -.053 | -.008 | COLD JAD |
| 3 FEB 64 0830 | ZORN | ZILCH | 1409.606 | 1409.605 | -6.01 | 1415.615 | 1415.618 | -.003 | -.056 | -.007 | COLD LOP |

*Figure 140. Sample field notes for an azimuth gyro.*

nomic observations should adequately determine the instrument error. A record should be kept of all gyro azimuths which provide a comparison to astronomic azimuths. This record is used to determine the instrument correction. The record is kept on BA Form 5–72. A separate record is kept for each azimuth gyro. The cover and the first page of the record should completely identify the instrument. Figure 140 shows a sample record. The entries made in the 12 columns of the open double page of DA Form 5–72, as shown in the sample, are explained in (1) through (12) below.

(1) The date and hour of the observations are entered in the *date-time* column (column 1).

(2) The name of the station over which the instrument is set up is entered in the *sta* column (column 2).

(3) The name of the station used as an azimuth mark is entered in the *az mk* column (column 3).

(4) The azimuth of the observed line if known to a higher degree of accuracy than can be determined by artillery astronomic observations is entered in the *known grid azimuth* column (column 4).

(5) The grid azimuth as determined by the azimuth gyro is entered in the *computed grid azimuth* column (column 5). The gyro correction from column 11 and the convergence from column 6 are applied to the observed gyro azimuth to obtain the computed grid azimuth. A comparison may be made here as a check during training.

(6) The grid convergence is entered in the *C* column (column 6). The convergence must be computed or scaled from a map.

(7) The astronomic azimuth computed from the observations is entered in the *astro azimuth* column (column 7).

(8) The azimuth determined from one set of gyro observations is entered in the *gyro azimuth* column (column 8).

(9) The gyro correction is entered in the *gyro corr* column (column 9). The correction is obtained by subtracting the gyro azimuth in column 8 from the astronomic azimuth in column 7.

(10) The total of the entries in column 9 is entered in the *total* column (column (10). The entry on each line of column 10 is the sum of the gyro correction on that line and the total on the preceding line.

(11) The mean correction is entered in the *mean corr* column (column 11). The mean correction is obtained by dividing the number in column 10 by the number of entries included in the total.

(12) The weather, the initials of the gyro operator, and any other data which might affect the accuracy of the result are entered in the *remarks* column (column 12).

*e.* If for any reason, such as cloud cover, an astronomic azimuth cannot be observed and a reliable grid azimuth is available for the observed line, the gyro azimuth can be compared with the grid azimuth. This is done by applying the convergence, with sign reversed to the grid azimuth to obtain a true azimuth. The result is entered in the *astro azimuth* column and the value is inclosed in brackets to indicate that it is computed. The other values for entry on DA Form 5–72 are obtained in the same manner as when an astromonic azimuth is used for comparison. All events which might affect the accuracy or gyro correction of the instrument should be written boldly across the double page. If it is certain that the accuracy is affected, a new series of totals should be started. If it is probable that the gyro correction is not affected, the series may be continued by the survey officer should watch the corrections carefully to determine if a change in the correction occurs. Examples of events which should be entered as follows:

(1) Transported 25 miles over smooth road.

(2) Transported 10 miles over rough road.

(3) Transported 2 miles across country.

(4) Trim pots adjusted.

(5) Severe cold (minus 50° F in warehouse) 2 days.

(6) Severe heat (140° F in warehouse) 12 hours.

(7) Serviced by maintenance section.

(8) Hit severe bump during transportation.

### 321. Taking Down the Instrument

*a.* After measurement is made with the azimuth gyro approximately 10 minutes is required from the time the gyro rotor is shut off until it comes to rest. To diminish this coasting time when the SELECTOR switch is in FWD, turn the SELECTOR switch to REV for 45 seconds and then to OFF; when the SELECTOR switch is in REV, turn the SELECTOR to FWD for 45 seconds and then to OFF. This method of power reversal brings the rotor nearly to a standstill. Monitor the rotation of the rotor by placing an ear against the sensing element.

***Caution:* To avoid possible damage or misalinement, *never* remove the sensing element from the tripod or transport the sensing element while the gyro rotor is running.**

*b.* Turn the SELECTOR and CIRCUIT TEST switches to OFF and secure the azimuth lock with light pressure.

*c.* Disconnect the power source.

*d.* Disconnect cable number 4 from the sensing element.

*e.* Disconnect cables number 4, 6, and 1 (or 5) from the control indicator.

*f.* Store the cables in the canvas bag with the loose equipment.

*g.* Close the control indicator cover and secure the cover with the five latches.

*h.* If the sensing element is to be transported, remove the theodolite from the bracket and carry the theodolite in the issued theodolite base and carrying case.

*i.* Connect the carrying case heater wire to the sensing element connector.

*j.* Unscrew the tripod fixing screw and, using the two handles provided, remove the sensing element from the tripod and carefully place it in the carrying case.

*k.* Connect the heater wire from the sensing element to the bracket receptacle.

*l.* Position the collar and cushioning.

*m.* Check to see that tools are secure.

*n.* Install the carrying case cover and secure it with the six hook-type clamps.

*o.* Close the pressure relief valve and secure the dust cap on the electrical connector.

*p.* Clean, fold, and secure the tripod legs.

### 322. Care and Maintenance

Adjustment and repair of the azimuth gyro must be performed by qualified instrument repair personnel. Artillery units, therefore, should turn the instrument in for any necessary adjustments or repair to the engineer unit responsible for providing maintenance service. TM 5–6675–207–15 outlines the categories of maintenance for the instrument.

# PART FOUR

# CONVERTING DATA

## CHAPTER 15

## CONVERSION TO COMMON CONTROL

### 323. General

*a.* In order to permit the delivery of accurate field artillery fires without adjustment and to permit the massing of fires of two or more artillery units, all field artillery units operating under the tactical control of one commander should be located and oriented with respect to a single datum plane or grid. This grid can be based on the UTM (UPS) grid coordinates of points previously established by survey, or the grid may be based on assumed data.

*b.* The common grid is established by the highest survey echelon present in the area. The headquarters which exercise tactical control over artillery units are battalion, division, and corps. The mission of the subordinate unit requires it to initiate survey operations without waiting for survey control to be established by a higher echelon. Therefore, at all levels, survey is started and completed as soon as possible, and, when higher echelon survey control becomes available, the original data is converted to place the unit on the grid of the higher echelon. Thus, it may be necessary for a battalion assigned or attached to a division artillery to operate first on the grid established by the battalion (battalion grid), then on the grid established by division artillery (division grid), and finally on the grid established by corps artillery (corps grid). When survey at one or more echelons is based on assumed data, data established by the lower echelon must be converted to the grid established by the higher echelon.

### 324. Variations in Starting Control

The methods by which starting control for field artillery survey can be obtained are listed in order of preference in *a* through *c* below.

*a. Use of Known Coordinates and Heights of Points Located With Respect to a UTM (or UPS) Grid.* The points for which the coordinates and heights are known may be points established by surveys performed by the higher echelon, or they may be points which were located by surveys performed prior to the start of military operations. The locations of points established prior to the commencement of military operations are contained in trig lists prepared and published by the Corps of Engineers.

*b. Use of Assumed Coordinates and Heights and Correct Grid Azimuth.* Correct grid azimuth can be determined, in many cases, through astronomic observation or through the use of an azimuth gyro. Correct grid azimuth should always be used whenever possible. If both higher and lower survey echelons initiate surveys by using correct grid azimuths, any discrepancy which exists between surveys due to assumption of coordinates will be constant for all points located (fig. 141). When it is necessary to assume the coordinates and height of the starting point, they should approximate the correct coordinates and height as closely as possible. The approximate coordinates can be determined from a large-scale map. The use of starting data determined from a map must always be considered assumed data.

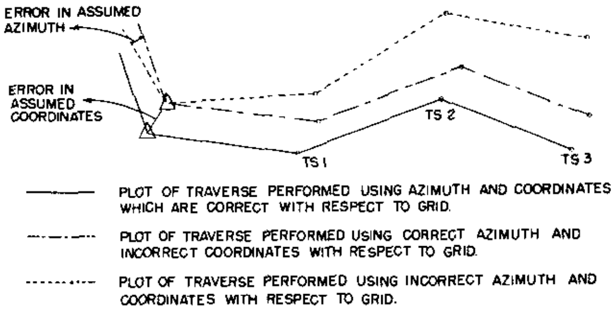



*Figure 141. Discrepancies in survey control caused by use of assumed starting data.*

*c. Use of Known or Assumed Coordinates and Assumed Azimuth.* Assumed azimuth should be used for a starting azimuth only when azimuth cannot be determined by astronomic observations, an azimuth gyro or computation. The assumed azimuth should approximate the correct grid azimuth as closely as possible. The approximate grid azimuth can be determined by scaling from a large-scale map or by using a declinated aiming circle. If either (or both) higher or lower echelon survey operations are initiated with assumed azimuths, differences of varying magnitude will exist between the coordinates of points located by their surveys (fig. 141). This variation complicates the problem of conversion to common control. For this reason, assumed azimuth should never be used if the correct grid azimuth is known or can be determined.

## 325. Coordinates and Height Conversion (Sliding the Grid)

When both a higher and a lower survey echelon start survey operations with correct grid azimuth but one (or both) echelon(s) starts (start) with assumed coordinates and height, the lower echelon must apply coordinate and height corrections to the location of each critical point to convert to the grid of the higher echelon. This coordinate and height conversion is commonly referred to as sliding the grid (fig. 142) and is accomplished as follows:

*a.* Determine the difference in easting and northing coordinates and the difference in height between the assumed coordinates and height of the starting point and the common grid coordinates and height of the starting point.

| | *Easting* | *Northing* | *Height* |
|---|---|---|---|
| Assumed starting point: | 550000.00 | 3838000.00 | 400.0 |
| Common grid starting point: | 550196.52 | 3837887.89 | 402.3 |
| Correction: | +196.52 | −112.11 | +2.3 |

The difference becomes the correction when the difference is given a sign which will cause the algebraic sum of the assumed data and the correction to equal the common grid data.

*b.* Apply the corrections algebraically to the coordinates and height (as determined by the lower echelon) of each station to be converted.

## 326. Azimuth Conversion (Swinging the Grid)

If a unit initiates survey operations using correct grid coordinates but assume azimuth for the starting point, the coordinates of each station in the survey and the azimuths determined by survey will be in error when correct direction is determined for the starting point.

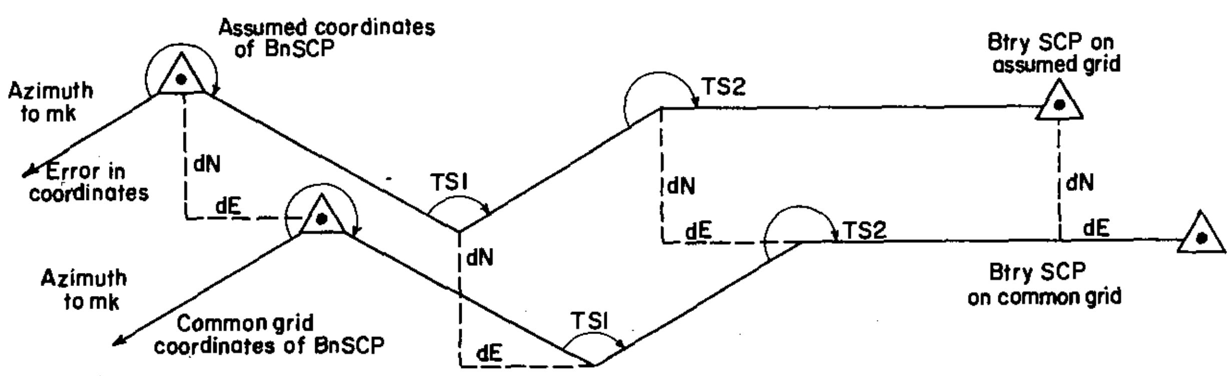



*Figure 142. Sliding the grid.*

In order to convert the assumed data to correct grid data, all azimuths and coordinates determined in the scheme must be corrected. The application of the azimuth correction is commonly referred to as swinging the grid. The procedures for swinging the grid are as follows:

*a.* Determine the difference between the assumed starting azimuth and the azimuth obtained from common control.

| | |
|---|---|
| Assumed starting azimuth: | 2,800.0 mils |
| Common grid starting azimuth: | 2,922.7 mils |
| Azimuth correction: | +122.7 mils |

The difference becomes the azimuth correction when the difference is given a sign which will cause the algebraic sum of the correction and the assumed azimuth to equal the common grid azimuth.

*b.* Apply the azimuth correction to each leg of the survey.

*c.* Since this will change the azimuth of each, the bearing angle of each leg will be changed. Recompute each leg of the survey by using the corrected azimuths and new coordinates determined for each station in the survey, thus placing all stations on the common grid.

*d.* If it is desired to determine the common grid data for a specific point only, compute the azimuth and distance from the starting point to the designated point (assumed data). Apply the azimuth correction to the azimuth determined and recompute the location of the designated point from the starting point, using the corrected azimuth and the distance determined by computation (fig. 143).

*e.* To correct the azimuth of an orienting line, apply the azimuth correction to the azimuth determined through the use of assumed data.

## 327. Azimuth, Coordinates, and Height Conversion (Swing and Sliding the Grid)

If either (of both) a higher or a lower survey echelon initiates survey operation with assumed azimuth, coordinates, and height, the lower echelon must apply azimuth, coordinate, and height corrections to critical locations and

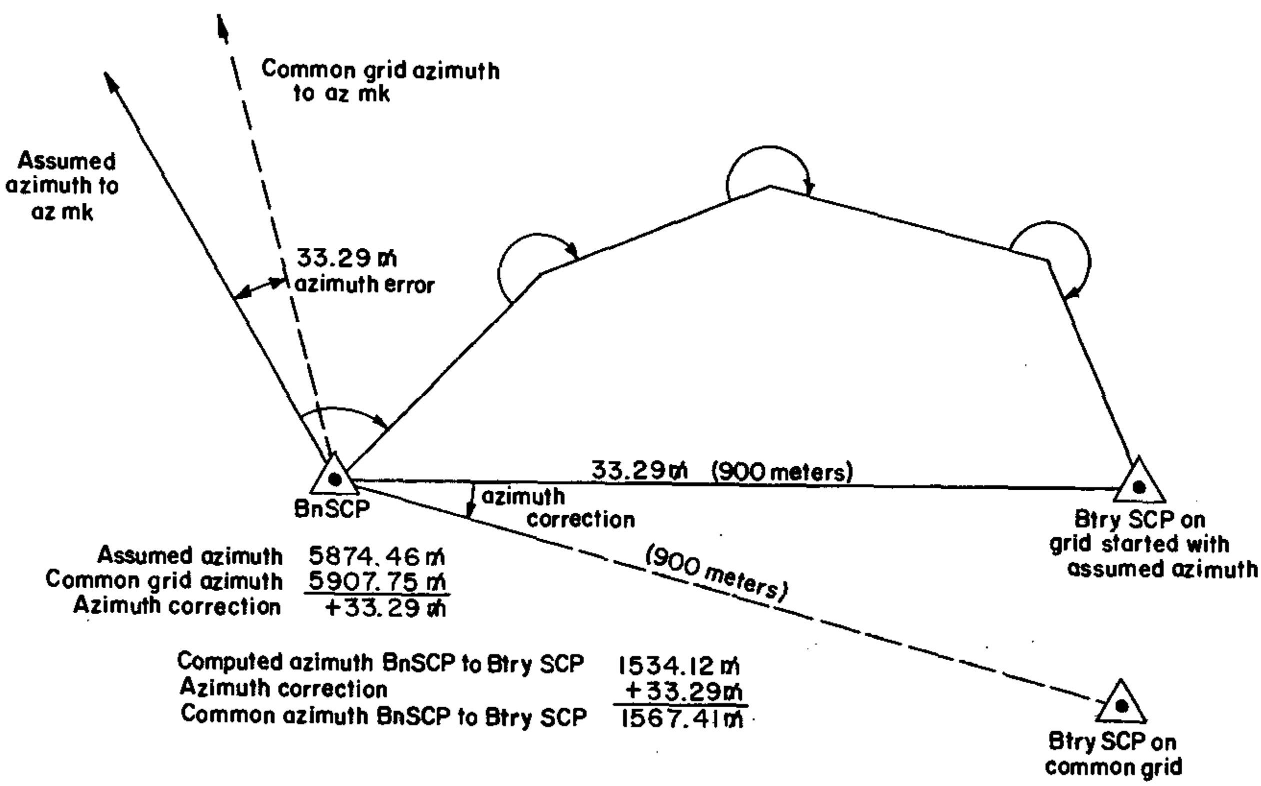



*Figure 143. Swinging the grid for a specific station.*

directions to convert to the grid of the higher echelon. This technique is commonly referred to as swinging and sliding the grid and both swinging and sliding may be accomplished at the same time. Only the critical points (e.g., battery centers, Registration Points, OP's) are converted. The steps in swinging and sliding the grid (fig. 144) are as follows:

*a.* Using the assumed coordinates, compute the azimuth and distance from the starting point to the first critical point and from the first critical point to the second critical point. Continue this sequence of computations until the closing point is reached.

*b.* Determine the azimuth correction by comparing the assumed starting direction with the common grid starting direction. Apply the azimuth correction to each of the computed azimuths determined in *a* above.

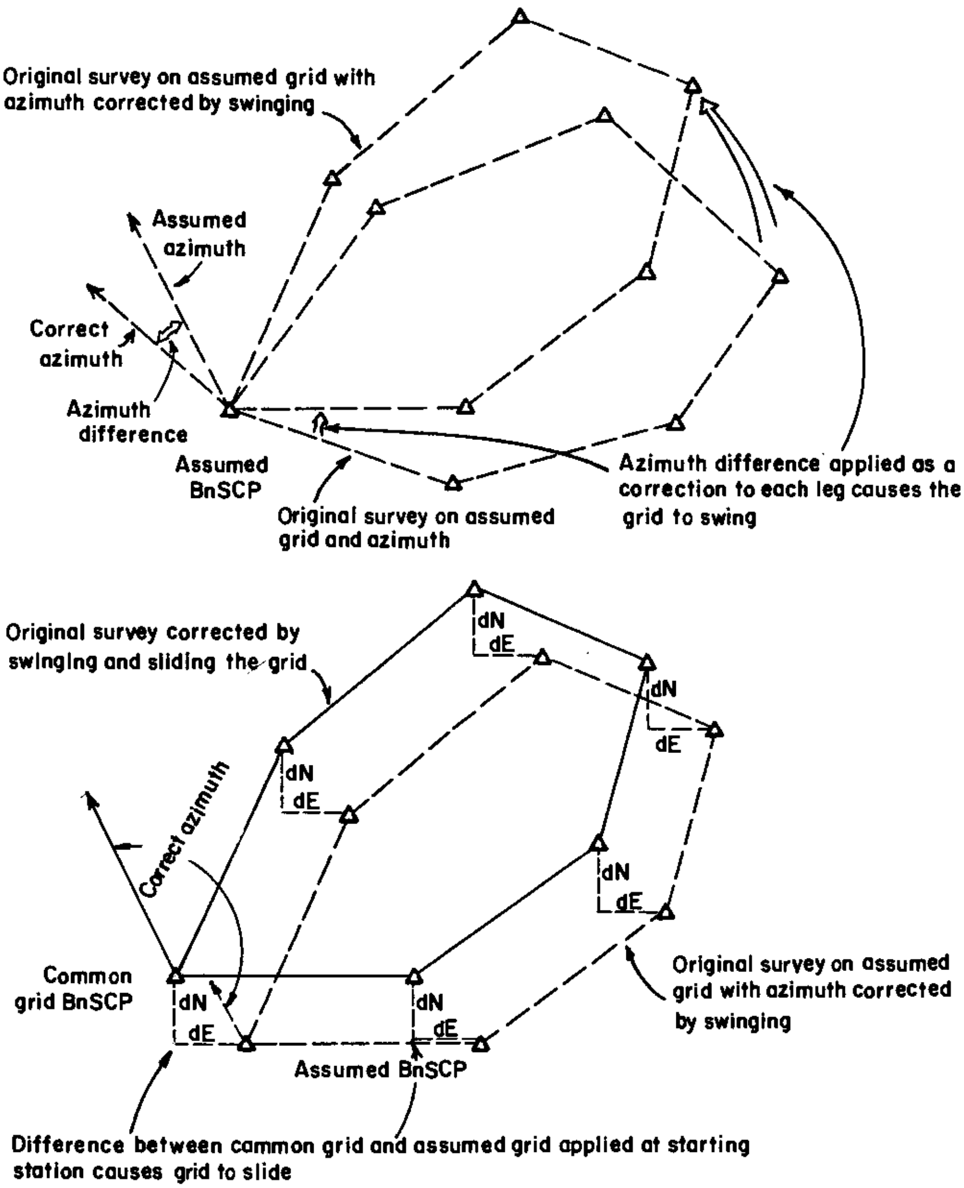



*Figure 144. Swinging and sliding the grid.*

*c.* Using the common grid coordinates of the starting point, the corrected azimuths (*b* above), and the computed distances between critical points (*a* above), compute the coordinates of the first critical point. Using the new coordinates of the first critical point, the corrected azimuth, and the computed distance to the second point, recompute the coordinates of the second critical point and continue the computations until the closing point is reached.

*d.* Correct the height of the critical points by applying the height correction.

## 328. Swinging and Sliding the Grid (Graphically)

The procedures discussed in paragraph 327 require considerable mathematical computations in order to convert to common control. If time is critical, a graphical solution to conversion to common control can be used. However, control cannot be extended from data obtained from a graphical solution. Normally, the graphical solution is used in conjunction with a firing chart. An overlay is made of the existing critical points, including the battalion survey control point and a line of direction to the azimuth mark, and then the critical points are transferred to a new chart. The procedures are as follows:

*a.* Plot the coordinate locations, as determined from assumed data, for the battalion SCP and all critical points. Plot the azimuth (assumed) to the mark on the chart.

*b.* Place a sheet of overlay paper over the chart and prick the locations of the battalion SCP and critical points.

*c.* Trace the line of direction from the chart to the overlay.

*d.* Plot the common control coordinates of the battalion SCP and the common control azimuth to the mark on a new chart.

*e.* Place the overlay on the new chart, alining battalion SCP on battalion SCP and azimuth line on azimuth line.

*f.* Prick the locations of all critical points shown on the overlay onto the new chart.

# CHAPTER 16

# CONVERSION AND TRANSFORMATION

## Section I. CONVERSION OF COORDINATES

### 329. General

Occasionally it may be necessary to convert grid data to geographic and/or geographic data to grid data.

*a*. When coordinates are transformed from a UTM zone to a UPS zone or from a UPS zone to a UTM zone, it is necessary to convert grid coordinates to geographic coordinates and then to convert the geographic coordinates to grid coordinates for the new zone. (To transform a grid azimuth from a UTM zone to a UPS zone or from a UPS zone to a UTM zone, it is necessary to convert the true azimuth to a grid azimuth for the new zone; this is accomplished by subtracting the convergence from the grid azimuth for the old zone and applying the convergence for the new zone.)

*b*. When only the geographic coordinates are known for a point which will be used to initiate or check survey operations, it is necessary to convert the geographic coordinates to UTM (or UPS) grid coordinates. (Geographic coordinates must be correct to the nearest 0.001 second to obtain UTM (UPS) coordinates correct to 0.03 meter.)

*c*. When azimuth is obtained from astronomic obesrvations, it is necessary to know the latitude and longitude of the astronomic observation station. If they are not known, the geographic coordinates of the station can be obtained by conversion from grid coordinates.

### 330. Conversion of Distance

Before the distance between two points can be determined, the coordinates of both points must be based on a common system (for example, both geographic coordinates or UTM coordinates). If the distance is computed from UTM coordinates, the log scale factor must be applied to obtain ground distance.

### 331. Procedures for Conversion of Coordinates

*a*. The procedures for converting UPS grid coordinates to geographic coordinates and for converting geographic coordinates to UPS grid coordinates are discussed in TM 5–241–1.

*b*. In artillery surveys, UTM grid coordinates are converted to geographic coordinates and geographic coordinates are converted to UTM grid coordinates by using DA Forms 6–22, 6–23, and 6–25 together with the technical manuals containing data relative to the appropriate spheroid. TM 5–241–1 contains a map showing the various spheroids. A spheroid is an assumed size and shape of the earth for the purpose of computing geodetic positions.

*c*. The spheroids and their associated technical manuals are shown below:

*International Spheroid* (South America, Europe, Australia, China, Hawaii, and South Pacific): TM 5–241–3/1 and TM 5–241–3/2.

*Clarke 1866 Spheroid* (United States, Mexico, Alaska, Canada, and Greenland): TM 5–241–4/1 and TM 5–241–4/2.

*Bessel Spheroid* (Japan, USSR, Korea, Borneo, Celebes, and Sumatra): TM 5–241–5/1 and TM 241–5/2.

*Clarke 1880 Spheroid* (Africa): TM 5–241–6/1 and TM 5–241–6/2.

*Everest Spheroid* (India, Tibet, Burma, Malay, and Thailand): TM 5–241–7.

### 332. Use of DA Form 6–22 (Computation—Conversion UTM Grid Coordinates to Geographic Coordinates (Machine))

DA Form 6–22 (fig. 145) is used to convert UTM grid coordinates to geographic coordinates. Instructions for the use of the form are contained on the reverse side of the form. Figure 145 shows an example of the entries that are made on DA Form 6–22 for converting UTM grid coordinates to geographic coordinates. The longitude of the central meridian (item 39) can be obtained from the UTM grid zone by using the table on the reverse side of DA Form 6–22. The UTM grid zone number can be determined from a map or from a trig list.

### 333. Use of DA Form 6–23 (Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Logarithms))

*a.* DA Form 6–23 (fig. 146) is used to convert geographic coordinates to UTM grid coordinates. Instructions for the use of the form are contained on the reverse side of the form. Figure 146 shows an example of the entries that are made on DA Form 6–23 for converting geographic coordinates to UTM grid coordinates. Longitude of the central meridian (and UTM grid zone number) (item 2) is obtained from the table on the reverse side of DA Form 6–23.

*b.* Logarithms entered on DA Form 6–23 must be correct to the seventh digit in the mantissa. The complete number for which the logarithm is obtained must be used as the argument in obtaining the logarithm. The mantissa of the logarithm must be determined to the eighth digit and then rounded off to the seventh digit. Antilogarithms must be determined to the third digit after the decimal point.

### 334. Use of DA Form 6–25 (Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Machine))

DA Form 6–25 (fig. 147) can also be used to convert geographic coordinates to UTM grid coordinates. (DA Form 6–25 is a machine computation form, whereas DA Form 6–23 is a logarithm computation form.) Instructions for the use of the form are contained on the reverse side of the form. Figure 147 shows an example of the entries that are made on DA Form 6–25 for converting geographic coordinates to UTM grid coordinates. Longitude of the central meridian (and UTM grid zone number)—(item 2) — is obtained from the table on the reverse side of DA Form 6–25.

## COMPUTATION – CONVERSION UTM GRID COORDINATES TO GEOGRAPHIC COORDINATES *(MACHINE)*

| STATION | UTM GRID COORDINATES | HEMISPHERE / ZONE |
|---|---|---|
| Flat Top # 2 | E 559,858.430 N 3,836,637.310 | HEMISPHERE: [X] NORTH [ ] SOUTH; UTM GRID ZONE NUMBER 14 |

| Step | Operation | Value |
|---|---|---|
| 1 | EASTING COORDINATE OF STATION *(As accurately as known)* | 559 , 858 , 430 |
| 2 | | 5 0 0 , 0 0 0 , 0 0 0 |
| 3 | IF (1) IS MORE THAN (2), USE (1) − (2) IF (1) IS LESS THAN (2), USE (2) − (1) *(Sign always +)* (+) | 59 , 858 , 430 |
| 4 | REPEAT (3) WITH DECIMAL POINT MOVED LEFT SIX PLACES | 059 , 858 , 430 |
| 5 | (4) X (4) | 003 , 583 , 032 |
| 6 | (3) X (4) | 000 , 214 , 475 |
| 7 | (6) X (4) | 000 , 012 , 838 |
| 8 | NORTHING COORDINATE OF STATION [*(As accurately as known)* IF HEMISPHERE IS SOUTH, USE 10,000,000.000 MINUS NORTHING COORDINATE OF STATION] | 1 0 , 0 0 0 , 0 0 0 , 0 0 0 <br> 3 , 836 , 637 , 310 |
| 9* | TABULAR VALUE FUNCTION I NEAREST TO AND LESS THAN VALUE IN (8) | 3 , 835 , 882 , 131 |
| 10* | LATITUDE IN DEGREES AND MINUTES OPPOSITE VALUE IN (9) | 34° 40' |
| 11* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION I IN (9) | 30 , 801 , 99 |
| 12* | TABULAR VALUE FUNCTION VII OPPOSITE LATITUDE IN (10) | 1 , 758 , 849 |
| 13* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION VII IN (12) | 0 , 018 , 12 |
| 14* | TABULAR VALUE FUNCTION VIII OPPOSITE LATITUDE IN (10) | 23 , 10 |
| 15* | GRAPHIC VALUE D6 = SECONDS OF ARC [USE VALUE IN STEP 4 AS ARGUMENT. ENTER GRAPH AT LEFT SIDE *(Sign always −)*] (−) | 0 |
| 16 | (8) − (9) | 755 , 179 |
| 17 | (16) ÷ (11) | 24 , 517 |
| 18 | (17) + (10) = APPROXIMATE LATITUDE OF STATION IN DEGREES, MINUTES, SECONDS | 34° 40' 24 , 517 |
| 19 | (13) X (17) | 0 , 444 |
| 20 | (19) + (12) | 1 , 759 , 293 |
| 21 | (20) X (3) = SECONDS OF ARC | 6 , 304 |
| 22 | CONVERT (21) TO MINUTES AND SECONDS OF ARC *(Sign always −)* (−) | ' 6 , 304 |
| 23 | (7) X (14) = SECONDS OF ARC | 0 , 000 |
| 24 | ALGEBRAIC SUM OF (15), (18), (22), AND (23) = LATITUDE OF STATION IN HEMISPHERE SHOWN ABOVE | N/S 34° 40' 18 , 213 |

| Step | Operation | Value |
|---|---|---|
| 25* | TABULAR VALUE FUNCTION IX OPPOSITE LATITUDE IN (10) | 39 , 291 , 762 |
| 26* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION IX IN (25) | 0 , 131 , 19 |
| 27* | TABULAR VALUE FUNCTION X OPPOSITE LATITUDE IN (10) | 315 , 254 |
| 28* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION X IN (27) | 0 , 004 , 23 |
| 29* | GRAPHIC VALUE $\Delta^2$(1X) [USE (17) AS ARGUMENT. ENTER GRAPH AT LEFT SIDE *(Sign always −)*] (−) | 001 |
| 30* | GRAPHIC VALUE $E_5$ = SECONDS OF ARC [USE STEP (4) AS ARGUMENT AT LEFT SIDE OF GRAPH. USE STEP (10) AS ARGUMENT AT TOP OF GRAPH] | 0 |
| 31 | (17) X (26) | 3 , 216 |
| 32 | ALGEBRAIC SUM (25), (29), AND (31) *(Sign always +)* (+) | 39 , 294 , 977 |
| 33 | (32) X (4) = SECONDS OF ARC *(Sign always +)* (+) | 2 , 352 , 136 |
| 34 | (17) X (28) | 0 , 104 |
| 35 | (34) + (27) | 315 , 358 |
| 36 | (33) X (6) = SECONDS OF ARC *(Sign always −)* (−) | 0 , 068 |
| 37 | ALGEBRAIC SUM (30), (33), AND (36) = SECONDS OF ARC *(Sign always +)* (+) | 2 , 352 , 068 |
| 38 | CONVERT (37) TO DEGREES, MINUTES, SECONDS OF ARC | 0° 39' 12 , 068 |
| 39 | LONGITUDE OF CENTRAL MERIDIAN OF UTM GRID ZONE BEING USED *(Use table)* | 99° ~~EAST~~ WEST LONGITUDE |
| 40 | LONGITUDE OF STATION | 98° 59' 60" 000 |
| | IF (39) IS WEST LONGITUDE AND (1) IS LESS THAN (2), USE (38) + (39) | 39 12 068 |
| | IF (39) IS WEST LONGITUDE AND (1) IS MORE THAN (2), USE (39) − (38) | |
| | IF (39) IS EAST LONGITUDE AND (1) IS LESS THAN (2), USE (39) − (38) | E/W |
| | IF (39) IS EAST LONGITUDE AND (1) IS MORE THAN (2), USE (38) + (39) | 98° 20' 47" 932 |

* *Obtained from UTM Grid Tables for spheroid being used, Volume II.*

COMPUTER: Kissinger

CHECKER: West

DATE: 19 January 1961

**DA FORM 1 SEP 57 6-22**

*Figure 145. Entries made on DA Form 6-22 for converting UTM grid coordinates (machine).*

## COMPUTATION – CONVERSION GEOGRAPHIC COORDINATES TO UTM GRID COORDINATES (*Logarithms*)

STATION: **STILL** — HEMISPHERE: [X] NORTH [ ] SOUTH

LATITUDE: 34° 38′ 31″ 738 — LONGITUDE: 98° 23′ 14″ 830 [ ] EAST [X] WEST

| | | |
|---|---|---|
| 1 | LONGITUDE OF STATION (*as accurately as known*) | 98° 23′ 14″ 830 |
| 2 | LONGITUDE OF CENTRAL MERIDIAN OF UTM GRID ZONE BEING USED | 99° |
| 3 | IF (1) IS MORE THAN (2), USE (1)−(2); IF (1) IS LESS THAN (2), USE (2)−(1) (*Sign always +*) (+) | 98° 23′ 14″ 830<br>0 36 45 170 |
| 4 | CONVERT (3) TO SECONDS OF ARC | 2 205″ 170 |
| 5 | REPEAT (4) WITH DECIMAL POINT MOVED LEFT FOUR PLACES | 0 220 517 0 |
| 6 | LOG (5) | 9 343 4421 |
| 7 | REPEAT (6) | 9 343 4421 |
| 8 | (6) + (7) | 8 686 8842 |
| 9 | REPEAT (6) | 9 343 4421 |
| 10 | (8) + (9) | 8 030 3263 |
| 11 | REPEAT (6) | 9 343 4421 |
| 12 | (10) + (11) | 7 373 7684 |
| 13 | *TABULAR VALUE FUNCTION I OPPOSITE LATITUDE (*Degrees, minutes*) OF STATION (+) | 3 832 185 907 |
| 14 | *TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION I IN (13) (+) | 30 801 82 |
| 15 | *TABULAR VALUE FUNCTION II OPPOSITE LATITUDE (*Degrees, minutes*) OF STATION (+) | 3 507 616 |
| 16 | *TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION II IN (15) (±) | 0 012 92 |
| 17 | *TABULAR VALUE FUNCTION III OPPOSITE LATITUDE (*Degrees, minutes*) OF STATION (±) | 2 123 |
| 18 | *GRAPHIC VALUE $A_6$ (*Use value in Step (3) as argument. Enter Graph at left side*) (±) | 0 000 |
| 19 | LOG (*seconds*) LATITUDE OF STATION (*Use seconds part of latitude of station shown at top of computation*) | 1 501 5796 |
| 20 | LOG (14) | 1 488 5761 |
| 21 | (19) + (20) | 2 990 1557 |
| 22 | REPEAT (19) | 1 501 5796 |
| 23 | LOG (16) | 8 111 2625 |
| 24 | (22) + (23) | 9 612 8421 |
| 25 | REPEAT (15) (+) | 3 507 616 |
| 26 | NUMBER HAVING LOG (24) IF SIGN OF (16) IS (+), USE SIGN (+) IF SIGN OF (16) IS (−), USE SIGN (−) (±) | 0 410 |
| 27 | ALGEBRAIC SUM (25) AND (26) (*Sign always +*) (+) | 3 508 026 |
| 28 | LOG (27) | 3 545 0633 |
| 29 | REPEAT (8) | 8 686 8842 |
| 30 | (28) + (29) | 2 231 9475 |
| 31 | LOG (17) | 0 326 9500 |
| 32 | REPEAT (12) | 7 373 7684 |
| 33 | (31) + (32) | 7 700 7184 |
| 34 | NUMBER HAVING LOG (33) IF SIGN OF (17) IS (+), USE SIGN (+) IF SIGN OF (17) IS (−), USE SIGN (−) (±) | 0 005 |
| 35 | REPEAT (18) (±) | 0 000 |
| 36 | ALGEBRAIC SUM (34) AND (35) (±) | 0 005 |
| 37 | REPEAT (13) (+) | 3 832 185 907 |
| 38 | NUMBER HAVING LOG (21) (*Sign always +*) (+) | 977 588 |
| 39 | NUMBER HAVING LOG (30) (*Sign always +*) (+) | 170 588 |
| 40 | (37) + (38) + (39) (+) | 3 833 334 083 |
| 41 | REPEAT (36) (±) | 0 005 |
| 42 | ALGEBRAIC SUM (40) AND (41) (*Sign always +*) (+) | 3 833 334 088 |
| 43 | NORTHING UTM GRID COORDINATE OF STATION<br>IF HEMISPHERE OF STATION IS NORTH, REPEAT (42)<br>IF HEMISPHERE OF STATION IS SOUTH, USE 10,000,000.000 − (42) | 3 833 334 09 |

| | | |
|---|---|---|
| 44 | *TABULAR VALUE FUNCTION IV OPPOSITE LATITUDE (*Degrees, minutes*) OF STATION (+) | 254 608 158 |
| 45 | *TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION IV IN (44) (−) | 0 848 86 |
| 46 | *TABULAR VALUE FUNCTION V OPPOSITE LATITUDE (*Degrees, minutes*) OF STATION (±) | 35 622 |
| 47 | *TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION V IN (46) (±) | 0 001 03 |
| 48 | *GRAPHIC VALUE $B_5$ [USE LATITUDE (*Degrees, Minutes*) AS ARGUMENT AT TOP OF GRAPH. USE VALUE IN STEP (3) AS ARGUMENT AT LEFT SIDE OF GRAPH] (±) | 0 000 |
| 49 | *GRAPHIC VALUE $\Delta^2$ (IV) [USE LATITUDE (*Seconds*) OF STATION AS ARGUMENT. ENTER GRAPH AT LEFT SIDE] (+) | 003 |
| 50 | REPEAT (44) (+) | 254 608 158 |
| 51 | (49) + (50) (+) | 254 608 161 |
| 52 | LOG (45) | 9 928 8361 |
| 53 | REPEAT (19) | 1 501 5796 |
| 54 | (52) + (53) | 1 430 4157 |
| 55 | LOG (47) | 7 012 8372 |
| 56 | REPEAT (19) | 1 501 5796 |
| 57 | (55) + (56) | 8 514 4168 |
| 58 | REPEAT (46) (±) | 35 622 |
| 59 | NUMBER HAVING LOG (57) [USE SIGN OF (47)] (±) | 0 033 |
| 60 | ALGEBRAIC SUM (58) AND (59) (±) | 35 589 |
| 61 | LOG (60) | 1 551 3158 |
| 62 | REPEAT (10) | 8 030 3263 |
| 63 | (61) + (62) | 9 581 6421 |
| 64 | REPEAT (51) (+) | 254 608 161 |
| 65 | NUMBER HAVING LOG (54) (−) | 26 941 |
| 66 | ALGEBRAIC SUM (64) AND (65) (*Sign always +*) (+) | 254 581 220 |
| 67 | LOG (66) | 5 405 8264 |
| 68 | REPEAT (6) | 9 343 4421 |
| 69 | (67) + (68) | 4 749 2685 |
| 70 | NUMBER HAVING LOG (63) [USE SIGN OF (60)] (±) | 0 382 |
| 71 | REPEAT (48) (±) | 0 000 |
| 72 | ALGEBRAIC SUM (70) AND (71) (±) | 0 382 |
| 73 | NUMBER HAVING LOG (69) (*Sign always +*) (+) | 56 139 494 |
| 74 | REPEAT (72) (±) | 0 382 |
| 75 | ALGEBRAIC SUM (73) AND (74) (*Sign always +*) (+) | 56 139 876 |
| 76 | EASTING UTM GRID COORDINATE OF STATION<br>IF LONGITUDE IS EAST AND (1) IS MORE THAN (2), USE 500,000.000 + (75)<br>IF LONGITUDE IS EAST AND (1) IS LESS THAN (2), USE 500,000.000 − (75)<br>IF LONGITUDE IS WEST AND (1) IS MORE THAN (2), USE 500,000.000 − (75)<br>IF LONGITUDE IS WEST AND (1) IS LESS THAN (2), USE 500,000.000 + (75) | 5 0 0 0 0 0 0 0 0<br>556 139 88 |

*Obtained from UTM Grid Tables for spheroid being used, Volume I

COMPUTER: **SFC J DOE**

CHECKER: **Cpl R ROE**

DATE: **1 Feb 61**

DA FORM 1 SEP 52 6-23

*Figure 146. Entries made on DA Form 6–23 for converting geographic coordinates to UTM grid coordinates (logarithms).*

**COMPUTATION – CONVERSION GEOGRAPHIC COORDINATES TO UTM GRID COORDINATES *(MACHINE)***

| STATION | LATITUDE ° ' " | LONGITUDE ° ' " | ☐ EAST ☒ WEST | HEMISPHERE |
|---|---|---|---|---|
| SILL | 34 38 31.738 | 98 23 14.830 | WEST | ☒ NORTH ☐ SOUTH |

| | | | |
|---|---|---|---|
| 1 | LONGITUDE OF STATION *(As accurately as known)* | | 98° 23' 14." 830 |
| 2 | LONGITUDE OF CENTRAL MERIDIAN OF UTM GRID ZONE BEING USED | | 99° |
| 3 | IF (1) IS MORE THAN (2), USE (1)−(2) IF (1) IS LESS THAN (2), USE (2)−(1) *(Sign always +)* | (+) | 98° 23' 14." 830 / 0° 36' 45." 170 |
| 4 | CONVERT (3) TO SECONDS OF ARC | | 22 05 . 170 |
| 5 | REPEAT (4) WITH DECIMAL POINT MOVED LEFT FOUR PLACES | | 0 . 220 517 0 |
| 6 | (5) X (5) | | 0 . 048 627 7 |
| 7 | (6) X (5) | | 0 . 010 723 |
| 8 | (7) X (5) | | 0 . 002 4 |
| 9* | TABULAR VALUE FUNCTION I OPPOSITE LATITUDE *(Degrees, minutes)* OF STATION | | 3 832 185 . 907 |
| 10* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION I IN (9) | | 30 . 801 82 |
| 11* | TABULAR VALUE FUNCTION II OPPOSITE LATITUDE *(Degrees, minutes)* OF STATION | | 3 507 . 616 |
| 12* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION II IN (11) | (±) | 0 . 012 192 |
| 13* | TABULAR VALUE FUNCTION III OPPOSITE LATITUDE *(Degrees, minutes)* OF STATION | (±) | 2 . 123 |
| 14* | GRAPHIC VALUE $A_6$ [USE VALUE IN STEP (5) AS ARGUMENT. ENTER GRAPH AT LEFT SIDE] | (±) | 0 . 000 |
| 15 | (10) X LATITUDE *(Seconds)* OF STATION | (+) | 977 . 588 |
| 16 | (12) X LATITUDE *(Seconds)* OF STATION | (±) | 0 . 410 |
| 17 | ALGEBRAIC SUM (11) AND (16) *(Sign always +)* | (+) | 3 508 . 026 |
| 18 | (17) X (4) | (+) | 170 . 587 |
| 19 | (13) X (6) | (±) | 0 . 005 |
| 20 | ALGEBRAIC SUM (9), (14), (15), (18), AND (19) *(Sign always +)* | | 3 833 334 . 087 |
| 21 | NORTHING UTM GRID COORDINATE OF STATION. IF HEMISPHERE OF STATION IS NORTH, REPEAT (20). IF HEMISPHERE OF STATION IS SOUTH, USE 10,000,000.000 − (20) | | 3 833 334 . 09 |

| | | | |
|---|---|---|---|
| 22* | TABULAR VALUE FUNCTION IV OPPOSITE LATITUDE *(Degrees, minutes)* OF STATION | | 254 608 . 158 |
| 23* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION IV IN (22) | (−) | 0 . 848 86 |
| 24* | TABULAR VALUE FUNCTION V OPPOSITE LATITUDE *(Degrees, minutes)* OF STATION | (±) | 35 . 622 |
| 25* | TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION V IN (24) | (±) | 0 . 001 03 |
| 26* | GRAPHIC VALUE $B_5$ [USE LATITUDE *(Degrees, minutes)* AS ARGUMENT AT TOP OF GRAPH. USE VALUE IN STEP (5) AS ARGUMENT AT LEFT SIDE OF GRAPH] | (±) | 0 . 000 |
| 27* | GRAPHIC VALUE $\Delta^2$ *(IV)* [USE LATITUDE *(Seconds)* OF STATION AS ARGUMENT. ENTER GRAPH AT LEFT SIDE] | (+) | . 003 |
| 28 | (23) X LATITUDE *(Seconds)* OF STATION | (−) | 26 . 941 |
| 29 | (25) X LATITUDE *(Seconds)* OF STATION | (±) | 0 . 033 |
| 30 | ALGEBRAIC SUM (24) AND (29) | (±) | 35 . 589 |
| 31 | (30) X (7) | (±) | 0 . 382 |
| 32 | ALGEBRAIC SUM (22), (27), AND (28) *(Sign always +)* | (+) | 254 581 . 220 |
| 33 | (32) X (5) *(Sign always +)* | (+) | 56 139 . 487 |
| 34 | ALGEBRAIC SUM (26), (31), AND (33) *(Sign always +)* | (+) | 56 139 . 869 |
| 35 | EASTING UTM GRID COORDINATE OF STATION. IF LONGITUDE IS EAST AND (1) IS MORE THAN (2), USE 500,000.000 + (34). IF LONGITUDE IS EAST AND (1) IS LESS THAN (2), USE 500,000.000 − (34). IF LONGITUDE IS WEST AND (1) IS MORE THAN (2), USE 500,000.000 − (34). IF LONGITUDE IS WEST AND (1) IS LESS THAN (2), USE 500,000.000 + (34) | | 500 000 . 000 / 556 139 . 87 |

*OBTAINED FROM UTM GRID TABLES FOR SPHEROID BEING USED, VOLUME I

COMPUTER: SFC J DOE

CHECKER: Cpl R ROE

DATE: 1 February 1961

DA FORM 1 SEP 52 6-25

*Figure 147. Entries made on DA Form 6–25 for converting geographic coordinates to UTM grid coordinates (machine).*

### 335. General

When field artillery units are operating across grid zone junctions, it will frequently be necessary to transform the grid coordinates of points and the grid azimuth of lines from the grid for one zone to the grid of the adjacent zone. Special tables, which are available through the Army Map Service, permit transformation across several zones in a single computation.

*a.* The method of transforming grid coordinates from a UTM zone to a UPS zone or from a UPS zone to a UTM zone is discussed in paragraph 329.

*b.* In the UTM grid system are overlap areas east and west of zone junctions. However, transformation is not restricted to these overlap areas. Grid coordinates (and azimuths) can be transformed from any point in one zone into terms of an adjacent zone. To understand what takes place when transformation is performed, refer to figure 148. Figure 148 shows two adjacent UTM zones, 14 and 15. In terms of northing coordinates they are numbered the same, since the origin of the northing coordinate is the equator. However, the easting coordinates from left to right are not a continuous series of numbers, since the origin of the easting coordinate for each zone is the central meridian (CM) for that zone and is numbered 500,000. Within each zone, the coordinates increase to the east and decrease to the west from the central meridian. Visualize point P in zone 14. The coordinates are 800,003–3,700,000. If the coordinates of point P were to be transformed to the adjacent grid (zone 15), the action taken would be the equivalent of superimposing the grid of zone 15 over the grid of

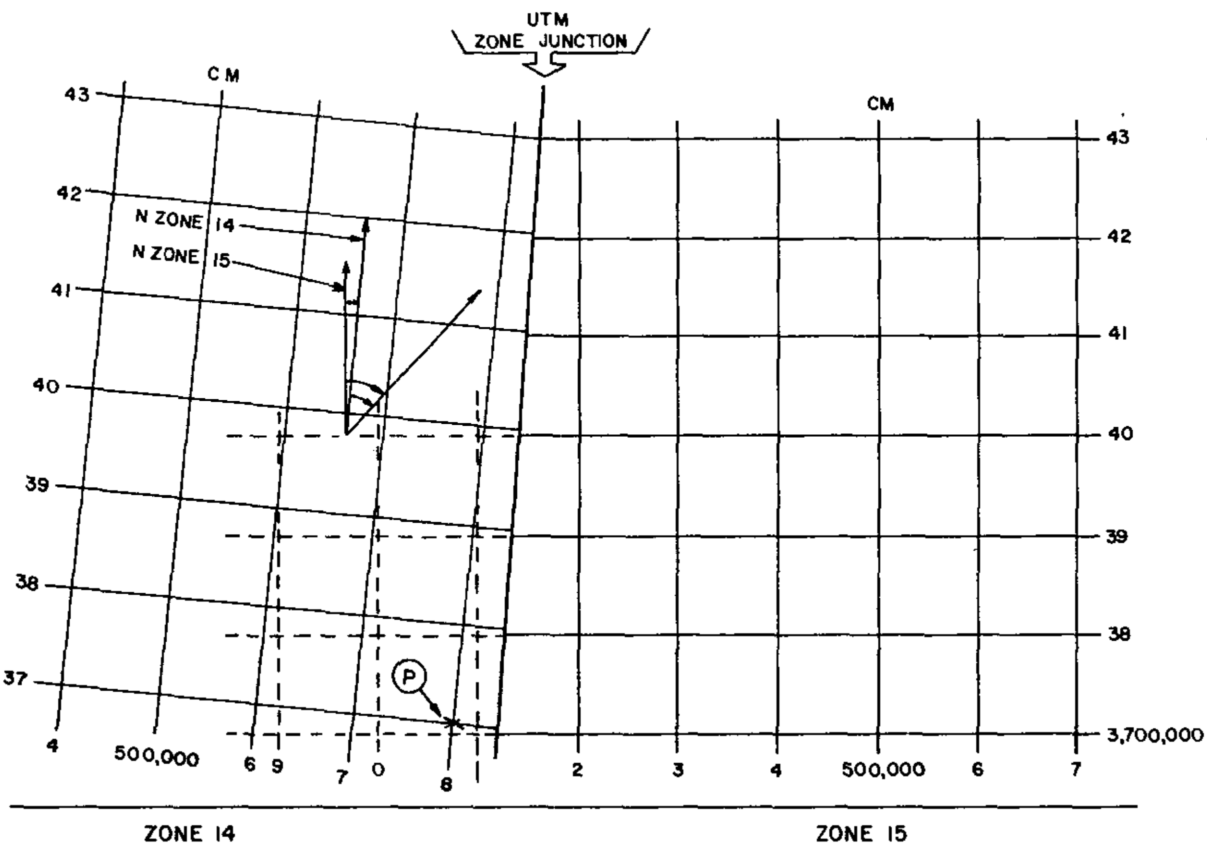



*Figure 148. Transformation requirements.*

zone 14 as indicated in figure 148. Actually, transformation of coordinates involves only the mathematical continuation of the adjacent grid to the grid being used and the subsequent corrections for locations due to the change in grid north reference. Although the location of point P on the ground will not be changed, the value of its original coordinates will change with the transformation. The value in terms of zone 15 would be less than 100,000 meters in easting and greater than 3,700,000 meters in northing. In transformation there will be a major change in the easting coordinates due to the coordinate numbering system of each zone and the change in grid north reference, but there will be only a small change in the northing coordinate, based only on the difference in the grid north reference.

## 336. Use of TM 5–241–2 (Formerly AMS TM NR 50)

*a.* In using TM 5–241–2 to extract the function required for the formulas used in transformation, determine first the spheroid to be used by referring to the map of the world in the back of the technical manual and using it as an index to determine which spheroid tables should be used. The formulas for solving transformation computations are also contained in the technical manual.

*b.* The tables in TM 5–241–2 are compiled for 100,000-meter intervals of easting and northing. A station is considered to be in a 100,000-meter square, and the coordinates of the nearest corner of this square are used for the determination of e and n and for the entering arguments.

*c.* Certain procedures must be followed to insure proper extraction from the tables.

(1) When transforming to the east (such as zone 14 to zone 15), use the e value on the right side of the table and the upper sign if two signs are shown.

(2) When transforming to the west (such as zone 15 to zone 14), use the e value on the left side of the table and the lower sign if two signs are shown.

*d.* When the computations are performed on DA Form 6–36, if the initial zone is considered to be A, the resulting E and N coordinates are for the adjacent zone B. In the Southern Hemisphere, the transformed northing must be subtracted from 10,000,000 to compute the correct coordinate.

## 337. Use of DA Form 6–36

*a.* The use of forms will simplify transformation computations. The form used for zone-to-zone universal transverse Mercator grid coordinates transformation is DA Form 6–36 (fig. 149). This form is designed for use with a computing machine. If a computing machine is not available, multiplication is performed on a separate paper by using logarithms or direct multiplication, and the results are entered in the proper spaces. The form is executed in a straight numerical sequence with the values in lines 11 through 18 ($N_0$, $E_0$, $a_1$, $a_2$, $b_1$, $b_2$, $c_1$, and $c_2$) extracted from TM 5–241–2 for the proper spheroid.

*b.* Formulas on which DA Form 6–36 is based are shown on the back of the form.

## 338. Transformation of UTM Grid Azimuth From Zone to Zone

The reasons for transforming grid coordinates (para 335) are applicable to grid azimuths, and the same reference tables (TM 5–241–2) are employed for the extractions of functions. To understand what transpires in the transformation of azimuth, refer again to figure 148. On the UTM zone to the left (zone 14), a line of direction has been indicated. The azimuth of this line is represented by a horizontal clockwise angle from the grid north for zone 14. If the azimuth of that line is transformed to the grid of the adjacent zone (zone 15), the line of direction does not change; however, due to a new grid north reference line, the azimuth of the line will increase. In figure 148 it is apparent that if azimuth is transformed from a west zone to an east zone, the azimuth will increase; conversely, if azimuth is transformed from an east zone to a west zone, azimuth will decrease.

## 339. DA Form 6–34

*a.* DA Form 6–34 is used for zone-to-zone UTM grid azimuth transformation (fig. 150).

## ZONE TO ZONE UTM GRID COORDINATES TRANSFORMATION

| STATION | LOCALITY |
|---|---|
| SILL | FT SILL, OKLAHOMA |
| FROM ZONE A 14 TO ZONE B 13 | SPHEROID CLARKE 1866 |

| | | | |
|---|---|---|---|
| 1 | E (Zone A) | + | 556 139 87 |
| 2 | (1) TO NEAREST 100,000 METERS (e) | − | 600 000 00 |
| 3 | ALGEBRAIC SUM (1) AND (2) | ⊖ | 43 860 13 |
| 4 | REPEAT (3) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = e' | ⊖ | 0.4386013 |
| 19 | (15) | − | 8 904 |
| 20 | (10) x (17) | ⊖ | 0 012 |
| 21 | ALGEBRAIC SUM (19) AND (20) | ⊖ | 8 916 |
| 22 | (4) x (18) CHANGE SIGN OF RESULT | ⊕ | 0 114 |
| 23 | ALGEBRAIC SUM (21) AND (22) | ⊖ | 8 802 |
| 24 | (16) | ⊖ | 68 056 |
| 25 | (10) x (18) | ⊕ | 0 087 |
| 26 | (4) x (17) | ⊕ | 0 016 |
| 27 | ALGEBRAIC SUM (24), (25), AND (26) | ⊖ | 67 953 |
| 28 | (13) | + | 100 336 277 |
| 29 | (10) x (23) | ⊖ | 2 934 |
| 30 | ALGEBRAIC SUM (28) AND (29) | ⊕ | 100 333 343 |
| 31 | (4) x (27) CHANGE SIGN OF RESULT | ⊖ | 29 804 |
| 32 | ALGEBRAIC SUM (30) AND (31) | + | 100 303 539 |
| 33 | (14) | ⊖ | 5 958 532 |
| 34 | (10) x (27) | ⊖ | 22 652 |
| 35 | (4) x (23) | ⊕ | 3 861 |
| 36 | ALGEBRAIC SUM (33), (34), AND (35) | ⊖ | 5 977 323 |

Enter AMS Technical Manual No. 50 for proper spheroid using values from lines (2) and (8) as arguments. When transforming to east, use (e) value on right side of table and upper of signs; for transforming to west, use (e) value on left side of table and lower of signs.

| | | | |
|---|---|---|---|
| 5 | USE ONLY FOR SOUTHERN HEMISPHERE | | 10 000 000 00 |
| 6 | N (Zone A) | + | 3 833 334 09 |
| 7 | (5) − (6) FOR SOUTHERN HEMISPHERE | + | |
| 8 | (6) OR (7) TO NEAREST 100,000 METERS = (n) | − | 3 800 000 00 |
| 9 | ALGEBRAIC SUM (6) OR (7) AND (8) | ⊕ | 33 334 09 |
| 10 | REPEAT (9) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = n' | ⊕ | 0.3333409 |
| 11 | $N_0$ | + | 3 822 297 707 |
| 12 | $E_0$ | ⊕ | 652 499 349 |
| 13 | $a_1$ | + | 100 336 277 |
| 14 | $a_2$ | ⊖ | 5 958 532 |
| 15 | $b_1$ | − | 8 904 |
| 16 | $b_2$ | ⊖ | 68 056 |
| 17 | $c_1$ | ⊖ | 0 037 |
| 18 | $c_2$ | ⊖ | 0 261 |
| 37 | FALSE EASTING | + | 500 000 000 |
| 38 | (12) | ⊕ | 652 499 349 |
| 39 | (10) x (36) | ⊖ | 1 992 486 |
| 40 | (4) x (32) | ⊖ | 43 993 263 |
| 41 | ALGEBRAIC SUM (37), (38), (39), AND (40) E (Zone B) | ⊕ | 1 106 513 600 |
| 42 | (11) | + | 3 822 297 707 |
| 43 | (10) x (32) | ⊕ | 33 435 272 |
| 44 | ALGEBRAIC SUM (42) AND (43) | ⊕ | 3 855 732 979 |
| 45 | (4) x (36) CHANGE SIGN OF RESULT | ⊖ | 2 621 662 |
| 46 | ALGEBRAIC SUM (44) AND (45) N (Zone B) | + | 3 853 111 317 |
| 47 | USE ONLY FOR SOUTHERN HEMISPHERE | | 10 000 000 00 |
| 48 | REPEAT (46) | | |
| 49 | (47) − (48) FOR SOUTHERN HEMISPHERE N (Zone B) | + | |

| COMPUTER | CHECKER | DATE |
|---|---|---|
| SFC J DOE | Cpl R ROE | 1 Feb 1961 |

DA FORM 1 AUG 54 6-36

*Figure 149. Completed DA Form 6–36.*

## ZONE TO ZONE UTM GRID AZIMUTH TRANSFORMATION

| | |
|---|---|
| STATION: SILL | LOCALITY: FT SILL, OKLAHOMA |
| FROM ZONE A 14 TO ZONE B 13 | SPHEROID: CLARKE 1866 |

| | | | |
|---|---|---|---|
| 1 | AZIMUTH TO BE TRANSFORMED FROM ZONE A TO ZONE B = $T_1$ | | 751 768 m |
| 2 | E (Zone A) | + | 556 139.87 |
| 3 | (2) TO NEAREST 100,000 METERS = (e) | − | 600 000.00 |
| 4 | ALGEBRAIC SUM (2) AND (3) | ± | 43 860.13 |
| 5 | REPEAT (4) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = e' | ± | 0.4386013 |

Enter AMS Technical Manual No. 50 for proper spheroid using values from Lines (3) and (9) as arguments. When transforming to east, use (e) value on right side of table and upper of signs: for transforming to west, use (e) value on left side of table and lower of signs.

| | | | |
|---|---|---|---|
| 6 | USE ONLY FOR SOUTHERN HEMISPHERE | | 10 000 000 00 |
| 7 | N (Zone A) | + | 3 833 334.09 |
| 8 | (6) − (7) FOR SOUTHERN HEMISPHERE | + | |
| 9 | (7) OR (8) TO NEAREST 100,000 METERS = (n) | − | 3 800 000.00 |
| 10 | ALGEBRAIC SUM (7) OR (8) AND (9) | ± | 33 334.09 |
| 11 | REPEAT (10) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = n' | ± | 0.3333409 |
| 12 | $a_1$ | + | 100 336.277 |
| 13 | $a_2$ | ± | 5 958.532 |
| 14 | $b_1$ | − | 8.904 |
| 15 | $b_2$ | ± | 68.056 |
| 16 | $c_1$ | ± | 0.037 |
| 17 | $c_2$ | ± | 0.261 |

| | | | |
|---|---|---|---|
| 18 | (14) X 2 | − | 17.808 |
| 19 | (11) X (16) X 3 | ± | 0.039 |
| 20 | ALGEBRAIC SUM (18) AND (19) | − | 17.847 |
| 21 | (5) X (17) X 3, CHANGE SIGN OF RESULT | ± | 0.342 |
| 22 | ALGEBRAIC SUM (20) AND (21) | − | 17.505 |
| 23 | (15) X 2 | ± | 136.112 |
| 24 | (11) X (17) X 3 | ± | 0.261 |
| 25 | (5) X (16) X 3 | ± | 0.048 |
| 26 | ALGEBRAIC SUM (23), (24), AND (25) | ± | 135.803 |
| 27 | (12) | + | 100 336.277 |
| 28 | (11) X (22) | ± | 5.835 |
| 29 | ALGEBRAIC SUM (27) AND (28) | + | 100 330.442 |
| 30 | (5) X (26) CHANGE SIGN OF RESULT | ± | 59.563 |
| 31 | ALGEBRAIC SUM (29) AND (30) | + | 100 270.879 |
| 32 | (13) | ± | 5 958.532 |
| 33 | (11) X (26) | ± | 45.269 |
| 34 | (5) X (22) | ± | 7.678 |
| 35 | ALGEBRAIC SUM (32), (33), AND (34) | ± | 5 996.123 |
| 36 | | | 10 000 0000 |
| 37 | LOG (31) | | 5 001 1710 |
| 38 | (36) − (37) | | 4 998 8290 |
| 39 | LOG (35) | | 3 777 8703 |
| 40 | (38) + (39) | | 8 776 6993 |
| 41 | ANGLE WHOSE LOG TAN IS (40), USE SIGN OF (35) | ± | 60 839 m |
| 42 | (1) | + | 751 768 m |
| 43 | REPEAT (41), CHANGE SIGN FOR SOUTHERN HEMISPHERE | ± | 60 839 |
| 44 | ALGEBRAIC SUM (42) AND (43) AZIMUTH (Zone B) | | 690 929 m |

| COMPUTER | CHECKER | DATE |
|---|---|---|
| SFC L.T. BURK | CPL THIEN | 1 FEB 19__ |

DA FORM 1 AUG 54 6-34

*Figure 150. Completed DA Form 6–34.*

This form, which is similar to DA Form 6–36, also is designed for use with a computing machine. The procedure used for computations on DA Form 6–36 is used on DA form 6–34 if a computing machine is not available. Also, values for lines 12 through 17 ($a_1$, $a_2$, $b_1$, $b_2$, $c_1$, and $c_2$) are extracted directly from TM 5–241–2, using the tables for the proper spheroid.

*b*. Formulas on which DA Form 6–34 is based are shown on the back of the form.

# CHAPTER 17

# QUALIFICATION TESTS FOR SURVEY SPECIALISTS

## 340. Purpose and Scope

This chapter describes the tests to be given in the qualification of survey specialists at all echelons. Tests based on these outlines are designed to measure a soldier's skill in artillery survey. School training or a technical background is not required prior to taking these tests. Tests based on these outlines are designed to determine the relative proficiency of an individual artillery soldier in the performance of duties as a member of a survey section and are not designed as a basis for determining the relative proficiency of batteries or higher units. These tests are also designed to serve as an incentive for individuals in survey organization to expand their knowledge to cover all duties in the survey organization, thereby increasing their value to the unit.

## 341. Preparation of Tests

The tests will be prepared under the direction of the battalion commander, and should consider the following:

*a.* Tests should be standardized so that the difference between test scores of any two individuals will be a valid measurement of differences in their skills.

*b.* Each crewman interested is a prospective candidate and the tests should be available upon his request.

## 342. Test Organization

The qualification test is organized into three sections with each section designed to test and qualify the individual progressively as a second-class specialist, a first-class specialist and as an expert in artillery survey. Section I is designed to evaluate the qualification of the individual in the basic skills of an artillery surveyor. Section II expands the skill coverage for evaluating the qualifications of an individual in artillery survey. Section III is designed as a comprehensive coverage of the skills required in all echelons of artillery survey.

## 343. Administration of Tests

*a.* The tests based on these outlines are designed to provide for qualification of survey specialists at all echelons. Because of organizational differences and differences in equipment, some modification will be necessary for the administration of these tests to most units. The tests are designed where possible to facilitate this modification. Modification other than those options presented in the tests should be accompanied by a reevaluation of the weighting system.

*b.* The battery commander will be responsible for the testing of personnel within his battery. Generally, tests will be administered as follows:

(1) An officer, warrant officer, or enlisted man who is fully qualified and experienced in the subject covered by the test will be detailed as "examiner" to administer the test.

(2) Each section of the qualification tests may be administrated over a period of time that will be standardized throughout the battalion.

(3) A single test, when started, will be conducted from start to finish without interruption.

(4) The candidate will receive no unauthorized assistance. Assistance will be furnished to the candidate as required for each test. If a candidate fails any test because of the examiner

or any assistant, the test will be disregarded and the candidate will be given another test of the same nature.

(5) Times are not prescribed for each test due to the different requirements of units and because of varying effects of weather on the tests. However, the examiner should make appropriate cuts when "excessive time" is taken to complete a portion of the tests. A decision by the responsible officer as to what constitutes "excessive time" must be made prior to the administration of the tests, based on conditions existing at that time.

(6) The examiner will explain to the candidate the scope of the test and indicate the men who will act as his assistants. The examiner will critique the candidate's performance at the completion of the test and turn the tentative score in to the battery commander. The battery commander will finalize the score and forward the test score to the battalion.

## 344. Qalification Scores

A maximum score of 100 is possible for each section of the test. An individual must achieve a score of 90 percent on section I to be eligible to take section II. A score of 90 percent on section II is required prior to taking section III.

| *Individual classification* | *Points* |
|---|---|
| Expert | 90 on section III |
| First-class specialist | 85 on section II |
| Second-class specialist | 85 on section I |

## 345. Outline of Tests

| Para No. | Subject | Number of tests | Points each | Maximum credit |
|---|---|---|---|---|
| | SECTION I | | | |
| 346 | Map Reading | 4 | | 6 |
| | Tests 1 and 2 | (2) | 2 | (4) |
| | Tests 3 and 4 | (2) | 1 | (2) |
| 347 | Recording | 2 | 11 | 22 |
| 348 | Computing | 4 | | 28 |
| | Tests 1 and 4 | (2) | 5 | (10) |
| | Test 2 | (1) | 8 | (8) |
| | Test 3 | (1) | 10 | (10) |
| 349 | Taping | 1 | 20 | 20 |
| 350 | Instrument Operation | 2 | 12 | 24 |
| | Total | | | 100 |
| | SECTION II | | | |
| | Section I score × .40 | | | 40 |
| 351 | Recording | 2 | 10 | 20 |
| 352 | Computations | 3 | | 20 |
| | Tests 1 and 2 | (2) | 7 | (14) |
| | Test 3 | (1) | 6 | (6) |
| 353 | Instrument Operation | 3 | | 20 |
| | Test 1* | (1) | 8 | (8) |
| | Test 2 | (1) | *8 (12) | *(8)(12) |
| | Test 3 | (1) | *4 (8) | *(4)(8) |
| | * When tellurometer or DME is not issued to a unit Test 1 will be disregarded and point value of Test 1 will be redistributed as follows: Test 2, 12 points; Test 3, 8 points. | | | |
| | Total | | | 100 |
| | SECTION III | | | |
| | Section II total × .50 | | | 50 |
| 354 | Map Reading | 1 | | 5 |
| 355 | Grid Computations | 3 | | 10 |
| | Tests 1 and 2 | (2) | 4 | (8) |
| | Test 3 | (1) | 2 | (2) |
| 356 | Survey Planning | 1 | 15 | 15 |
| 357 | Supervision and Operation | 1 | 20 | 20 |
| | Total | | | 100 |

SECTION I

## 346. Map Reading

*a. Scope of Tests.* Four tests will be conducted to determine the candidate's knowledge of map reading.

*b. Special Instructions.* Prior to the start of the test the examiner will provide the candidates with the following equipment:

(1) Topographic map, scale 1:50,000 or larger.

(2) Boxwood scale or coordinate scale, protractor and map pins.

(3) Military slide rule (if desired by candidate).

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | IDENTIFY THESE SIGNS AND SYMBOLS. (Examiner points to 10 different commonly used military and topographic signs and symbols.) | Identifies signs and symbols as they are pointed out, orally or by writing answer. |
| 2 | COMPUTE THE SCALE OF THIS MAP. (Examiner designates two points on the map at least four inches apart, and gives the candidate a false ground distance between them.) | Measures the map distance between the two points. Computes the scale using the map distance and the false ground distance. Announces or records the result. |
| 3 | MEASURE THE GRID AZIMUTH FROM ________ TO ________. (Examiner points out two prominent points on map at least four inches apart.) | Measures the grid azimuth with the protractor. Announces or records results. |
| 4 | DETERMINE COORDINATES AND HEIGHT OF ________________. (Examiner points out or designates arbitrary feature on map. Advise candidate to read coordinates and height as accurately as possible.) | Reads coordinates of designated point and determines height. Announces or records results. |

*d. Penalties.*

(1) *Test 1.* Deduct 0.2 point for each symbol or sign identified incorrectly.

(2) *Test 2.* Deduct 1 point if the denominator of the representative fraction is in error by more than 100 units and deduct all credit if in error by more than 200 units.

(3) *Test 3.* Deduct 0.5 point if the azimuth is in error by more than 5 mils and 1 point if in error by over 10 mils.

(4) *Test 4.*

(*a*) Deduct 0.6 point if either the easting or northing coordinate is in error by over 50 meters.

(*b*) Deduct 0.4 point if the height is in error by more than one-half of the contour interval of the map.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 347. Recording

*a. Scope of Test.* Two tests will be conducted to determine the candidate's knowledge of recording. The first test will check procedures used with the aiming circle and the second test will be on procedures for the basic survey instrument authorized by TOE.

*b. Special Instructions.* Prior to the start of the test the examiner will make the following preparations:

(1) Provide equipment as listed below:

(*a*) Blank mimeographed sheets from recorder's notebook.

(*b*) 4H and 6H pencil.

(*c*) Straightedge.

(2) Prepare the data so the examiner can read angles and distances, etc., in the same manner as a recorder would receive the data if he were accompanying a survey team in the field. Prepare a rough sketch of the area to permit the candidate to complete the remarks and sketch portion of the field notes.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | RECORD DATA FOR AIMING CIRCLE TRAVERSE. (Examiner reads data in same manner as normally available to recorder.) | Records data as prescribed in chapter 7. Turns in field notes to examiner at completion of the test. |

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 2 | RECORD DATA FOR THEODOLITE TRAVERSE. (Examiner reads data in same manner as normally available to recorder. Include at least one multiple angle. Triangulation or astronomic observation are authorized substitutions.) | Records data as prescribed in chapter 7. Turns in field notes to examiner at completion of the test. |

*d. Penalties.* Penalties will be assessed as follows:

(1) Failure to use proper procedure for recording horizontal or vertical angles, 3 points.

(2) Failure to mean angles correctly, 3 points.

(3) Incomplete or incorrect remarks section, 1 point.

(4) Failure to record data in a neat and legible manner, 10 points.

(5) Any other procedural error, 3 points.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 348. Computing

*a. Scope of Tests.* Four tests will be conducted to determine the candidate's knowledge and ability to solve various survey problems.

*b. Special Instructions.* Prior to the start of the tests the examiner will make the following preparations:

(1) Provide the following equipment:

(*a*) One set of logarithmic tables (six- or seven-place as appropriate) for each candidate.

(*b*) DA Forms 6–1, 6–2, 6–8, 6–19.

(2) Prepare simulated or actual field data for all tests in the format prescribed for the recorder's field notebook. Read or issue copy of data to the candidate.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | COMPUTE THE AZIMUTH AND DISTANCE FROM POINT A TO POINT B. (Furnish coordinates of each point.) | Computes azimuth and distance with DA Form 6–1. |
| 2 | COMPUTE THE FOLLOWING TRAVERSE: COMPUTE ACCURACY RATIO AND AZIMUTH ERROR OF CLOSURE. (Provide coordinates of starting point and azimuth to azimuth mark. Furnish angles and distance in the same manner in which a computer would normally receive this information. Provide coordinates of closing point and azimuth to azimuth mark if different than starting point.) | Computes coordinates of each station on DA Form 6–2. Computes accuracy ratio: azimuth error of closure. |
| 3 | COMPUTE THE FOLLOWING TRIANGLE CHAIN. (Provide starting data and simulated or actual field work to enable candidate to solve the triangulation problem. Data should be made available in the same sequence as normally provided to the computer by a survey party in the field.) | Uses field data provided and DA Form 6–8 to solve triangle chain. |
| 4 | COMPUTE THE FOLLOWING THREE-POINT RESECTION TO DETERMINE COORDINATES AND HEIGHT OF THE OCCUPIED STATION. (Provide candidate with necessary valid field data to perform the computation.) | Records field data on DA Form 6–19 and computes coordinates and height of occupied station. |

*d. Penalties.*

(1) *Tests 1 and 3.* Deduct—

(*a*) 0.5 point for each mathematical error.

(*b*) 1.0 point for each logarithmic error.

(*c*) 3.0 points for each procedural error.

(2) *Test 2.* Deduct—

(*a*) 0.5 point for each mathematical error.

(*b*) 1.0 point for each logarithmic error.

(*c*) 3.0 points for each procedural error.

(*d*) 1.0 point if accuracy ratio is computed incorrectly and 0.5 point if the azimuth error of closure is computed incorrectly.

(3) *Test 4.* Deduct—

(*a*) 0.5 point for each mathematical error.

(*b*) 1.0 point for each logarithmic error.

(*c*) 1.0 point for each procedural error.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 349. Taping

*a. Scope of Test.* One test will be conducted to determine the candidate's ability to function as a tapeman.

*b. Special Instructions.* Prior to the start of the test the examiner will make the following preparations:

(1) Provide equipment as listed below:

(*a*) One 30-meter steel tape.

(*b*) Two plumb bobs.

(*c*) One set of eleven taping arrows.

(*d*) Two taping knuckles.

(*e*) One handle, steel tape, tension 30 lbs.

(*f*) Two ranging poles w/tripods.

(2) Prepare a traverse course consisting of two stations, A and B. Determine the accurate distance between the two. Use terrain that will require breaking tape. Require candidate to tape both ways but change position from front tapeman to rear tapeman on the return run. Use a second candidate or assistant examiner for the second tapeman.

*c. Outline of Test.*

| Examiner commands— | Action of candidate |
|---|---|
| TAPE TRAVERSE LEG FROM A TO B AND FROM B TO A TO A COMPARATIVE ACCURACY OF 1:5000. COMPUTE COMPARATIVE ACCURACY THE TWO TAPED DISTANCES. | Tapes traverse leg as prescribed in chapter 6. Computes comparative accuracy. |

*d. Penalties.* A penalty of 3.0 points will be assessed for each of the following errors:

(1) Failure to maintain correct tape tension.

(2) Failure to maintain the tape in a horizontal position.

(3) Improper handling of the plumb bob.

(4) Failure to aline front tapeman.

(5) Errors in breaking tape.

(6) Errors in recording distance.

(7) Incorrect computation of accuracy ratio.

(8) Accuracy ratio below 1:5000. Accuracy ratio below 1:3000, cut 10 points.

(9) Any other procedural error.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 350. Instrument Operation

*a. Scope of Test.* Two tests will be conducted to determine the candidate's ability to set up and operate an aiming circle and the theodolite.

*b. Special Instructions.* Prior to the start of the test the examiner will make the following preparations:

(1) Provide equipment as listed below:

(*a*) Aiming circle w/tripod.

(*b*) Theodolite w/tripod.

(2) Prepare stations as necessary and accurately determine angles, distances, azimuths, etc., to be used as a check on accuracy. Provide an assistant examiner as recorder for all tests.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | MEASURE THE HORIZONTAL AND VERTICAL ANGLES AZ–MK–Bn SCP–TS 1 WITH THE AIMING CIRCLE. (Designate the Bu SCP and identify the Az Mk and TS 1.) | Sets up aiming circle and measures horizontal and vertical angles as precribed in chapter 7. Means the angles and announces the results. |
| 2 | MEASURE THE HORIZONTAL AND VERTICAL ANGLES TS1–TS2–TS3 WITH THE THEODOLITE. (Designate TS 2 as the occupied station of a traverse and identify the rear and forward stations.) | Sets up the theodolite and measures horizontal and vertical angles as prescribed in chapter 7. Means the angles and announces the results. |

*d. Penalties.*

(1) *Test 1.* Deduct—

(*a*) 3.0 points for improper setup, leveling or handling of the instrument.

(*b*) 2.0 points for each procedural error in the angle measurement.

(*c*) 4.0 points if the horizontal or vertical angle is in error by more than 1.0 mil but less than 2.0 mils.

(*d*) 6.0 points if the horizontal or vertical angle is in error by more than 2.0 mils.

(2) *Test 2.*

(*a*) Deduct 3.0 points for improper set up, leveling or handling of the instrument.

(*b*) Deduct 2.0 points for each procedural error in the angle measurement.

(*c*) For accuracy of measurement of horizontal and vertical angles, cut as indicated:

| *T16* | *T2 (1 sec)* | *T2 (mils)* | *Cut* |
|---|---|---|---|
| Less than 0.1 mil | Less than 05″ | Less than 0.02 mil | 0.0 |
| 0.1–0.2 | 05″–15″ | 0.02–0.08 mil | 3.0 |
| More than 0.2 mil | More than 15″ | More than 0.08 mil | 6.0 |

*e. Credits.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## SECTION II

(Consists of 40 percent of the earned score from section I plus the score earned in paragraphs 351–353.)

### 351. Recording

*a. Scope of Tests.* Two tests will be conducted to determine the candidate's ability to record triangulation field notes and an astronomic observation problem.

*b. Special Instructions.* Prior to the start of the test the examiner will make the following preparations:

(1) Provide equipment as listed below:

(*a*) Field notebook or mimeographed pages.

(*b*) 4H and 6H pencil.

(*c*) Straightedge.

(2) Prepare simulated or actual field data to present to candidate in the same manner as a recorder would normally receive this information.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | RECORD THE FOLLOWING TRIANGULATION SURVEY. (Present field data from triangulation problem in the same sequence a recorder would normally receive this data.) | Records survey field data as prescribed in chapter 7. |
| 2 | RECORD THE FOLLOWING ASTRONOMIC OBSERVATION. (Present field data from the observation in the same sequence that a recorder would normally receive the data.) | Records field data from the astronomic observation as prescribed in chapter 7. |

*d. Penalties.* Deduct—

(1) 2.0 points for each angle or time meaned incorrectly.

(2) 4.0 points for each procedural error.

(3) 4.0 points if field notes are not neat and legible.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 352. Computing

*a. Scope of Tests.* Three tests will be conducted to determine the candidate's ability as a computer. The first test is solving a triangle by trilateration and the second is computing an azimuth from an astronomic observation. The third test is computing grid convergence for a specific area.

*b. Special Instructions.*

(1) Provide equipment as listed below:

(*a*) Logarithmic tables (seven place).

(*b*) TM 6–300–(current year).

(*c*) DA Forms 6–7a, 6–10, 6–10a or 6–11, and 6–20.

(2) Prepare actual or simulated field data for each test.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | SOLVE THE FOLLOWING TRIANGLE BY TRILATERATION. THE KNOWN LENGTH OF THE SIDES ARE:<br>a ________<br>b ________<br>c ________<br>DETERMINE THE SIZE OF EACH ANGLE. | Records given data on DA Form 6–7a and solves for interior angles. |
| 2 | COMPUTE GRID AZIMUTH BY ASTRONOMIC OBSERVATION BY THE ALTITUDE (HOUR ANGLE) METHOD OF THE SUN (STAR). (Provide data from three sets of observations. Furnish grid convergence to permit candidate to determine grid azimuth.) | Uses field data provided and DA Forms 6–10, 6–10a or 6–11, and 6–20. Computes all three sets, mean sets and rejects any set that varies from the mean by more than the tolerance prescribed in chapter 13. Applies grid convergence to mean of at least two sets to get grid azimuth. |
| 3 | COMPUTE GRID CONVERGENCE<br>GIVEN DATA:<br>STATION: Bn SCP<br>LATITUDE: ________N(S)<br>LONGITUDE: ________E(W)<br>COORDINATES: ________<br>________ | Computes grid convergence. Uses DA Form 6–20 and TM 6–300–current year. |

*d. Penalties.* Deduct 0.5 point for each mathematical error, 2.0 points for each logarithmic error and 4.0 points for each procedural error.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 353. Instrument Operation

*a. Scope of Tests.* Three tests will be conducted to determine the candidate's ability to operate the tellurometer or DME and the surveying instrument azimuth gyro and one test will be conducted to determine the candidate's ability to perform theodolite adjustments. Units not issued the tellurometer or DME will disregard Test 1.

*b. Special Instructions.* Prior to the start of the test the examiner will make the following preparations:

(1) Provide equipment as listed below:
- (*a*) One master and one remote tellurometer unit or two DME units complete with cables, tripods and batteries.
- (*b*) One Surveying Instrument Azimuth Gyro Artillery complete with control panel and power source.
- (*c*) One theodolite with tripod.
- (*d*) DA Form 5–139 (Field Record and Computations — Tellurometer) or DA Form 2972 (Field Record and Computations—DME).
- (*e*) Logarithmic tables (seven place).

(2) Provide an assistant examiner to operate the remote or responder unit.

(3) Provide a recorder for tests 1 and 2.

(4) Provide stations and azimuth marks as necessary to conduct tests 1 and 2.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | MEASURE THE DISTANCE TS 2–TS 3 WITH THE TELLUROMETER OR DME. (Stations must be at least 152 meters apart. Require the candidate to operate master station or measurer and instruct remote operator. Remote or responder operator can be another candidate or an assistant examiner. Delete this test for units not issued the tellurometer or DME. Redistribute credit to other two tests.) | Sets up the master or measurer unit; instructs remote or responder operator; measures distance. Resolves transit time and determines sea level distance in meters using DA Form 5–139, or DA Form 2972. |
| 2 | DETERMINE AZIMUTH TO AZIMUTH MARK WITH THE SURVEYING INSTRUMENT AZIMUTH GYRO ARTILLERY. (Identify orienting station and azimuth mark. Provide grid convergence to candidate. Determination of azimuth by astronomic observation is an authorized substitution.) | Sets up azimuth gyro and determines azimuth to azimuth mark. Applies grid convergence to attain grid azimuth. |
| 3 | PERFORM THE FOLLOWING TESTS AND ADJUSTMENTS ON THE THEODOLITE:<br>a. PLATE LEVEL.<br>b. OPTICAL PLUMB.<br>c. VERTICALITY (NOT APPLICABLE ON T–16.)<br>d. HORIZONTAL COLLIMATION.<br>e. VERTICAL COLLIMATION. | Performs tests and adjustments as prescribed in chapter 7. |

*d. Penalties.*

(1) *Test 1.* Deduct—
- (*a*) 2 points for improper setup or handling of the instrument.
- (*b*) 1 point if instructions by candidate to remote operator prior to beginning the measurement are inadequate.
- (*c*) 3 points for each procedural error in the measurement.
- (*d*) 2 points for each procedural error in the computation.

(*e*) 0.5 point for each mathematical error in the computation.

(*f*) 3 points if the accuracy is less than 1:7,000 but more than 1:5,000 when compared to the previously determined distance.

(*g*) 6 points if the accuracy is less than 1:5,000 when compared to the previously determined distance.

(2) *Test 2.*

(*a*) Deduct 2 (3) points for improper setup, leveling or handling of the instrument.

(*b*) Deduct 3 (4) points for each procedural error in the azimuth measurement.

(c) Deduct 1 (2) point for each computational error.

(*d*) Deduct 6 (8) points if accuracy normally required by candidate's unit is not attained. (Specifications for accuracies are the same as listed in chapter 13 for astronomic observations.)

(*e*) The penalty points in parentheses in (*a*) through (*d*) above will be applied when Test Number 1 is not given.

(3) *Test 3.*

(*a*) Deduct 1 (2) point for each test or adjustment that is not conducted as prescribed in chapter 7.

(*b*) Deduct 1 (2) point if test and adjustments are not conducted in the sequence specified in chapter 7 for the instrument used.

(*c*) The penalty points in parentheses in (*a*) and (*b*) above will be applied when Test 1 is not given.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

SECTION III

(Consists of 50 percent of the earned score from section II plus the score earned in paragraphs 354–357).

## 354. Map Reading

*a. Scope of Tests.* One test will be conducted to determine the candidate's ability to scale geographic coordinates from a map.

*b. Special Instructions.* Prior to the start of the tests the examiner will make the following preparations and provide equipment as listed below:

(1) Map 1:50,000 or larger.

(2) Straightedge.

(3) Military slide rule (if desired by candidate).

*c. Outline of Test.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | DETERMINE THE GEOGRAPHIC COORDINATES OF ______________ TO THE NEAREST 30 SECONDS. | Determine geographic coordinates of designated point. |

*d. Penalties.* Deduct—

(1) 2 points if easting or northing is in error by more than 30 seconds but less than 60 seconds.

(2) All credit if easting or northing is in error by more than 60 seconds.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 355. Grid Computations

*a. Scope of Tests.* Three tests will be conducted to determine the candidate's knowledge of detailed survey computations consisting of converting geographic coordinates to grid coordinates, zone to zone transformation, and conversion to common control.

*b. Special Instructions.* Prior to the start of the test the examiner will make the following preparations:

(1) Provide equipment as listed below:

(*a*) TM 5–241 (as appropriate depending on spheroid involved).

(*b*) DA Forms 6–1, 6–2, 6–23, 6–34, 6–36.

(*c*) Logarithmic tables (six- or seven-place).

(*d*) TM 5–241–2.

(2) Prepare realistic requirements to issue as tests 1-3. Solve and check requirements.

*c. Outline of Tests.*

| Test No. | Examiner commands— | Action of candidate |
|---|---|---|
| 1 | CONVERT THE FOLLOWING GEOGRAPHIC COORDINATES TO GRID COORDINATES: ________ ° ________ ' ________ " N (S) ________ ° ________ ' ________ " E (W) | Converts geographic coordinates to grid. Uses DA Form 6–25 and TM 5–241–(3/1, 4/1, 5/1, 6/1 and 7). |
| 2 | TRANSFORM THE FOLLOWING COORDINATES FROM ZONE ________ TO ZONE ________: E ________ N ________. | Converts coordinates from one zone to the other. Uses DA Form 6–36 and TM 5–241–2. |
| 3 | CONVERT THE FOLLOWING TRAVERSE TO THE COMMON GRID: ASSUMED DATA: COORDINATES BN SCP ________ ________ ________ HEIGHT BN SCP ________ AZIMUTH TO AZIMUTH MARK ________. KNOWN DATA (COMMON GRID): COORDINATES BN SCP ________ ________ ________ HEIGHT BN SCP ________ AZIMUTH TO AZIMUTH MARK ________. (Require candidate to convert all or selected points of the traverse run with assumed data to the common grid.) | Converts designated points of traverse to common grid. Uses DA Forms 6–1 and 6–2. |

*d. Penalties.*

(1) Tests 1 and 2. Deduct 0.2 point for each mathematical error, 1 point for each logarithmic error and 2 points for each procedural error.

(2) Test 3. Deduct 0.2 for each mathematical error, 0.4 point each logarithmic error and 0.5 point for each procedural error.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 356. Survey Planning

*a. Scope of Test.* One practical test will be conducted to determine the candidate's ability to plan a survey. This test will include a briefin by the examiner, map reconnaissance, ground reconnaissance, and the survey order.

*b. Special Instructions.* Prior to the start of the test, the examiner will make the following preparations:

(1) Provide an area in which a survey can be conducted.

(2) Provide a 1:50,000 map of the area.

(3) Prepare a situation to include unit mission, time available, designation and general location of points to be surveyed and restrictions on use of routes, transportation and radios.

(4) Provide a vehicle and driver for the candidate.

*c. Outline of Test.*

| Examiner commands— | Action of candidate |
|---|---|
| PREPARE A SURVEY PLAN TO SUPPORT THE UNIT'S MISSION. THE MISSION ASSIGNED IS AS FOLLOWS: ________ ________ ________. EXTEND SURVEY CONTROL TO THE FOLLOWING POINTS: ________ ________ ________ ________ ________ ________. YOU WILL HAVE ________ HOURS TO COMPLETE THE SURVEY. THE FOLLOWING RESTRICTIONS ARE IN FORCE: ________ ________ ________ ________ ________ ________ ________ ________ | Makes a map reconnaissance to include plotting installations requiring control. Makes a detailed ground reconnaissance and formulates a plan. Issues a survey order to the survey party (examiner). |

*d. Penalties.* Deduct—

(1) 2 points if the survey plan is not simple, timely or flexible.

(2) 5 points if the plan is not adaptable or if it does not provide for checks.

(3) 10 points if the plan cannot provide survey control to the required accuracy at all installations which require survey.

(4) 5 points if the survey order is not adequate to insure the mission is accomplished.

(5) 3 points if equipment is not utilized to best advantage.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 345.

## 357. Supervision and Operation

*a. Scope of Test.* The test will determine the candidate's ability to organize and direct a survey party.

*b. Special Instructions.* Prior to the start of the test the examiner will provide a survey party complete with equipment and personnel authorized by applicable TOE.

*c. Outline of Test.*

| Examiner commands— | Action of candidate |
|---|---|
| ORGANIZE THE SURVEY PARTY AND EXECUTE THE PLANNED SURVEY. (After the survey has started require the candidate to operate the instrument for at least one station.) | Briefs members of the survey party. Directs and supervises operation until completion. Functions as instrument operator when directed. |

*d. Penalties.*

(1) Deduct 2 points for any failure to—

(*a*) Orient all personnel.

(*b*) Initiate the survey as soon as possible.

(*c*) Display an aggressive attitude in supervising the party while the survey is in progress.

(2) Deduct 3 points if the instrument is not set up, leveled and angles measured as prescribed in chapter 7. (Applicable only when the candidate is functioning as instrument operator.)

(3) Deduct 3 points for each failure to—

(*a*) Provide computers with necessary data to begin computations.

(*b*) Properly select traverse (triangulation) stations.

(*c*) Supervise the work of the computers by spot checking their azimuths, bearing angles, distances and coordinates.

(*d*) Periodically verify the recorder's notes.

(*e*) Check taping procedures.

(*f*) Correct erratic procedures immediately on discovery.

(*g*) Check results by plotting surveyed points on a map.

(*h*) Supervise the instrument operator during theodolite, tellurometer, or surveying instrument azimuth gyro artillery operations.

*e. Credit.* Subject to the penalties assessed in *d* above, credit will be awarded as indicated in paragraph 357.

# APPENDIX I

# REFERENCES

## 1. Miscellaneous Publications

| | |
|---|---|
| AR 117–5 | Military Mapping and Geodesy. |
| AR 320–5 | Dictionary of United States Army Terms. |
| AR 320–50 | Authorized Abbreviations and Brevity Codes. |
| AR 600–20 | Army Command Policy and Procedures. |
| DA Pam 108–1 | Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings. |
| DA Pam 310-series (as applicable) | Military Publications Indexes. |
| FM 6–10 | Field Artillery Communications. |
| FM 6–20–1 | Field Artillery Tactics. |
| FM 6–20–2 | Field Artillery Techniques |
| FM 6–40 | Field Artillery Cannon Gunnery. |
| FM 6–120 | Field Artillery Target Acquisition Battalion and Batteries. |
| FM 6–121 | Field Artillery Target Acquisition. |
| FM 6–122 | Artillery Sound Ranging and Flash Ranging. |
| FM 6–135 | Adjustment of Artillery Fire by the Combat Soldier. |
| FM 6–140 | Field Artillery Cannon Battalions and Batteries. |
| FM 21–5 | Military Training. |
| FM 21–6 | Techniques of Military Instruction. |
| FM 21–26 | Map Reading. |
| FM 21–30 | Military Symbols. |
| FM 21–31 | Topographic Symbols. |
| FM 30–5 | Combat Intelligence. |
| FM 44–1 | US Army Air Defense Employment. |
| FM 44–2 | Light Antiaircraft Artillery (Automatic Weapons). |
| FM 61–100 | The Division. |
| TM 5–231 | Mapping Functions of the Corps of Engineers. |
| TM 5–232 | Elements of Surveying. |
| TM 5–236 | Surveying Tables and Graphs. |
| TM 5–241–1 | Grids and Grid References. |
| TM 5–241–2 | Universal Transverse Mercator Grid, Zone-to-Zone Transformation Tables. |
| TM 5–241–3/1 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°; International Spheroid (Meters). Volume I, Transformation of Coordinates from Geographic to Grid. |
| TM 5–241–3/2 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°; International Spheroid (Meters). Volume II, Transformation of Coordinates from Grid to Geographic. |
| TM 5–241–4/1 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°; Clarke 1866 Spheroid (Meters). Volume I, Transformation of Coordinates from Geographic to Grid. |

| | |
|---|---|
| TM 5–241–4/2 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°; Clarke 1866 Spheroid (Meters). Volume II, Transformation of Coordinates from Grid to Geographic. |
| TM 5–241–5/1 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°, Bessel Spheroid (Meters). Volume I, Transformation of Coordinates from Geographic to Grid. |
| TM 5–241–5/2 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°; Bessel Spheroid (Meters). Volume II, Transformation of Coordinates from Grid to Geographic. |
| TM 5–241–6/1 | Universal Transverse Mercator Grid Tables for Latitudes 0°–80°; Clarke 1880 Spheroid (Meters). Volume I, Transformation of Coordinates from Geographic to Grid. |
| TM–5–241–6/2 | Universal Transverse Mercator Grid Table for Latitudes 0°–80°; Clarke 1880 Spheroid (Meters). Volume II, Transformation of Coordinates from Grid to Geographic. |
| TM 5–241–7 | Universal Transverse Mercator Grid Tables for 0°–45°. Everest Spheroid (Meters). Transformation of Coordinates from Geographic to Grid and from Grid to Geographic. |
| TM 5–241–8 | Universal Transverse Mercator Grid. |
| TM 5–241–9 | Universal Polar Stereographic Grid Tables for Latitudes 79° 30′–90°; International Spheroid (Meters). Transformation of Coordinates from Geographic to Grid and from Grid to Geographic. |
| TM 5–441 | Topographic Surveying. |
| TM 5–6675–200–15 | Operator, Organizational Field and Depot Maintenance Manual, Theodolite, Wild T16. |
| TM 5–6675–202–15 | Operator, Organizational, Field and Depot Maintenance Manual, Tellurometer. |
| TM 5–6675–203–15 | Operator, Organizational, Field and Depot Maintenance Manual, Altimeter, Surveying. |
| TM 5–6675–205–15 | Operator, Organizational, Field and Depot Maintenance Manual, Theodolite, Wild T2, 0.002 Mil Graduation. |
| TM 5–6675–207–15 | Operator, Organizational, Field and Depot Maintenance Manual, Surveying Instrument, Azimuth; Gyro; Artillery (ABLE). |
| TM 5–6675–213–15 | Operator, Organizational Field and Depot Maintenance Manual, Theodolite, Wild T2, 1 Second Graduation. |
| TM 5–9421 | Altimeters, Surveying. |
| TM 6–230 | Logarithmic and Mathematical Tables. |
| TM 6–231 | Seven Place Logarithmic Tables. |
| TM 6–240 | Slide Rule, Military, Field Artillery, With Case, 10-inch. |
| TM 6–300–( ) | Army Ephemeris. (appropriate year) |
| TM 9–1290–262–35 | Field and Depot Maintenance Manual, Aiming Circle M2. |
| TM 9–6166 | Operator and Organizational Maintenance: Aiming Circle M2. |
| | Tellurometer Handbook, Tellurometer (PTV) Ltd, Cape Town, South Africa (issued with each unit). |
| | Instruction Manual, EM 2171, for ABLE (Surveying Instrument, Azimuth, Gyro Artillery), Model XCZA System with Modified Electronic Package, Autonetics, North African Aviation, Inc. |

## 2. DA Forms

| | |
|---|---|
| 5–72 | Level, Transit, and General Survey Record Book. |
| 5–139 | Field Record and Computations–Tellurometer. |

| | |
|---|---|
| 6–1 | Computation—Azimuth and Distance from Coordinates. |
| 6–2 | Computation—Coordinates and Height from Azimuth, Distance, and Vertical Angle. |
| 6–2b | Computation—Trigonometric Heights. |
| 6–5 | Record—Survey Control Point. |
| 6–7a | Computation—Plane Triangle. |
| 6–8 | Computation—Plane Triangle Coordinates and Height from One Side, Three Angles and Vertical Angles. |
| 6–10 | Computation—Astronomic Azimuth by Hour-Angle Method, Sun. |
| 6–10a | Computation—Astronomic Azimuth by Hour-Angle, Method, Star. |
| 6–11 | Computation—Astronomic Azimuth by Altitude Method, Sun or Star. |
| 6–18 | Computation—Coordinates and Height from Two-Point Resection. |
| 6–19 | Computation—Coordinates and Height from Three-Point Resection. |
| 6–20 | Computation—Convergence (Astronomic Azimuth to UTM Grid Azimuth). |
| 6–21 | Computation and Instruction for Use with Star Identifier. |
| 6–22 | Computation—Conversion UTM Grid Coordinates to Geographic Coordinates (Machine). |
| 6–23 | Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Logarithms). |
| 6–25 | Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Machine). |
| 6–27 | Computation—Altimetric Height (Single-Base or Leapfrog Method). |
| 6–34 | Zone to Zone UTM Grid Azimuth Transformation. |
| 6–36 | Zone to Zone UTM Grid Coordinates Transformation. |
| 2973 | Fifth-Order Astronomic Azimuth Computation. |
| 2972 | Field Record and Computations—DME. |

## 3. Other U.S. Government Publications

The following publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

*a. Department of Commerce.*

Coast and Geodetic Survey: Special Publication No. 225, Manual of Reconnaissance for Triangulation. Special Publication No. 234, Signal Building. Special Publication No. 237, Manual of Geodetic Triangulation.

*b. Department of the Navy.*

Naval Observatory: American Ephemeris and Nautical Almanac (published annually). Air Almanac (published annually). Hydrographic Office: H. O. No. 205, Radio Time Signals (current series).

## 4. Standardization Agreements

| | |
|---|---|
| STANAG 2202 | Map Conventional Signs. |
| STANAG 2210 | Trig (Lists of Geodetic Data). |
| STANAG 2211 | Geodetic Datums, Spheroids, Grids, and Grid References. |

# APPENDIX II

## SURVEY SPECIFICATIONS

TRAVERSE*

| *Requirement* | *Fourth-order* | *Fifth-order* |
|---|---|---|
| Adjusted | Yes | No |
| Closing error (position) | Use smaller of $\sqrt{K}$ or 1:3,000 | 1:1,000 |
| Not to exceed (Height) | $\sqrt{K}$ | ±2 meters |
| (Azimuth) | Use smaller of 0.1m̸ $\sqrt{N}$ or 0.04m̸ × N | 0.1m̸ × N |
| Station between azimuth checks not to exceed | 25 | NA |
| Horizontal angles | 1 position (1 D/R) | 1 position (1 D/R) |
| Vertical angles | 1 D/R | 1 D/R |
| Distance: | | |
| Tape | Double tape to a comparative accuracy of 1:5,000 | Single tape Check by pacing |
| Tellurometer | 2 coarse, 4 fine readings | 2 coarse, 4 fine readings |
| DME | Measure in both directions | Measure in both directions |
| Scale factor | Yes | No |
| Horizontal and vertical angles recorded to | 0.001 mil | 0.1 mil |
| Azimuth carried to | 0.001 mil | 0.1 mil |
| Vertical angles and bearing angles used in computations to | 0.01 mil | 0.1 mil |
| Easting and northing coordinates computed to | 0.01 meter | 0.1 meter |
| Height computed to | 0.1 meter | 0.1 meter |
| Log tables used | 7 place | 6 place |

* Always closed: on second point as first choice, on starting point as second choice.

*Remarks:*

K = length of traverse in kilometers.

N = number of main scheme angles in the traverse.

m̸ = mil.

## TRIANGULATION*

### *INTERSECTION-RESECTION*

| *Requirement* | | *Fourth-order* | *Fifth-order* |
|---|---|---|---|
| Adjusted | | Yes | No |
| | (Position)* | $1.4\sqrt{K}$ | 1:1,000 |
| Closing error | (length) | 1:3,000 | 1:1,000 |
| Not to exceed | (Height) | $\sqrt{K}$ | ±2 meters |
| | (Azimuth) | 0.1 m̸ $\sqrt{N}$ or 0.04 m̸ × N | 0.1m̸ × N |
| Maximum $\Sigma R_1$ | | 200 | NA |
| Between bases | | (or not to exceed 5 figures) | |
| Azimuth check (normally with base line check) | | (Not to exceed 5 figures) | |
| Horizontal angles | | 2 positions (2 D/R) | 1 position (1 D/R) |
| Vertical angles | | 1 D/R | 1 D/R |
| Base determination | | 17,000 | 1:3,000 |
| Known coordinates | | See para 227*a*(3) | See para 227*a*(3) |
| Tape | | Double tape | Double tape |
| Tellurometer | | 2 coarse, 4 fine readings | 2 coarse, 4 fine readings |
| DME | | Measure in both directions | Measure in both directions |
| Horizontal and vertical angles recorded to | | 0.001 mil | 0.1 mil |
| Azimuth carried to | | 0.001 mil | 0.1 mil |
| Vertical angles and bearing angles used in computations to | | 0.01 mil | 0.1 mil |
| Easting and Northing coordinates computed to | | 0.01 meter | 0.1 meter |
| Height computed to | | 0.1 meter | 0.1 meter |
| Log tables used | | 7-place | 6-place |
| Scale factor | | Yes | No |
| Minimum distance angles | | 400 mils | 400 mils |
| Triangle closure | | Avg for scheme 0.05 mil per triangle; max per triangle 0.06 mil | 0.3 mil |

## TRILATERATION

| *Requirement* | *Fourth-order* |
|---|---|
| Permissible figure | Quadrilateral. |
| Desirable minimum side length | 5 kilometers. |
| Minimum permissible angle | 400 mils. |
| Height | Altimeter (0.1 meter). |
| Azimuth | Established at terminal point by gyro or astro. |
| Distances | Measure in both directions; comparative accuracy 1:25,000. |

* Closed on known control if possible: if not, through use of length checks (para 229*e*).

*Remarks:*

K = length in kilometers.

N = number of stations for carrying azimuth.

m̸ = mil.

| *Requirement* | *Fourth-order* |
|---|---|
| Angle check | At each corner the sum of the two small angles will be compared with the large angle. The two must agree within ± 0.2 mil. |
| Azimuth carried | To 0.01 mil through angles which most nearly equal 1,000 mils. |
| Positions carried (E and N) | To 0.01 meter through lines used for azimuth. Use angles from DA Form 6–7a or DA Form 6–2. |
| Method used when | a. No maps are available, *or* b. visual line of sight does not exist between stations due to weather, distance, or obstruction. |

ASTRONOMIC OBSERVATIONS

| | *Fourth-order* | *Fifth-order* | |
|---|---|---|---|
| Requirement | 1:3,000 | 1:1,000 | 1:500* |
| Minimum number of sets to be observed | 3 | 3 | 4 |
| Rejection limit | 0.15 mil | 0.3 mil | 0.3 mil |
| Number of sets that must remain and be remeaned | 2 | 2 | 3 |
| Horizontal angles | 1 position | 1 position | 2 readings |
| Vertical angles | 1 D/R | 1 D/R | 2 readings |
| Considered accuracy | 0.15 mil | 0.3 mil | 0.3 mil |

* Specifications apply for determining a fifth-order azimuth. If the direction is not to be extended from the line established by the observation, the rejection limit can be relaxed to 1.0 mil with a considered accuracy of 1.0 mil.

# APPENDIX III

# DUTIES OF SURVEY PERSONNEL

## 1. Survey Officer

The survey officer—

*a.* Coordinates and supervises the training of survey personnel.

*b.* Coordinates, supervises, and *emphasizes* the preventive maintenance program on survey equipment.

*c.* Coordinates, supervises, and establishes the survey information center (when the SIC is authorized at his echelon).

*d.* Accompanies the commander on reconnaissance.

*e.* Formulates and implements the survey plans.

*f.* Supervises and coordinates the field operation of survey parties under his jurisdiction.

*g.* Advises the commander and staff on survey matters.

*h.* Coordinates survey operations with survey officers of higher, lower, and adjacent headquarters.

## 2. Chief Surveyor

The chief surveyor—

*a.* Acts as the principal assistant to the survey officer and when directed performs any or all of the duties of the survey officer.

*b.* Supervises survey personnel in performance of routine reconnaissance, communications, and survey activities.

*c.* Performs other duties as directed.

## 3. Chief of Survey Party

The chief of survey party—

*a.* Trains his survey party.

*b.* Implements his party's portion of the survey plan.

*c.* Orients party members on the survey plan.

*d.* Supervises and coordinates the field operation of his survey party.

*e.* Maintains liaison with the survey officer or chief surveyor during field operations.

*f.* Supervises preventive maintenance on section equipment, to include vehicles and communications equipment.

*g.* Performs other duties as directed.

## 4. Survey Computer

The survey computer—

*a.* Maintains the required DA forms for computation of surveys.

*b.* Performs independent computations during field operations.

*c.* Performs other duties as directed.

## 5. Instrument Operator

The instrument operator—

*a.* Performs preventive maintenance on the authorized instruments.

*b.* Operates the instrument during field operations.

*c.* Verifies the vertical alinement of the range pole before measuring angles during field operations.

*d.* Reads the measured values to the recorder and checks the recorder's operation by use of a read-back technique.

*e.* Familiarizes himself with the fieldwork requirements for all survey methods.

*f.* Assists the tapemen in maintaining alinement during taping operations.

*g.* Performs other duties as directed.

## 6. Recorder

The recorder—

*a.* Maintains an approved notebook (DA Form 5–72, Level, Transit, and General Survey Record) or field book record of all surveys performed by the survey party.

*b.* Records survey starting data and all measured data with a 4-H pencil in a neat and legible manner during field operations.

*c.* Sketches, in the approved notebook, complete descriptions of principal stations occupied during field survey operations.

*d.* Checks, means, and adjusts angular data measured by the instrument operator.

*e.* Checks taped distances by pacing.

*f.* Provides required field data to the survey computers independently.

*g.* Performs other duties as directed.

## 7. Tapeman

The tapeman—

*a.* Maintains the fire control set, artillery survey set, third (fourth) order.

*b.* Tapes distances, using proper taping techniques, during field operations.

*c.* Computes an accuracy ratio for taped distance when required.

*d.* Reports measured distances to the recorder.

*e.* Operates and maintains the section radio equipment.

*f.* Performs other duties as directed.

*Note.* The rear tapeman commands the taping team.

## 8. Rodman

The rodman—

*a.* Maintains the station marking equipment.

*b.* Marks stations with hub and witness stakes during field operations.

*c.* Centers and plumbs survey range poles over survey stations as required during field operations.

*d.* Assists the tapeman in maintaining alinement of the tape.

*e.* Operates and maintains the section radio equipment.

*f.* Performs other duties as directed.

# APPENDIX IV

## GLOSSARY OF ASTRONOMICAL TERMS

*a.* The *north* and *south celestial poles* are the points where the prolonged polar axis of the earth intersects the celestial sphere.

*b.* The *celestial equator* is the great circle on the celestial sphere cut by the plane of the earth's equator extended. A *great circle* is one whose plane passes through the center of a sphere.

*c.* The *zenith* and *nadir* for any place on the earth's surface are the two points where an extension of the observer's plumbline intersects the celestial sphere.The zenith is the point directly overhead, and the nadir is the point directly underneath.

*d.* The *horizon* for any place on the earth's surface is the great circle cut on the celestial sphere by the extension of the plane of the observer's horizon.

*e.* A *vertical circle* is any great circle on the celestial sphere which passes through the zenith.

*f.* The *meridian* of any observer is the great circle on the celestial sphere which passes through the celestial poles and the observer's zenith.

*g.* The *prime vertical* for any place on the earths' surface is the vertical circle perpendicular to the meridian. It intersects the horizon at the points directly east and west.

*h.* The *ecliptic* is the great circle cut on the celestial sphere by the plane of the earth's orbit. If one could look past the sun and see the stars, he would see the sun and stars moving slowly across the sky. The sun would gain slightly on the stars each day. The earth is assumed to be stationary, and so the ecliptic is assumed to be the path of the sun instead of the earth. This ecliptic intersects the celestial equator at two points at an angle of $23\frac{1}{2}°$.

*i.* The *equinoxes* are the two points where the ecliptic intersects the celestial equator. The point where the sun crosses the celestial equator from south to north is called the *vernal equinox* or *first point of Aries.* The other point is called the *autumnal equinox* and is diametrically opposite the first point. The equinoctial points move slowly westward along the ecliptic at a rate of about 50 seconds a year. As a result, all the fixed stars gradually change their positions with respect to the equator and the vernal equinox.

*j.* The *solstices* are two points on the ecliptic midway between the equinoxes. When the ecliptic is north of the celestial equator, the midpoint is called the *summer solstice* and occurs about 21 June; when the ecliptic is south of the celestial equator, the midpoint is called the *winter solstice* and occurs about 21 December. It is easily seen, then, that the solstices occur when the sun as at the greatest distance north or south of the equator.

*k.* The *latitude* of any place on the earth's surface is the angular distance of that place from 0° to 90° north or south of the equator.

*l.* The *longitude* of any place on the earth's surface is the angular distance of that place from 0° to 180° east or west of the meridian of Greenwich which is used by most nations as the prime or initial meridian.

*m.* An *hour circle* is any great circle on the celestial sphere that passes through the celestial poles.

*n.* The *celestial coordinates* are coordinates used for locating a point on the celestial sphere.

The coordinates used by the artillery are declination and right ascension.

*o.* The *declination* of a celestial body is the angular distance from the celestial equator measured along the hour circle of the body. Declination is given a positive sign when the body is north of the celestial equator and a negative sign when the body is south. Declination coresponds to latitude on the earth.

*p.* The *right ascension* of a celestial body is the arc of the celestial equator measured from the vernal equinox eastward to the hour circle of the body. It is measured in units of time from 0 to 24 hours. Right ascension corresponds to longitude on the earth.

*q.* The *hour angle* of a celestial body is the angle at the celestial poles between the plane of the meridian of the observer and the plane of the hour circle of the star. Stated simply, the hour angle is the angle at the pole between the observer's meridian and the meridian (hour circle) of the celestial body. This angle is similar to differences in longitude on the earth's surface. It is measured westward from the observer's meridian. The hour angle is generally considered as an arc measured along the celestial equator toward the west and may be expressed in time or arc.

*r.* The *polar distance* of a celestial body is the algebraic complement of the declination; that is, 90° minus a positive declination or 90° plus a negative declination.

*s.* The *altitude* of a celestial body is the arc of its vertical circle measured from the horizon to the body, or it is the vertical angle at the observer's position between the horizon and the body.

*t.* The *azimuth* of a celestial body is the angle at the zenith between the meridian of the observer and the vertical circle of the body. It is actually measured as an arc in the plane of the horizon and may be east or west of north.

*u.* The *culmination* or transit of a celestial body is the passage of that body across the meridian of the observer. Every celestial body will have two culminations; passage across the upper arc of the meridian is *upper culmination* or upper transit, and passage across the lower arc is *lower culmination* or *lower transit.*

*v.* The elongations of a celestial body are two points in its apparent orbit at which the bearing from the observer's meridian is the greatest. A star is said to be at *eastern elongation* when its bearing is a maximum to the east and at *western elongation* when its bearing is a maximum to the west.

*w.* The *parallax* of a celestial body is the difference in altitude of a body as seen from the center of the earth and from a point on the surface of the earth. There is no apparent parallax of the fixed stars, but that of the sun and planets is measurable. Parallax makes the body appear lower than it actually is; therefore the correction is added.

*x.* The *refraction* of a celestial body is the apparent displacement of the body caused by the bending of light rays passing through layers of air of varying density. The celestial body will appear higher than it really is; therefore, the correction is subtracted. A simple example of refraction can be noted by placing a spoon in a glass half full of water.

# APPENDIX V

## STAR RATE INDEX

TO USE THE PLATES:

1. Place the star identifier corresponding to the observer's latitude over the plate in the appendix.

2. Trace the curve for the rate desired, using a sharp grease pencil.

3. The areas are marked on the plates as follows:

*a. Area A.* The rate is between 0 and 0.5. The dotted line indicates a rate of zero. Stars within this area are the most desirable for use in observations. Stars at higher altitudes are more difficult to use.

*b. Area B.* The rate is between 0.5 and 1.0. Stars within this area are the second most desirable. Fourth-order azimuth can be obtained from these stars using reasonable care.

*c. Area C.* The rate is between 1.0 and 3.0. Stars within this area are the third most desirable. Fifth-order azimuth can be obtained from these stars using reasonable care.

*d. Area D.* The rate is over 3.0. Stars within this area should not be used; however, if they are used, the azimuth must be determined by the hour-angle method.

4. The area above 60° altitude is blank, as stars in this area should not be used.

5. Select stars that are within the area best suited for the accuracy desired and will meet the tactical situation.

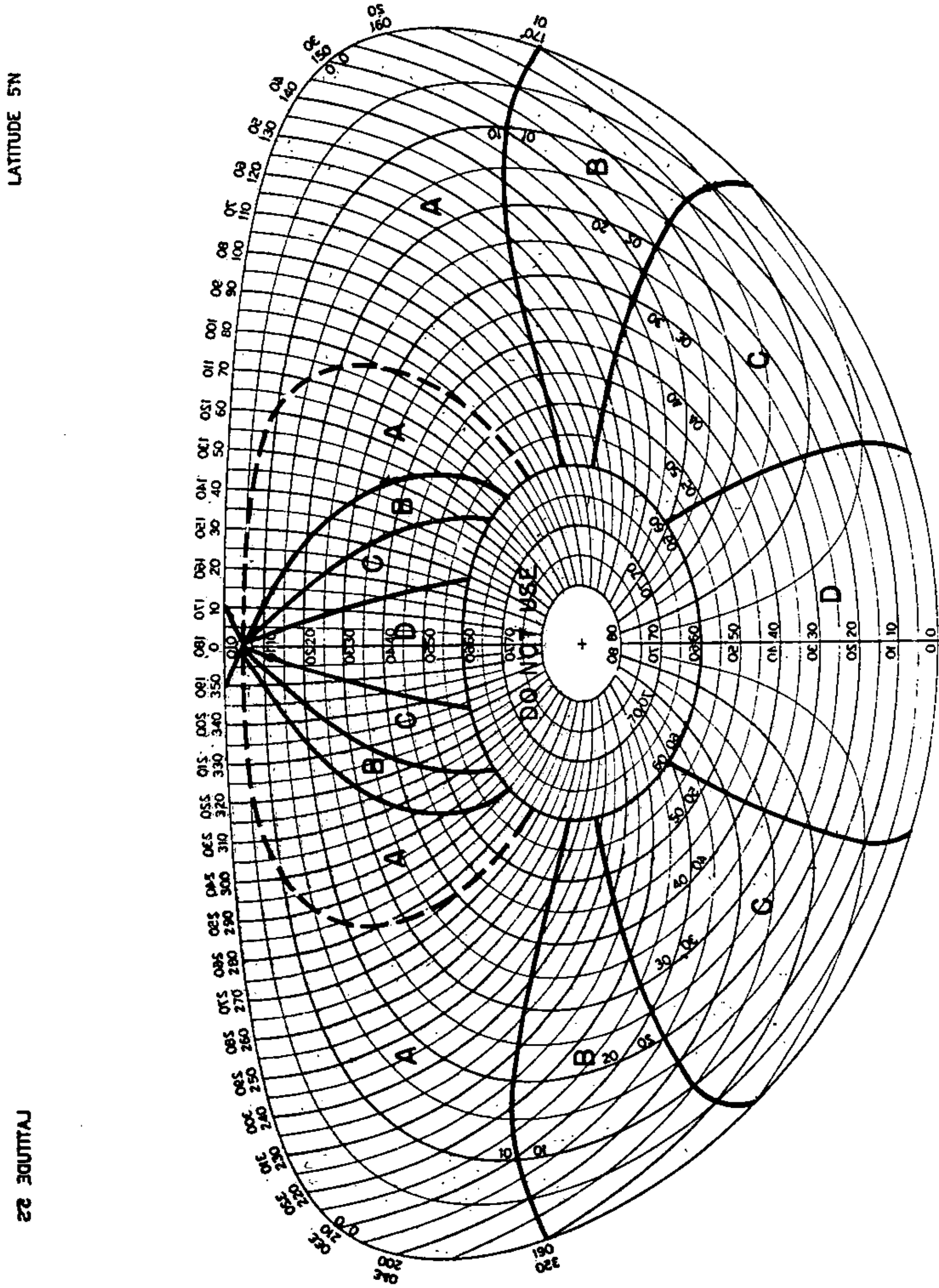



*Plate 1. Star Rate Plate 5°*

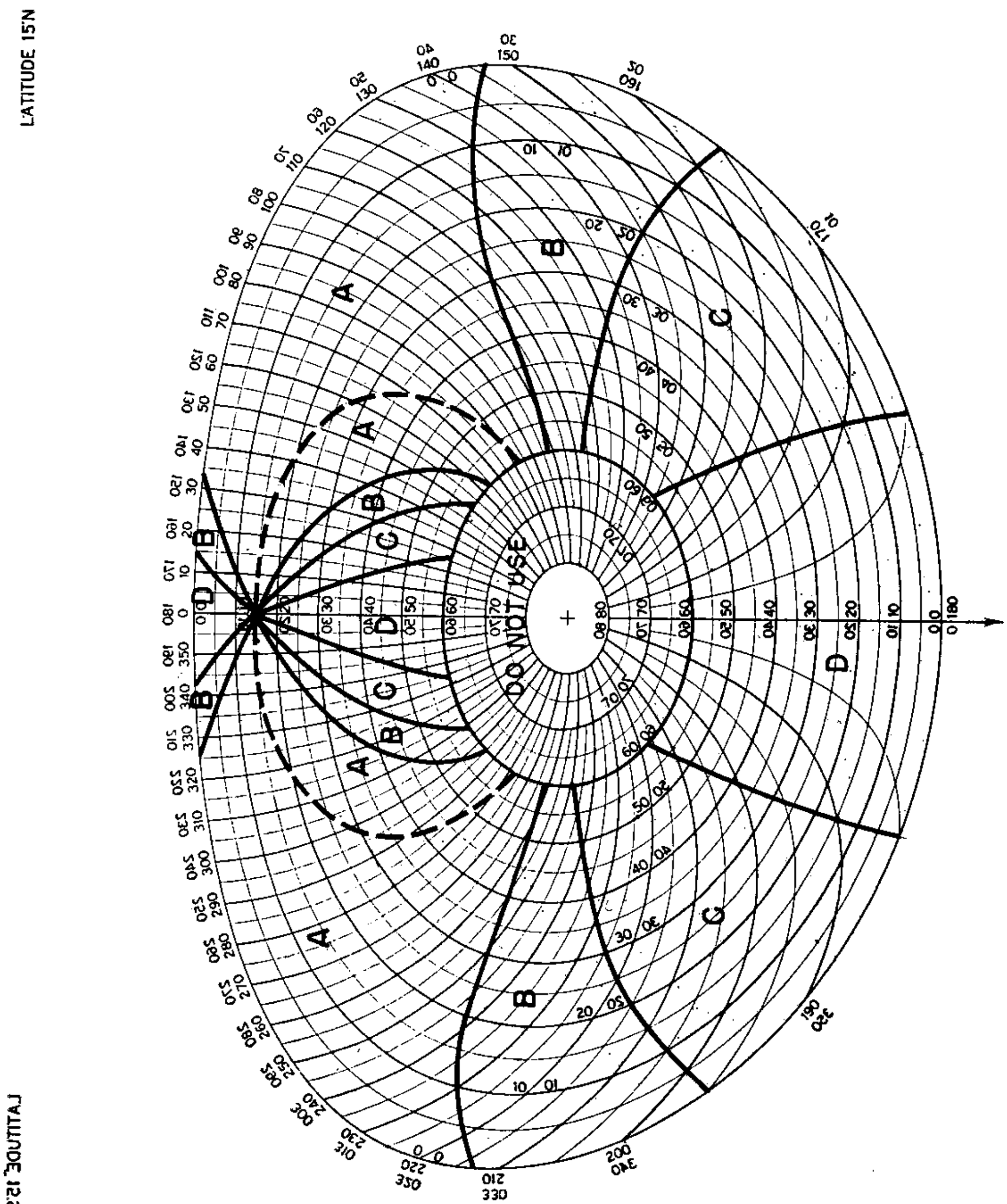



*Plate 2. Star Rate Plate 15°*

LATITUDE 25°S

LATITUDE 25°N



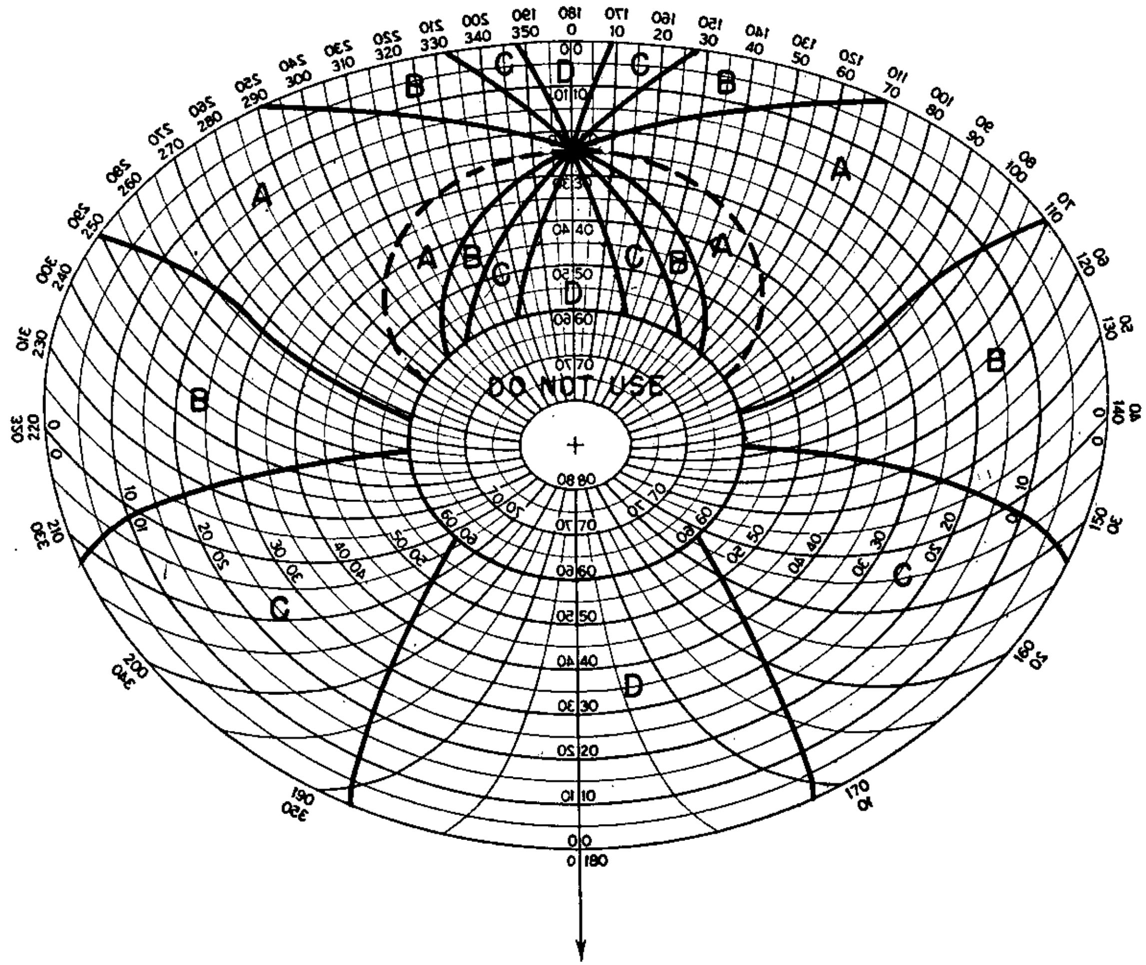



*Plate 3. Star Rate Plate 25°*

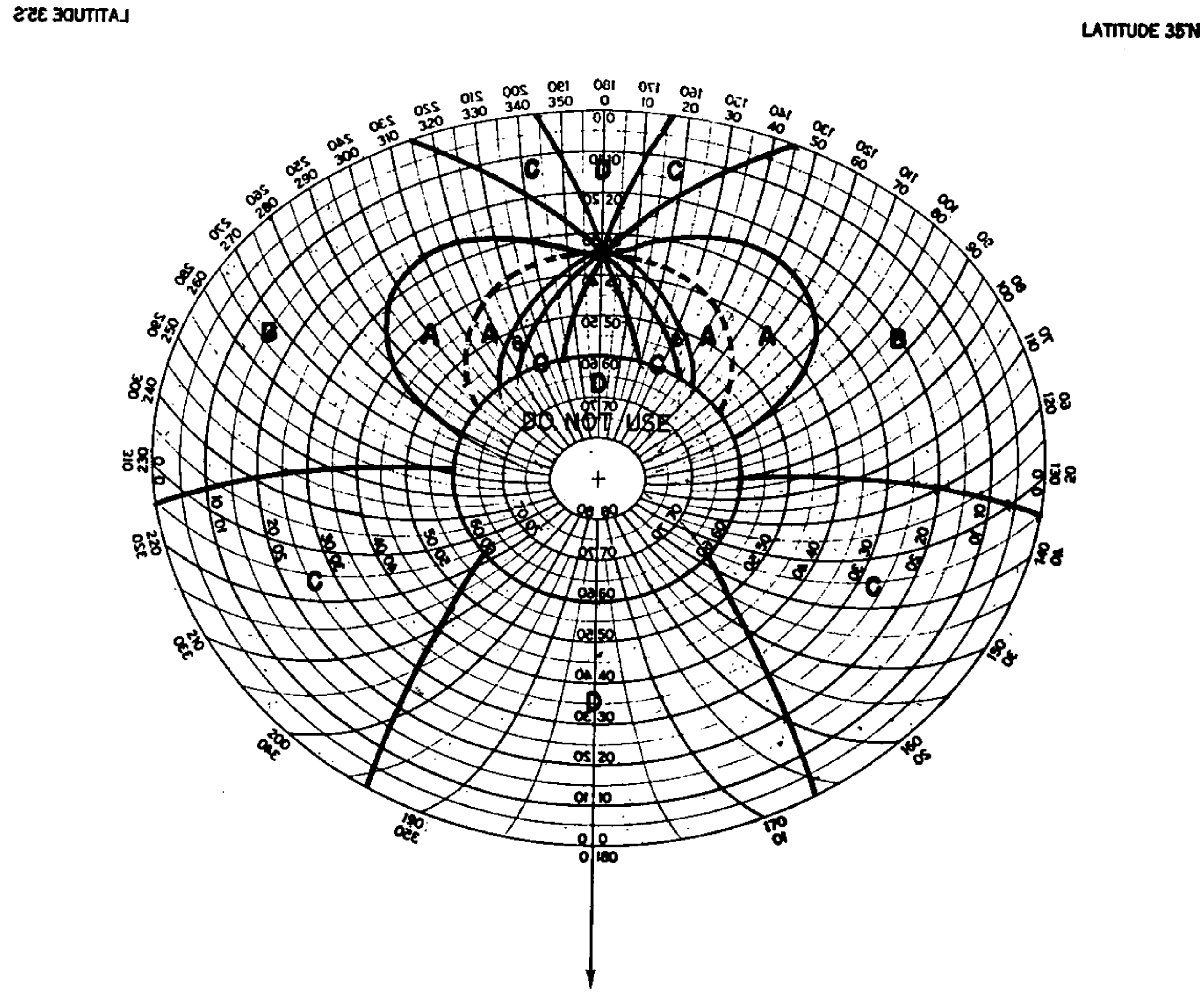



*Plate 4. Star Rate Plate 35°*

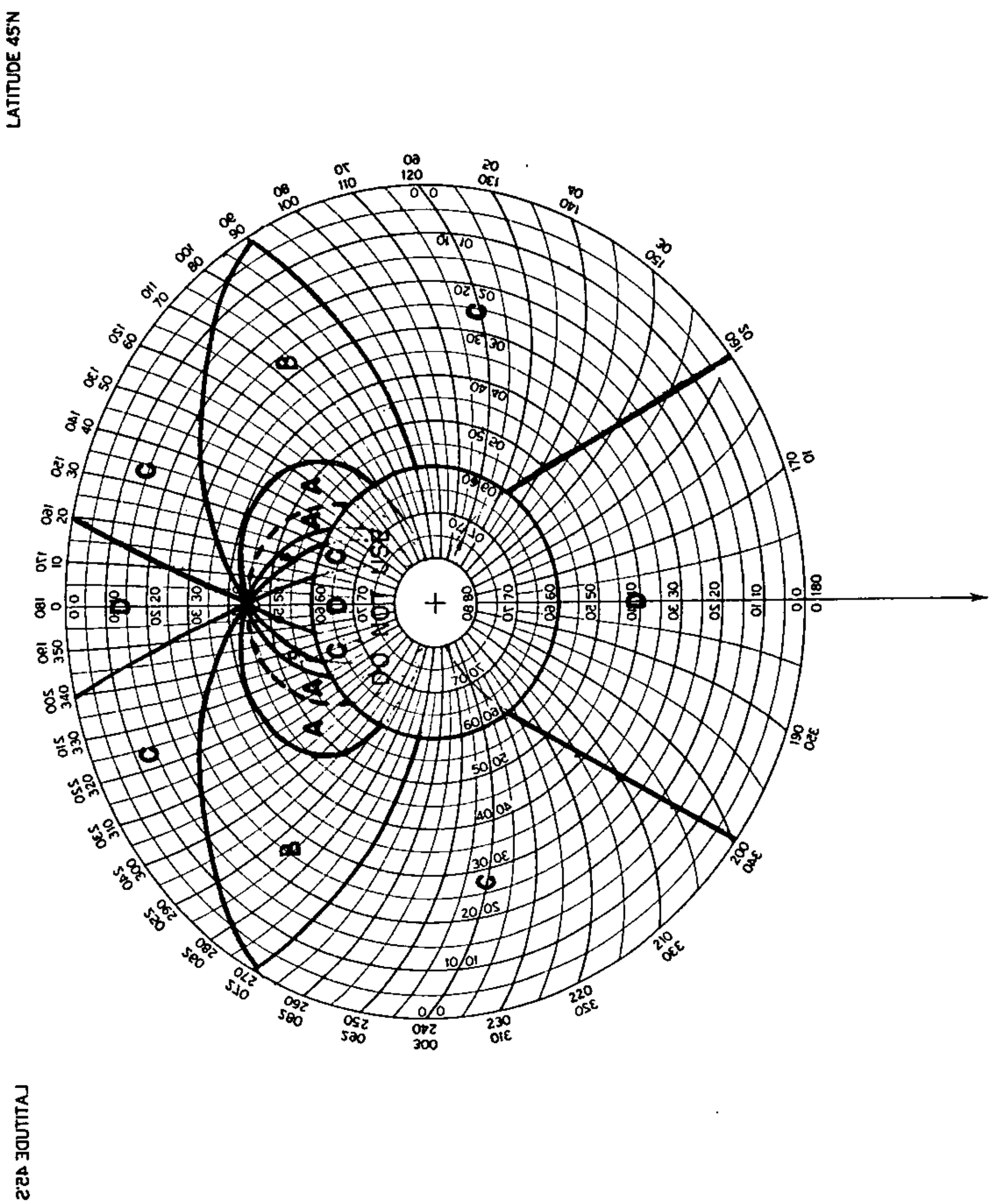



*Plate 5. Star Rate Plate 45°*

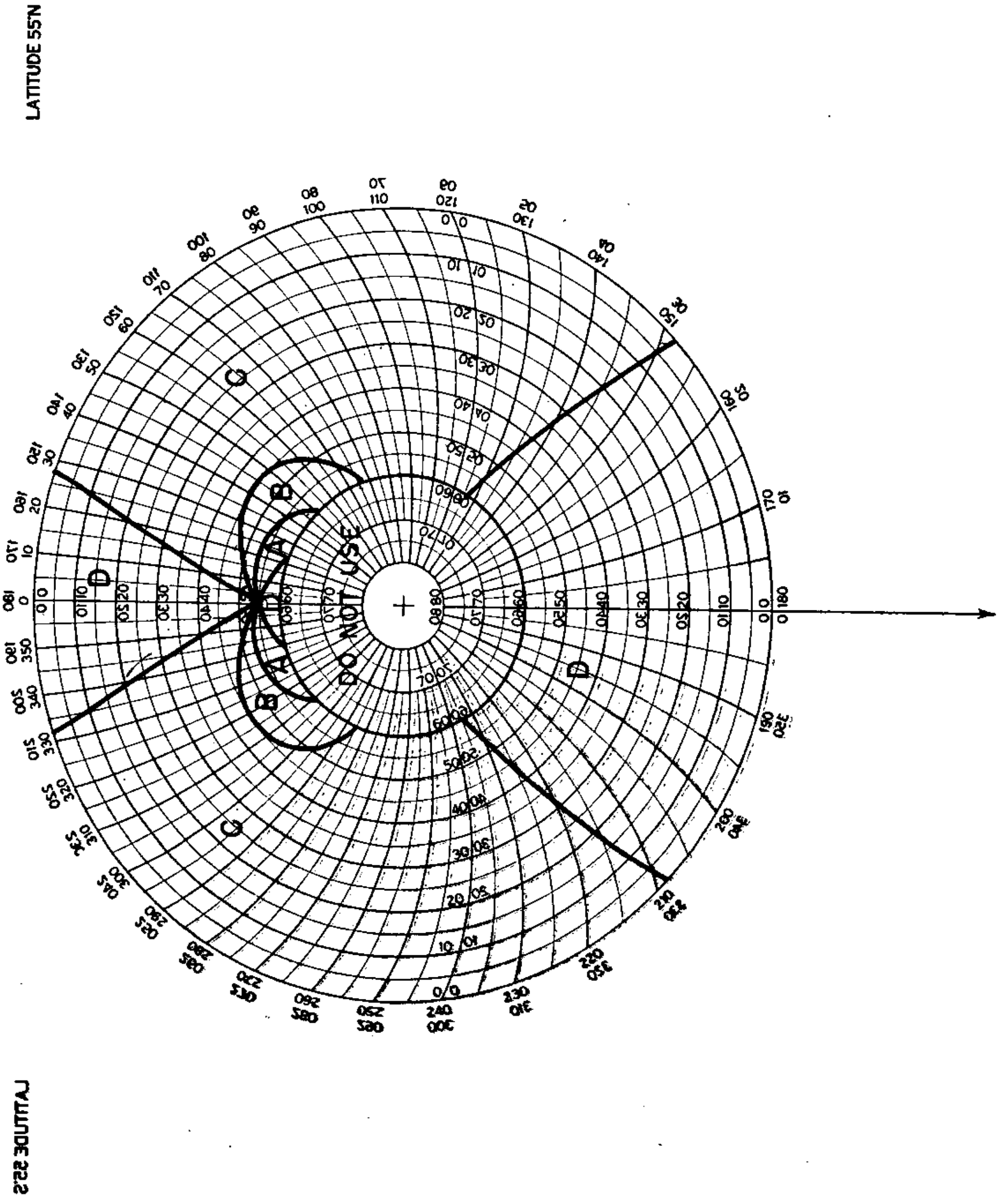



*Plate 6. Star Rate Plate 55°*

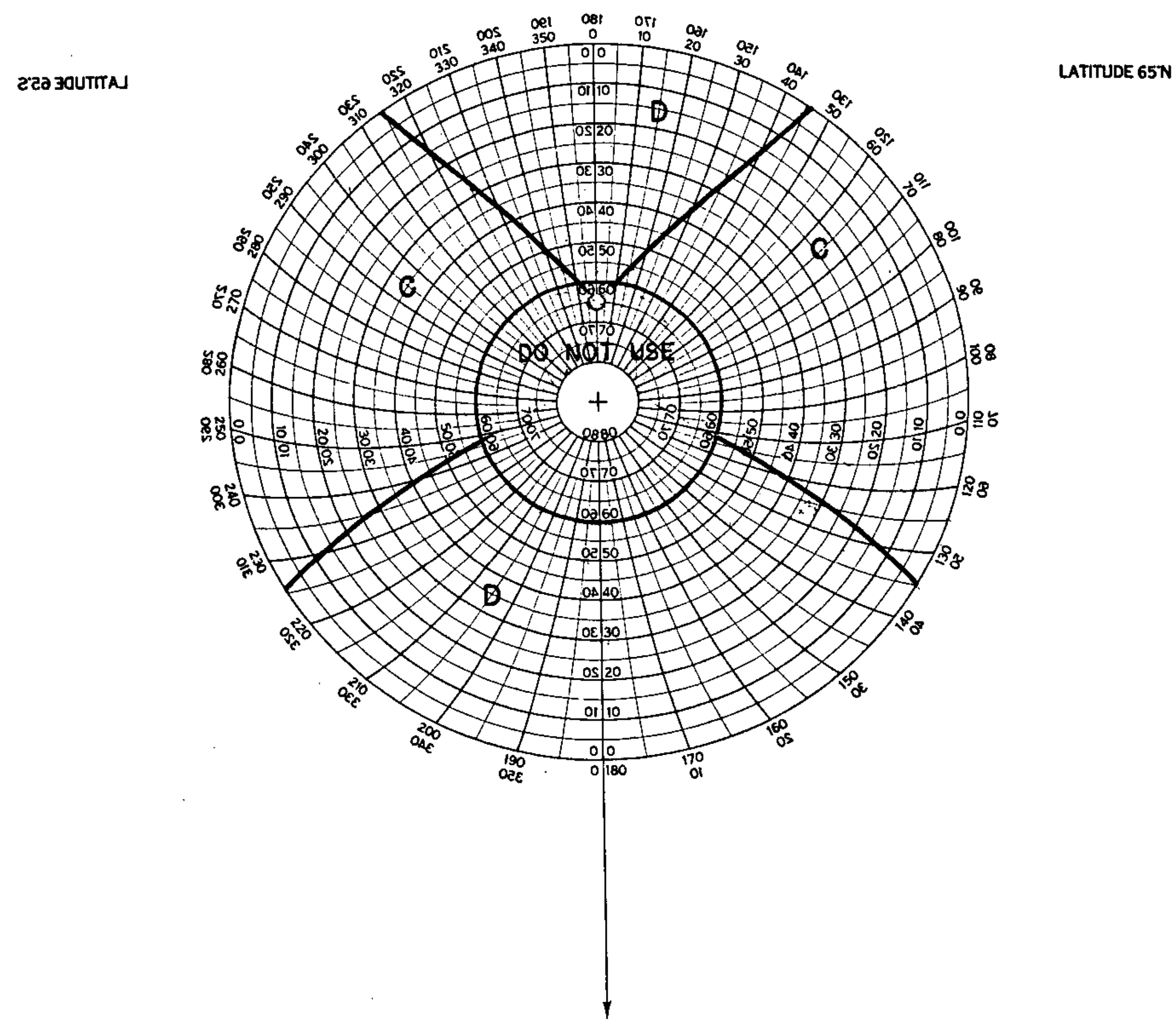



*Plate 7. Star Rate Plate 65°*

# INDEX

By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
*General, United States Army,*
*Chief of Staff.*

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USATC (2) except
USATC FA (5)
USMA (2)
Svc Colleges (2)
Br Svc Sch (2) except
USAABS (15)
Units org under fol TOE:
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6–575 (15)

*NG:* State AG (3); units—same as Active Army.

*USAR:* Units—same as Active Army except allowance is one copy to each unit.

For explanation of abbreviations used, see AR 320–50.

☆ U.S. Government Printing Office: 1965—781-256/10005A

# WORLD STAR CHART

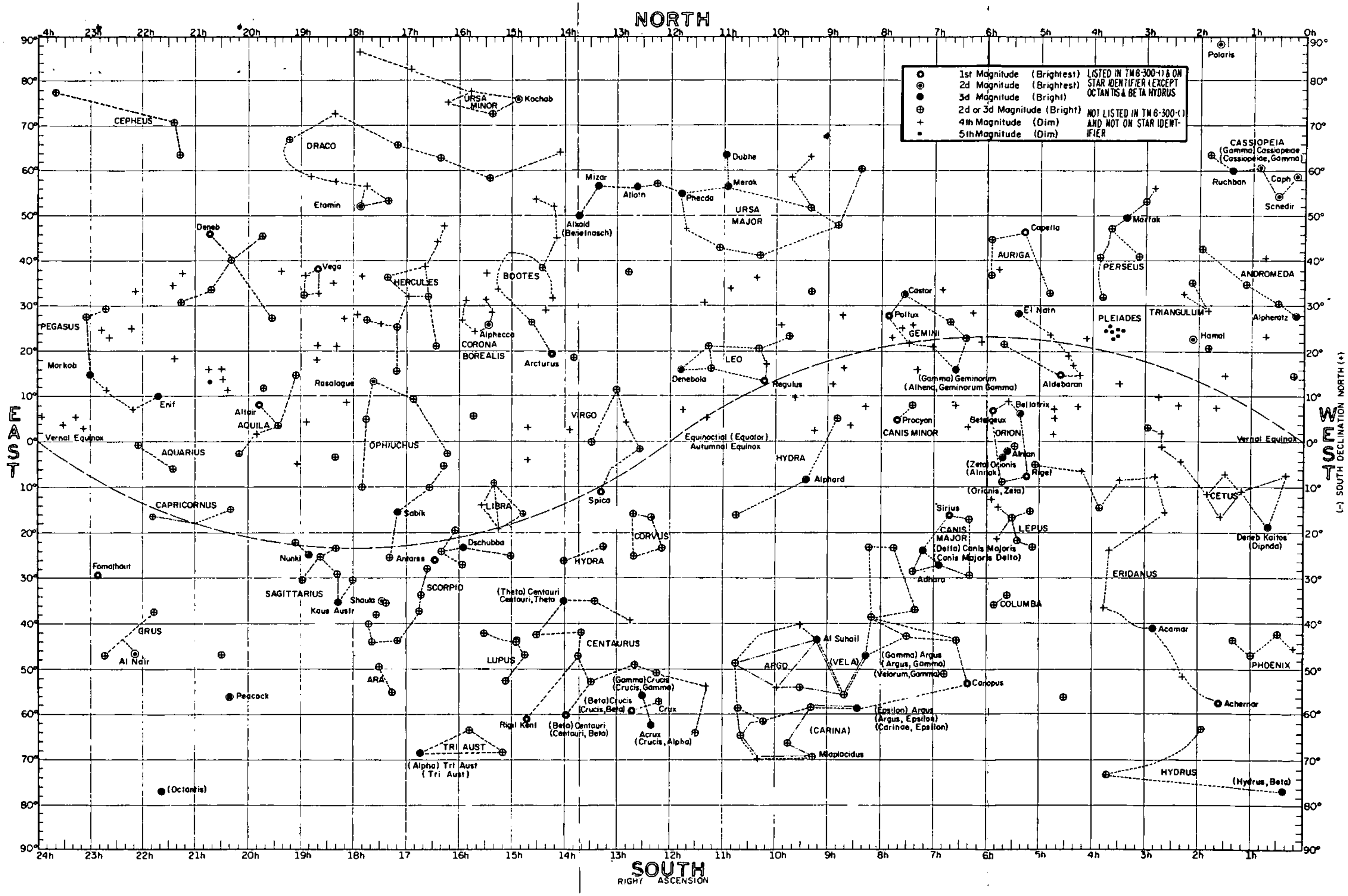


*Figure 121. World star chart.*