CHAPTER 1
Overview of Surveying

Surveyors determine horizontal and vertical distances between objects, measure angles between lines, determine the direction of lines, and establish points of predetermined angular and linear measurements. Once the field measurements are complete, surveyors use these to compute the data into a final report used for positioning by field artillery, air defense artillery, aviation, intelligence, communications, or construction control points.

Section I
MISSIONS, CLASSIFICATIONS, AND NETWORKS

MISSIONS

The missions of the military topographic surveyor are —

- Support deployable weapons systems (nuclear and nonnuclear) with position and azimuth.
- Support aviation with position, azimuth, and elevation.
- Support intelligence with precise position and azimuth.
- Support communications with line-of-sight profiles, position, and 360-degree visibility studies,
- Establish and extend basic control with field surveys.
- Forward survey data and station description cards to Defense Mapping Agency, the organization's survey information center (SIC), and colocated terrain analysis teams upon request,

These missions are defined in *AR 115-11,* in *FM 5-105,* unit table(s) of organization and equipment (TOE), and by directives from higher headquarters.

GEODETIC AND PLANE SURVEYS

The actual shape of the solid mass of the earth is referred to as the topography. The geoid is defined as the surface of the earth's gravity (attraction and rotation) which, on the average, coincides with mean sea level in the open undisturbed ocean. The spheroid (an ellipsoid of revolution), appears as a figure flattened at the poles and bulging at the equator. It can be described using a mathematical formula that approximately defines a part of the surface of the geoid, However, because of the great variations in topography, many different spheroids exist. Because the earth's surface is irregular and pieces of mathematical computations are unreliable, the surveys conducted depend on the purpose or level of accuracy required. In plane surveys all points are referenced to a flat plane, with curvature wholly or mostly ignored. In geodetic surveys, all established points are referenced to the curved surface of a spheroid and in all computations the effect of curvature is computed,

CLASSIFICATIONS

Technical Classifications

Geodetic surveys take into account the size and shape of the earth. Since the stations in geodetic surveys are routinely spaced over extended distances, more precise instruments and procedures are required than for plane surveys. All observations are made on the actual curved surface of the earth and this curvature is corrected through computations. The computational methods used in geodetic survey are discussed in *TM 5-237.*

Plane surveys ignore the actual shape of the earth and apply the principles of plane geometry and trigonometry. When the survey is less than 250 square kilometers in area and less accuracy is needed, curvature can be ignored. These surveys are treated as if the measurements were made on a flat plane, with all lines being straight. Most localized construction projects and boundary projects are plane surveys. The more extensive highway/railroad construction projects are generally plane surveys. The computational methods used in plane surveys are described in appropriate chapters of *FM 5-233* and *TM 5-237.*

Functional Classifications

Construction surveys. These surveys provide data, planning, and cost estimating essential to locate or lay out engineering works and are recorded on engineer maps. These surveys normally use plane surveying techniques. The methods, techniques, and procedures

used by the military construction surveyor are detailed in *FM 5-233.*

Artillery surveys.
Field artillery fire-control surveys are conducted to determine the relative positions of weapons systems to targets, but do not require the accuracy of geodetic surveying procedures despite the relatively large areas and long distances. The requirements, methods, and procedures used by the military field artillery surveyor are detailed in *FM 6-2.*

Air defense artillery weapons systems require the accuracy obtainable only with geodetic survey techniques.

Basic control (geodetic) surveys. These are surveys which provide horizontal and/or vertical positions of points which supplementary surveys may originate from and can be adjusted to. The basic control survey of the United States provides geographic positions and plane coordinates of triangulation/traverse stations and the elevations or bench marks, This information is used as the basis for the control of the topographic survey of the United States; for the control of many state, city, and private surveys; and for hydrographic surveys of the coastal waters. Techniques and procedures used by the military geodetic surveyor are discussed in this manual.

Astronomic surveys. The celestial determination of latitude and longitude separations are calculated by computing distances corresponding to measured angular displacements along the reference spheroids.

Satellite surveys. These surveys are conducted using artificial earth satellites for long-line surveys. Since distances between stations may vary from 100 to 1,500 miles, doppler transit satellites and the global positioning system (GPS) geocentric satellites are typical.

Special surveys.
Hydrographic surveys. These are surveys made on large bodies of water to determine channel depths for navigation and locations of rocks, sandbars, lights, and buoys. In the case of rivers, these surveys are made to support flood control projects, power development, navigation, water supply, and water storage.

Field classification and inspection surveys. These surveys help identify features not normally revealed using a compiler. Examples include political boundary lines, place names, road classifications, and buildings obscured by trees. They also help clarify aerial photographs using comparisons with actual ground conditions.

Gravity surveys. These surveys result in the intensity of the gravitational forces at or near the earth's surface. Gravity observations may be either absolute or relative, Absolute gravity is the gravity at a specific point, while relative gravity reflects gravitational variations from point to point.

Land surveys. This is the process of locating the boundaries and areas of tracts of land.

Inertial surveys. These surveys determine relative positions and azimuths. The position and azimuth determination system (PADS) is now being used extensively to support artillery survey requirements.

Airfield surveys. These surveys are made to determine any combination of the following:
- Location of obstacles within 10 nautical miles of the airfield center.
- Dimensions of runways and taxiways, heights of flight towers, and navigational aids.
- Safe approach angles to runways and minimum safe glide angle.
- Elevation of barometer on the airfield.
- Positions and azimuths of points designated for inertial navigational systems (INS) checkpoints.
- Requirements of the Federal Aviation Administration (FAA), United States Army Aeronautical Services Office (USAASO), or equivalent military activity.
- Incidents of a military aircraft crash or disaster.

SURVEY NETWORKS

Horizontal and vertical survey control within a country is usually established by a network of control areas. These areas are all referenced to a single datum and are related in position or elevation to each other. The networks are called basic, supplementary, and auxiliary. Currently, all horizontal networks in the United States are referenced to the *North American 1927 Datum (NAD 1927)* and *North American 1984 Datum (NAD 84* and *WGS 83* are the same) with coordinates currently being published in both data.

Mean Sea Level 1929 is being used for vertical control points. Within the continental United States, the following definitions are used.

Basic

Basic horizontal control networks. These networks are usually established by first-order geodetic

triangulation, precise electronic traverse, or satellite translocation. The lines of the basic network are typically spaced approximately 96 kilometers apart throughout a country.

Basic vertical control networks. These networks are established by first-order differential leveling in areas spaced from 90 to 160 kilometers apart throughout the country. Permanent bench marks are spaced approximately 3 kilometers apart on these lines.

Supplementary

Supplementary horizontal control network. This network is usually established by second-order survey procedures. The supplementary nets are used to fill in the areas between the basic control lines. Ultimately, a station of either the basic or supplementary networks will be spaced at intervals of between 6 to 16 kilometers across the country.

Supplementary vertical control network. This network is established by second-order differential leveling. These lines are run within the basic control arcs to provide a planned control line spacing of about 10 kilometers. Permanent bench marks are emplaced about 2 kilometers apart on these lines.

Auxiliary

Horizontal auxiliary (or additional) control networks. These networks are usually established by second- or third-order survey procedures. The networks are established to provide localized control to be used by surveyors for artillery control, construction engineering surveys, mapping projects, or other positioning requirements. Additionally, as more states require geodetic accuracies, these networks will be used by states and other agencies for boundary and property surveys.

Vertical auxiliary control networks. These networks are established by third-order differential leveling and are used to provide localized vertical control. This control is also used to support artillery construction and engineering projects.

Section II
FIELD WORK

Survey field work consists of making observations and measurements and recording the data. The surveyors must also overcome many factors that combine to affect working conditions.

OBSERVATION AND MEASUREMENT FUNCTIONS

Observations and measurements are generally made for the following reasons:

Observing Distances and/or Directions (Angles)

- To establish triangulation and traverse stations for basic, supplementary, and auxiliary control networks.
- To establish gun and target positions for artillery batteries.
- To establish horizontal control to support PADS.
- To establish point and lines of reference for locating detail such as boundary lines, roads, buildings, fences, rivers, bridges, and other existing features.
- To stake out or locate roads, buildings, landing strips, pipelines, and other construction projects,.
- To establish lines parallel to or at right angles to other lines; or to determine the area of tracts of land, measure inaccessible distances, or extend straight lines beyond obstacles.
- To establish picture points for data bases.
- To do any other work which may require use of geometric or trigonometric principles.

Observing Differences in Elevations

- To establish bench marks for basic, supplementary, or auxiliary vertical control networks.
- To determine differences in elevation of terrain along a selected line for plotting projects and computing grade lines.
- To stake out grades, cuts, and fills for earthmoving and other construction projects.
- For trigonometric elevations of triangulation and traverse stations for control nets and mapping projects.
- For gun and target position for field artillery batteries.

Recording Field Notes

Field notes are made to provide a permanent record of the field work. These notes take the form of-

- Field recording booklets.
- Single sheet recording forms.
- Magnetic tapes for automatic data recording.
- Plane table sheets.
- Land survey plans.
- Property plans.
- Recovery and station description cards.

- Control diagrams showing relative location, methods, and type of control established and/or recovered.

FACTORS AFFECTING FIELD WORK

The field surveyor must be constantly alert to the various conditions. Weather, terrain, personnel, equipment, purpose, required accuracy, systematic procedures, rates of progress (speed), and the enemy situation all influence the work.

Weather and Terrain

Weather and terrain can adversely affect field surveys. The effectiveness of optical and electro-optical instruments can be severely reduced by fog, mist, smog, or ground haze. Swamps and flood plains under high water can impede taping or leveling operations. Distances measured over open water and fields of flat unbroken terrain or near high-power transmission lines can create ambiguities when using microwave equipment. Maximum length measurements obtained by electro-optical distance measuring equipment (DME) can be reduced in bright sunlight. Good reconnaissance and proper planning can alert the field parties of the best times and methods to use.

Personnel

The level of training and experience of the personnel also affect field work. The rate of progress often varies in proportion to the personnel experience level.

Equipment

Modern, well-maintained equipment can often increase the rate of progress. Even older equipment, if properly maintained or adjusted, will yield accurate results. Repairing or replacing broken instruments or parts is sometimes responsible for slowing down or stopping a field survey. Therefore, equipment reliability must be considered when setting completion dates.

Purpose and Type of Survey

The purpose and type of survey determine the accuracy requirements. First-order triangulation, traverse, or leveling for the control networks must have high accuracy standards. At the other extreme, cuts and fills for a highway have much lower standards. In some surveys, distances to inaccessible points must be determined. Highly accurate distance and angle measurements are required so that these values, when used in trigonometric formulas, will yield acceptable results.

Required Accuracy

Accuracy requirements will dictate the equipment and procedures selected. For instance, comparatively rough procedures can be used in plane table operations, but control network leveling requires much more precise and expensive equipment as well as extensive, time-consuming procedures.

Errors

All measurements contain some error. The errors classified as systematic and accidental are the most common uncontrollable errors. Besides errors. measurements are susceptible to mistakes or blunders. These arise from misunderstanding the problem, poor judgment, confusion, or carelessness. The overall effect of mistakes and blunders can be greatly reduced by establishing a systematic procedure. The system will be an advantage in all phases of the survey and can result in great time savings.

Rates of Progress (Speed)

Rates of progress vary depending on experience and repetition. As skill and confidence increase, so will speed. Proper preparation and planning will reduce duplication of effort and increase efficiency.

Enemy Situation

A hostile environment often forces a schedule adjustment. Night work will require greater speed, fewer lights, and increased security. Adding security forces increases the number of vehicles and personnel which, in turn, involves reduced efficiency, thus retarding even the most ambitious time schedule.

FIELD NOTES

Even the best field survey is of little value if the notes are not complete and clear. The field notes are the only record that is left after the survey party leaves the field site. The surveyor's notes must contain a complete record of all measurements or observations made during the survey. When necessary, sketches, diagrams, and narrations should be made to clarify notes. Write overs, erasing, use of ink eraser, correcting tape, and whiteout are strictly forbidden. These actions, when prohibited by the unit survey standing operating procedures (SOP), are cause for punishment under the Uniform Code of Military Justice. Recording errors are to be lined out, initialed by the recorder and the correct new reading entered on the recording form.

Recording Qualities

Good field notes share these qualities:

Neatness. The lettering conforms to the gothic style portrayed in *FM 5-553.* All entries are formatted according to local SOPs.

Legibility. Only one interpretation should be possible. Decimal points and commas must be clear and distinct.

Completeness. All entries are completed and all resolved data are finished according to local SOPs.

Done in field. All recording is done on the correct specified forms entirely in the field. Notes are never recorded on scrap paper and transcribed to a field recording form. If performing an underground survey, obtain and use a covered clipboard to protect the notes.

No erasures. All field work will be done in black or blue-black ink suitable for photocopying. The only exception is the field sheet of a plane table survey.

No write overs. Field notes show what happened in the field. If a number is changed, the correct procedure is to make a single slanted line through the incorrect number. The individual making the corrections inserts the correct number directly above or next to the corrected value, creating the new entry and initialing the change. A note will be entered in the Remarks column stating why the number was changed.

True picture. The field notes accurately describe the field experience. Sketches, diagrams, and notes reduce or eliminate questions.

Organizing Survey Notes

Survey notes are usually kept in a field notebook, or on individual recording forms, or on tape if an automatic data collector is used. Regardless of the type used, the following information must appear:

1 Instruction for return of the book or notes, if they should be lost. Usually, it will be returned to the commander of the particular unit.

2 Index of field notes contained in the book and cross--referenced to additional books or binders.

3 List of party personnel, their duties, and the dates on the project (from - to).

4 List of instruments used, to include types, serial numbers, calibration date, constant values, and dates used.

5 A generalized sketch and description of the project.

6 The actual survey notes on each page containing data. The heading must be filled out, to include –

- Station names, including establishing agency and date.
- Date of the survey.
- Personnel names and survey duty (instrument operator, notekeeper).
- Instruments used and serial numbers.
- Weather data.
- The actual observed data, to include all required reductions.
- Pertinent notes, as required.
- The observer's initials, indicating that the observer has checked all entries and ensured they are correct. The observer's initials will be at the bottom right corner of the recording form.

Loose-leaf sheets should be serially numbered to ensure that all sheets are kept and turned in. The cassette tapes must be clearly marked for return to the unit, and require special handling.

Types of Recording

Field note recording takes three general forms: tabulation, sketches, and descriptions.

Tabulation. Numerical data is recorded in columns following a prescribed format, depending on the type of operation, instrument used, and specifications for the type of survey.

Sketches. Sketches add much to the clarity of field notes and should be used liberally. They maybe drawn to scale, as in plane table surveys, or they can be drawn to an approximate scale, as in control cards. If an exaggerated scale is needed to show detail, the use of such a scale is recommended. Measurements should be added directly on the sketch or keyed in some way to avoid confusion. Sketches require the same qualities as all other field notes.

Descriptions. Tabulations with or without sketches can also be supplemented with narrative descriptions. The description may only consist of one or two words or it maybe very detailed. It must be remembered that survey notes become a part of historic records. A brief description entered at the time of the survey maybe important and helpful at some time in the future.

Abbreviations and Symbols

It is strongly recommended that standard abbreviations, signs, and symbols be used in all survey notes. These abbreviations, signs, and symbols must be in accordance with current guidelines in such publications as *AR 310-50, FM 21-31,* and *FM 101-5-1.* If there is

any doubt as to the meaning or interpretation of a symbol or abbreviation, the words must be spelled out.

Corrections

Field notes are considered legal documents, since they can and have been used in court proceedings. As such. NO ERASURES OR WRITE OVERS ARE PERMITTED. Individual numbers are corrected as stated in Recording Qualities, page 1-5. No position will be voided or rejected in the field except in the case of disturbing the instrument or target or observing the wrong target. In either case, the position should be **reobserved,** stating in the Remarks section the location of the reobserved data.

Waterproofing

Every effort must be made to protect field notes. Even in high humidity or rain, field notes can be waterproofed by spraying a thin coat of clear acrylic plastic on the field record. If applied before the recording, the paper will be waterproof but still allow recording with ordinary writing instruments. The field notes can be sprayed again after use, and the plastic fixes the writing and prevents water damage to the records. One such spray is *Krycor, workable FIXA T-IF #1306;* however, many other sprays are available and any of them may be used.

SURVEY COMMUNICATIONS

Survey party members may find themselves separated. The ability to communicate with each other may mean the difference between successfully completing a section of work or not. Even at relatively short distances (as in taping, plane table, or leveling operations), background noises can obscure direct voice contact. At longer distances such as in electronic distance measuring equipment (EDME) or direction measurement operations, effective direct voice contact is impossible. Therefore, some other types of communications are required.

Hand Signals

Communication over short distances can effectively be accomplished using hand and arm signals such as are shown in Figure 1-1. All party members must know the signals and their exact meaning. Each signal is given while facing the person being signaled.

Voice Communications

On long lines where hand signals are impossible, the radio must be used. Each theater of operations or Army command has published communications-electronics operation instructions (CEOI), with which the user units must comply. Only frequencies obtained through the local signal officer may be used. All personnel using radios must be familiar with the CEOI and the unit's communications SOP before using a radio. All radio communications must be kept as short and secure as possible.

Mirrors and Lights

Mirrors and lights can also be used for communication. The emergency signal mirror can use the sun as a light source and is a fairly accurate sighting device. Morse code or other prearranged signals can be used to effectively communicate during the day. At night, the same signals can be used with a 5-inch or other light.

Section III
OFFICE WORK

Surveying also consists of converting the field measurements into a more usable form. The conversions or computations maybe required immediately to continue the field work. At other times, they must be held until a series of field measurements is completed. This is called office work, even though some of the operations may be performed in the field during lapses between measurements.

OPERATIONS

Some office functions use special equipment (slide rules, conversion tables, calculators, computers, or drafting equipment) or require extensive references and working areas.

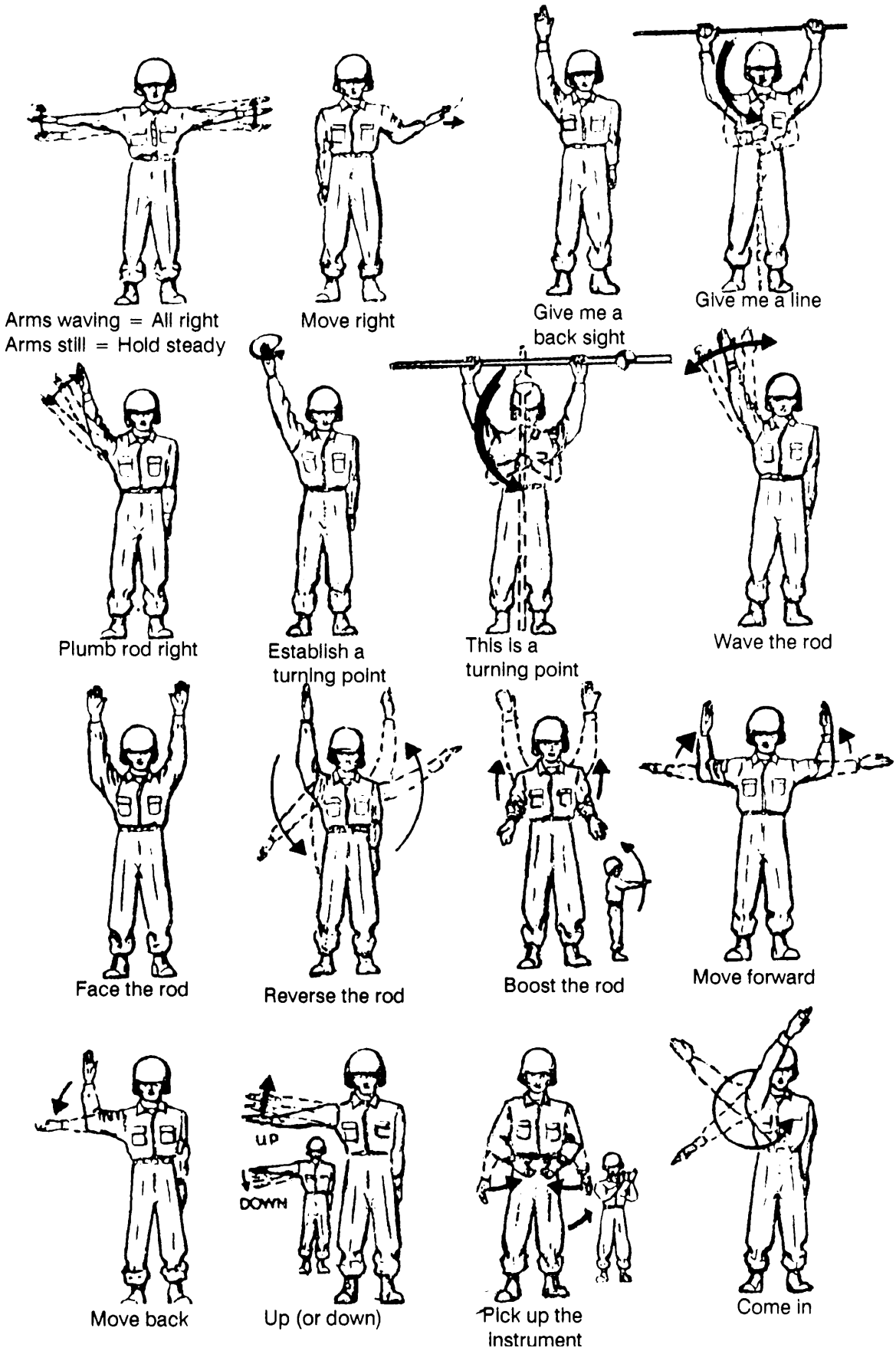
Working Up Field Notes

During survey operations, many field measurements require some form of arithmetical computation. It may be a simple addition of several full (tape) lengths and a partial tape length to record a total distance between two points. It maybe adding or subtracting differences in elevation to determine height of instrument or elevation during leveling, or it maybe checking angles to see that the allowable error is not exceeded.

Computing

Office computing converts distances, angles, and rod readings into a more usable form. The measurements may end up as a computed volume of dirt to be moved for a highway cut or fill, an area of land needed

Figure 1-1. **Hand and arm signals**



for a construction project, or an adjusted position of some point or mark from which other measurements can be made.

Distances. Distances measured by tape are measured in short horizontal distances. For higher accuracy, corrections to taped distances must be applied for temperature, tension, or sag of the tape. The desired result is the horizontal distance between two points, In electronic distance measuring (infrared and microwave), the distance is almost always on a slope and has to be corrected for temperature and barometric pressure, then reduced to corrected horizontal distance.

Azimuths and bearings. In many operations, the observed angles are converted into directions of a line from north (azimuths) or a north-south line (bearings).

Relative positions. The distance and direction of a line between two points determines the position of one point relative to the other point. If the direction is given as a bearing or azimuth, a trigonometric formula using the sine or cosine of the angle, multiplied by the distance, will result in a coordinate difference between the two points.

Adjusting

Some survey techniques are not complete until one more procedure is performed.

Definition. Adjusting is the determination and application of corrections to data. Adjustment causes the data to be consistent within themselves and to a given set of references. Small errors which are not apparent during individual measurements can accumulate to a sizable amount. For example, assume that 100 measurements were made to the nearest unit and required determining which unit mark is closer to the actual measurement. At the end of the course, an error of + 4 units resulted. Adjusting the result means reducing each measurement by 0.04 unit, Since the measurements were only read to the nearest unit, a single adjustment would not be measurable at any point and the adjusted result would be correct. Some of the more precise surveys require least square adjustments.

Traverse. Traverse is the measurement of lengths and determination of directions of a series of lines between known points and establishes the coordinates of the intermediate points. When computed, the accumulated closing error shows up as a position displacement of a known point. The displacement is corrected and distributed among the intermediate (traverse) points.

Triangulation. Adjusting triangulation consists of adjusting the three angles of each triangle to equal 180 degrees, then computing the lengths of the unknown sides of the triangle, using a measured or computed side (baseline). The newly computed sides become the known distance values of adjoining triangles. Computing continues through the triangulation net until a second baseline is reached. The closure (difference between the measured baseline distance and the distance as computed through the triangles) must be within prescribed limits. The amount of closure is then adjusted back through the net, affecting the positions of the stations.

Elevations. Depending on the purpose, the elevations on some level lines are computed as the measurements are taken. When the line is closed, the difference in elevation between the measured and the known elevation is adjusted over all the stations in the line. In higher order leveling, only the differences in elevation are recorded during the measuring, with all adjusting done at the completion of the line. The error is then distributed among the various sections of the line.

PROCEDURES

Establishing Records

Office computations reduce the field notes to a tabular or graphic form. This becomes a permanent record and is stored for further use or subsequent operations. Many standardized forms are available and cover most procedures. These forms are recommended when available, but the surveyor is not limited to these. As long as the sheets are clearly identified and bound as a set, they may be acceptable. Normally, all field notes will be abstracted and the field notes filed separately. The abstracts will be bound along with all computing forms into a single binder or folder, and maintained on file for further reference. All pages, either abstracts or computing forms, will bear the name and date of the person performing the work. The pages will also bear the name and date of at least one person who has checked that page. At no time will any of these records be disposed of or destroyed.

Checking

Surveying is a series of checks. The field notes should be checked by the observer, the recorder, and the party chief before the notes are turned in for office work. Prior to computing, the assigned person should check the notes again. Most mathematical problems

can be solved by more than one acceptable method. In checking a set of computations, a method which differs from the original computation may be desirable. An inverse solution, starting with the computed values and solving for the field data is one possibility. A graphic solution may be used. Each step that cannot be checked by any other means must be checked by a totally independent recomputation by another individual. Any errors or mistakes found must be resolved and rechecked before the computation is accepted.

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Change

NO. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 29 May 1990

FIELD MANUAL
TOPOGRAPHIC SURVEYING

FM 5-232, 27 September 1989, is changed as follows:

1. Line through the supersession notice and references as indicated below:

Page

i . . . .Supersession notice, line through: TM 5-232, 1 June 1971; TM 5-235, 18 September 1964.

2-References . . . . under Technical Manuals (TM) line through: TM 5-441 Geodetic and Topographic Surveying.

2. File this change sheet in front of the publication for reference purposes.

By Order of the Secretary of the Army:

CARL B. VUONO
General, United States Army
Chief of Staff

Official:

WILLIAM J. MEEHAN, II
Brigadier General, United States Army
The Adjutant General

DISTRIBUTION:

Active Army, ARNG, and USAR: To be distributed in accordance with DA Form 12-11E, requirements for FM 5-232, Topographic Surveying (Qty rqr block no. 4387), and TM 5-232, Elements of Surveying (Qty rqr block no. 652) and TM 5-441, Geodetic and Topographic Surveying (Qty rqr block no. 678).

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Chapter 2
Project Planning

Survey operations, whether under combat conditions or not, are like any other military operation. They must be carefully planned. Enthusiasm, technical proficiency, and dedication will not by themselves make up for poor planning. All plans must be dynamic in nature. They must be constantly evaluated and updated to remain current. This chapter will address project planning primarily from a logistics and administrative standpoint. Most of the information contained in this chapter is concerned with prebattle operations. Some general technical planning will be addressed but only as it impacts on administrative and logistics support. Project planning can be broken down into the following phases:

1. **Receipt of Project Directive.** This includes the initial project evaluation, determining the project requirements, assessing the unit's ability to accomplish the project, drafting the preliminary plan and milestone schedule, and coordinating the needed administrative and logistical support.
2. **Trips.** Trips are used to gather information to be used in the conduct of the project and to evaluate project progress. The information gathered will be logistical, administrative, or technical depending on the type of trip. Information obtained during these trips is used to refine the project plans and milestone schedules.
3. **Project Execution.** This is the actual conduct of the project – putting the project plans into effect. Unexpected or unusual circumstances will make additional plan modification necessary.

Section I
EVALUATING AND SCHEDULING

After receipt of a project directive, planning the project begins. This preliminary planning will involve evaluating the directive, assessing unit capability, and determining a preliminary schedule of events. It is important that all estimates, including time and funds, be labeled **preliminary** for all reports or briefings, If this is not done, the customer, supported units, or higher headquarters may not get an accurate picture of the true extent of the project.

PROJECT REQUIREMENTS

The first step in project planning involves evaluating the requirements as stated in the project directive. In many instances, requests will come from offices or units that have no real knowledge of survey requirements. When this happens, the support request must be carefully evaluated to ensure that what the customer has ordered is, in fact, what the customer needs. This evaluation is based on past experience and is usually done by the survey technician. Generally, there are three cases of requirement versus need:

1 The customer has-requested more accurate work than is really needed.

2 The customer has requested work that is less accurate than is needed.

3 The customer has requested work that matches the need.

In the first case, the customer is typically not survey-oriented and only sees the **orders and classes of accuracy** as words and numbers on a page. The customer simply does not understand the differences and the cost implications of each. Generally, telephonic explanation of the differences in orders of accuracies will resolve most potential conflicts. In those cases where the customer cannot be swayed from an erroneous perception of orders of accuracy, demonstrating the cost differences will generally change the customer's mind. If the customer remains adamant in the request, then planning to accomplish the request should begin. In those cases where the request is for less accuracy than is needed, the customer must also be contacted. The differences in orders of accuracy must be explained. Since funding costs usually go up in more or less direct proportion to the order or class of accuracy, it maybe even more difficult to change the customer's attitude about the request. Again, if the customer cannot be swayed, then planning to accomplish the request as is must begin. In both these instances, careful documentation of all contacts and conversations with the customer should be kept. At some future date, the customer may realize that the survey unit gave good advice and wish to change the initial request. If the recommendations for change are not accurately documented, the unit may be liable to correct the project.

In the third case, where it is determined that the customer has requested work that matches the need, planning can begin. Fortunately, this is usually the case, particularly in dealing with other military units that are routine survey users.

CAPABILITIES

Assessing the ability of the unit to conduct any type of survey is perhaps one of the most difficult tasks to be undertaken. Fortunately, many mechanisms exist to assist in this evaluation. The single best indicator is the commander's and survey technician's personal familiarity with their soldiers. Since this is not always accurate, a number of systems have been established to help in this evaluation.

Among these are the Army Training and Evaluation Program (ARTEP) and the skill qualification test (SQT). The ARTEP contains the mission training plan, battle drills, and evaluation guides for assessing the unit's ability to conduct various team tasks. The SQT is used to evaluate the technical abilities of individual soldiers. This annual evaluation of each soldier's technical ability can be used as an indicator of both weak and strong areas. Another tool that can be used is the unit's files. These records contain information on the unit's past performance on similar projects. They contain the names of personnel who conducted the project and the duration time. Also, any problems that arose are listed and explained in great detail. This information can prove to be very valuable not only for assessing the unit's ability to conduct the project, but in planning the project as a whole. The result of this assessment is a listing of the unit's training deficiencies. The survey technician will then develop a training program to address these shortcomings. Obviously, this program will be designed around the time constraint of the projected project start date. The tendency to always assign the most qualified personnel should be avoided. Usually, a mix of highly qualified and entry-level soldiers should be assigned to any project to ensure new people get the experience they need.

CONSTRAINTS ON ACCURACY

The Standards and Specifications for Geodetic Control Networks (SSGCN) were established by the Federal Geodetic Control Committee. These standards define the orders of accuracy for all geodetic quality work conducted in the United States. These SSGCN are used to ensure uniformity of all work conducted to support and extend the National Network. The United States Army, through the Corps of Engineers, is a member of the Federal Geodetic Control Committee and has signed the basic document agreeing to comply with the SSGCN. All Army survey activities conducted within the United States should be in compliance with these standards.

When possible, surveys in other nations should also be in compliance. Due to military necessity. there will be occasions when compliance is not possible due to mission requirements. Some of these situations are –

- Projects conducted in time of war.
- Projects conducted as training exercises designed as realistic war training exercises.
- Projects not intended for inclusion in the National Network.
- Projects conducted to support consumer requests that specifically exempt compliance.
- At the discretion of the survey technician in charge.

When feasible, all field activities should conform to the SSGCN. At some later date, it maybe determined that any given project should have been included in the National Network. If the field work was in total compliance, only the computations will need to be refined.

MILESTONES

Milestone schedules are developed to allow for estimating project duration and costs and managing personnel and resources. A milestone schedule generally takes the form of a time line, with events noted as they should occur. This time line allows a commander or customer to see at a glance how a project is proceeding. It is impossible for this manual to give specific guidance on the development of time lines for all types of survey activities. Therefore, general tips will be discussed. Under combat conditions, it may not be feasible to develop precise time lines. The flow of battle will dictate dramatic changes to any milestone schedule and most work will have to be accomplished on very short suspenses. In these situations, developing a time line will be time-consuming and in many cases counterproductive. Under normal prebattle operations, it is feasible and advisable to develop milestone schedules. Care should be taken to ensure that the resulting time line is not overly ambitious. There are a number of variables associated with anytime line. These include but are not limited to –

- Availability and type of equipment.
- Experience of party personnel.
- Terrain, vegetation, and weather.
- Extent or area of project.
- Priority of other projects.
- Enemy or adversary intervention.

Table 2-1 shows typical rates of progress for various types of survey operations. These are **rule-of-thumb** estimates. Each unit must develop its own rate of

Table 2-1. **Typical rates of progress for third-order surveys using the survey section**

Method of survey	Basic figure	Average distance per setup or figure			Daily progress (10-hour day)			Monthly progress			% Rerun		
		Terrain			Terrain			Terrain			Terrain		
		A	B	C*	A	B	C*	A	B	C*	A	B	C*
		Kilometers			Figures			Figures					
(1) Triangulation	Quad	9	9	15	3	3	2	40	40	20	5	5	5
	Triangle	6	6	10	7	7	4	100	100	40	5	5	5
		Kilometers			Kilometers			Kilometers					
(7) Traverse **(2) Microwave** **(1) (EDME)**	Linear	2	2	0.5 to 2	24	24	6 to 12	480	480	160	5	5	5
		Meters			Kilometers			Kilometers					
(6) (3) Leveling, differential (3-wire, looped)	Linear	250	150	100	6	4.5	3	120	90	60	10	10	15
(4) Astronomic azimuth	Station	1 per traverse every 30 to 50 stations, 1 per 12- to 15-figure triangulation			2-hour per observation								
(4) Baseline measurement microwave	Base	Every 10 figures of triangulation			1-hour per base								
(5) (8) Modular tower erection	Tower				6-hour erection per tower								

* In dense jungle areas, clearing parties of large size are required.

(1) Includes movement between stations–vehicle or helicopter.

(2) In planning microwave traversing, it must be realized that much depends on the transportation provided for moving equipment. Helicopter-supported, and with 10,000 meter observations, a rate of progress in excess of 100 kilometers per day is possible.

(3) Requires 1/2 survey section, foot travel.

(4) Requires 1/3 survey section, travel time not included.

(5) Requires 1/2 survey section, travel time not included.

(6) For single run levels, double the daily progress.

(7) Three EDMEs available per section.

(8) Number of towers required by triangulation or traverse is unpredictable without prior reconnaissance.

progress table based on the equipment and level of expertise of assigned personnel.

Project schedules can be established by several different approaches. The two most common are establishment based on a firm start date or on a firm end date. The techniques are similar in both cases, with some rather obvious differences. If the start date has been firmly established, then the project is laid out from beginning to end with each event occurring as it will happen. If the end date has been established, then the project must be reverse planned. That is, events that occur last must be programmed from the end of the project backward until the start time is established. In all cases, schedules must be realistic but not overly ambitious. Delays due to weather, equipment and personnel shortcomings, or any other problems must be built into the schedule. In most cases, it is better to estimate a longer duration time and finish early than to underestimate and miss a scheduled end date.

ADMINISTRATIVE SUPPORT

Administrative support is normally concerned with documentation, both technical and nontechnical. The technical support is usually the typing of reports, tabulating and preparing technical data, or preparing briefing materials. Technical administrative actions are often accomplished by the survey team itself with limited help from clerical personnel. Nontechnical support usually involves personnel actions. These actions are normally handled by specialists in administrative actions such as Personnel and Administration Center (PAC) or Adjutant General (AG) clerks. It is not the intent of this manual to outline specific methods of accomplishing these tasks. Rather, this section will deal with general guidance as to what should be accomplished and when. It deals primarily with peacetime operations conducted elsewhere than at the unit's installation. Wartime requirements are addressed in the various SOPs of the unit, parent unit, and major Army commands (MACOM),

Prior to Deployment

Before a survey unit deploys to another installation or area, a number of administrative actions should be accomplished. Basically, all routine personnel actions of all survey party members should be accomplished before departing. This ensures that there will be minimal actions to be accomplished while deployed. All soldiers should make sure that their pay portions, allotments, insurance statements, and other financial requirements are correct and up to date. Other actions that may be required are powers of attorney and routine medical checks such as physicals and dental checks. If a long duration time is anticipated, it is advisable that all personnel be scheduled for and complete a records review, to include promotion packets, personnel and finance records, and emergency data cards.

After all these actions have been completed, there will theoretically be no need for nontechnical administrative support. In reality, however, new actions will be required from time to time. Therefore, the party chief should make arrangements for handling any actions that may be required during the project. The local installation PAC or AG should provide this information. Depending on the nature of the required action, the party chief may be able to simply submit the paperwork through the mail. If these actions cannot be done through the mail or through telephonic contact, a visit to the AG at the project installation or the nearest military facility may be required.

During a Project

From the preceding paragraph, it is obvious that there will be times when the party chief or the individual is not able to complete some required action. The home installation should provide guidance to the party chief on how to overcome these problems. If the project is being conducted on a military installation, the party chief should check in with the local AG. This visit should be made before any problems are encountered. It is recommended that the project installation AG be contacted during the reconnaissance phase and a point of contact (POC) established. When this is done, this AG will know the survey unit is in the area and will usually give any assistance they can. As is often the case, the project may be in an area other than on a military reservation. In the United States, there will usually be a military representative of some type who can assist. It maybe possible to arrange for limited support from the local office of the Army Recruiting Command. In other instances, Army Reserve or National Guard units maybe able to offer assistance.

Regardless of the source of assistance, it must be established before it is needed. Nothing is more frustrating to a soldier than to have a personal problem and not have a ready solution. This hurts the soldier's performance and ultimately degrades the survey team's capability. Technical administrative support will usually be nonexistent and will be the responsibility of the survey team. Such actions will normally be restricted to typing technical reports and compiling/consolidating technical data.

After a Project

Nontechnical administrative support after the project is identical to prior support. The home installation PAC, AG, and finance and accounting office (FAO) will handle these actions. Among these actions are filing travel vouchers, initiating new personnel actions, and reviewing personnel and finance records. The parent unit will be able to assist in technical administrative support. This normally involves no more than a clerk typist to finalize the technical reports and information.

LOGISTICS

This section will give general guidance on the types of logistics arrangements and planning that should be accomplished. Many of these topics will be covered in very general terms. Because of the requirements of the various MACOMS and general support units, it is not possible for this section to be all-encompassing.

Preparation for Movement

Much of the specific information concerning preparation for moving a survey section or unit will be contained in the unit's or parent organization's SOP. It goes without saying that moving a unit of any size takes careful and thorough planning. When a unit moves, it is imperative that all equipment and personnel that will be required move as cohesively as possible, These movement plans should be developed to cover all contingencies and developed well in advance of any anticipated moves. They should address moving any size element of the unit or the entire unit. Most of the requirements for movement are described in *FM55-10.* This concise reference manual should be on hand when preparing any movement plans. The information contained is applicable to most situations, wartime or peacetime. In some cases, it maybe necessary to supplement the basic manual. The supplement will normally be drafted by the MACOM.

Communications

One of the most important and often overlooked aspect of any successful operation is communications. During movement, regardless of the mode of transportation, the unit will normally be dispersed in serials. During survey field procedures, the field teams will be located throughout the corps area. In all situations, it is imperative that the elements of the unit have the ability to communicate with the command and control section.

Planning communications support requires the same careful attention to detail as any other aspect. Depending upon the nature of the operation. it must first be determined how much and what type of communications equipment will be required. Normally, there will be some type of mix of hard-wire, land-line, and portable radios. After the number of devices is established for optimum use, the unit must determine how much of its own equipment is available to handle the load. If the unit does not have adequate equipment. there are two courses of action that can be taken. The first is to arrange for support from the customer or other organization. This is often a very satisfactory solution to the problem when it is possible. However, the unit will often have to operate within its own equipment limitations. In this case, it will be necessary to reevaluate the planned communications network and eliminate some nice-to-have communications elements. Another solution is the local purchase of handheld portable radios. The devices will normally be added to the unit's table of distribution and allowances (TDA) account. If this solution is used, it will probably be necessary to check with the communications center to ensure that there are no frequency conflicts as a result of nonstandard communications equipment. One of the best means of communication is the standard military radios available in all units. These devices give instant, usually reliable access to all users. However, there are a number of problems associated with these radios. Some major problem areas are –

- The lack of adherence to approved radio procedures.
- The potential of enemy exploitation of nonsecure communications. This exploitation can take the form of obtaining intelligence information, deception, radio direction finding, or jamming.
- Power supply or poor maintenance of the radios.
- Atmospheric conditions that render the radios inoperative.
- The range of single receivers without radio relay equipment.

The first two areas are directly related and the solutions are similar. All units have CEOIs that provide frequency and call sign allocations as well as security measures. Strict adherence to these procedures is mandatory. Training all personnel and radio telephone operators (RTO) in the proper procedures will ensure the denial of intelligence information to the enemy. It will also help prevent the other exploitation techniques any adversary may employ.

Power supply and maintenance problems must be addressed before the equipment is to be used. Proper maintenance procedures on all equipment can eliminate most problems. The entire communications system should be checked occasionally to ensure that

it is functioning as designed. Batteries for battery-operated systems should be stored in an approved fashion and checked/replaced as needed.

Atmospheric conditions are a major problem for which there are only limited solutions. It maybe necessary to establish land-line communications to overcome atmospheric problems. If this is the best solution, a series of communications checkpoints will have to be developed along routes of travel and throughout the area of operation. This system is often cumbersome, particularly if a move is over great distances or into undeveloped areas. The establishment of radio relays will in some cases overcome these difficulties. When required, the same techniques described in Chapter 3 for line of sight determination maybe used to establish radio relay positions. This method will require additional radio equipment and personnel. In a combat environment, it may be possible to contact the communications officer in the corps and arrange for radio repeater access. Once all problems have been resolved, the only aspect remaining is the use of the equipment that has been selected. The importance of proper radio procedures as specified in the CEOIs cannot be overemphasized. Communications security procedures must be strictly adhered to.

Material Support

It is not the intent of this manual to provide specific details on how to procure required materials or material support. This information is generally spelled out in the various SOPs of the units involved. Rather, the intention is to emphasize the importance of prior arrangements for these resources. As part of the planning process, an estimate of the time and materials will be developed. This estimate is based on previous experience with similar projects and the known requirements of the present project. These requirements should be originally developed with no regard to costs or difficulty of procurement. Determine what is needed, then figure out how to get it. Normally, most of the material support will be the responsibility of the customer. However, this cannot be assumed to be true. It should be clearly documented in the reports from the various trips mentioned above. In particular, the initial site visitation trip (ISVT) and reconnaissance trips should result in clear POCs for acquiring necessary materials. Technical supplies should be supplied by the unit through normal supply channels.

Section II
INFORMATION-GATHERING TRIPS

This section will describe trips as they apply to normal prebattle operations. In some instances, some of these trips can be consolidated or eliminated. The overall need for the various described trips will depend on a number of variables, including –

- The unit's familiarity with the area concerned.
- The amount of information already on hand concerning the project or supported unit.
- The anticipated duration of the project.
- The amount of problems encountered by the unit.

INITIAL SITE VISITATION TRIP

The ISVT is basically a fact-finding mission. This trip is normally conducted by the survey technician, the project noncommissioned officer in charge (NCOIC), and sometimes the unit commander or representative. The primary function of this trip is to gather information that will be used to plan the project and to establish POCSsfor the various support functions that will be required.

All project directives will identify an overall POC. This individual or office is normally concerned with the results of the project and may not be able to provide the types of assistance that will be required to work on and complete the project. Often, the overall POC will be able to assist in establishing POCs for all administrative and logistics requirements.

The types of support that must be arranged prior to any field activities include maintenance, medical and dental, personnel actions, supplies, billeting, messing and mail, and additional personnel. These arrangements must be geared specifically to meet the needs of the reconnaissance party and generally to support the project execution party.

For successful completion of the reconnaissance phase, all arrangements must be made with respect to care of personnel and equipment during the ISVT. Careful records should be maintained. with Memorandums of Agreement (MOA) being drafted as required. The types of documentation that must be prepared as a result of the ISVT are listed in Chapter 8, Section I.

RECONNAISSANCE TRIP

The purpose of the reconnaissance (recon) trip is to finalize arrangements for the project and specifically to lay out the field work. The conduct of the reconnaissance is discussed in Chapter 3. During the recon,

it is imperative that all arrangements made during the ISVT be checked to ensure that they are correct and viable. There may be a delay between the recon and project execution that causes some previously established POCs to be lost or changed. If this occurs, a replacement POC must be established. Any events which occur that have not been anticipated should be carefully documented. The documentation required as a result of the reconnaissance is discussed in Chapter 8.

PROJECT VISITATION

Project visitation trips are generally conducted by the survey technician or command representative. Their primary purpose is twofold. The first is to check on the progress of the project. This is the responsibility of the survey technician. Any recurring technical problems will be discussed at length and resolved in such a manner as to preclude recurrences. Obviously, if problems have been occurring prior to a visitation trip, contact with the parent unit should have been made previously. Technical difficulties that need resolution should not be left unresolved until a scheduled project visitation trip. The second function of the project visitation is to check on the health. welfare, and morale of the troops. This cannot be ignored. It is imperative that the commander knows how the troops are doing with respect to the job and as individuals. If numerous technical problems have been occurring, it is possible that some personal problems might be overlooked. The project visitation can often resolve these problems before they become major limiting factors on the project execution. The documentation for this trip is normally in the form of a trip report and should be included in the final project folder for historical purposes.

Section III
PROJECT EXECUTION

Project execution is merely executing the plans that have been laid. If all planning has been correctly done, the survey team should arrive and go straight to work with no delays. As problems occur, the POCs that have been previously established should be contacted and the problems resolved as expeditiously as possible.

Specific details on project execution are covered in the chapters concerning specific survey activities. The documentation required for all phases of project planning and execution is contained in Chapter 8.

Chapter 3
Reconnaissance

A proper reconnaissance will –

- Gather all existing survey data on the area.
- Test and determine the usability and visibility of existing stations.
- Select sites for the main and supplemental stations.
- Specify any signal heights.
- Determine monumentation requirements.
- Collect terrain and climatic information.
- Arrange for access with private property owners or local government officials.
- Check on the availability of billeting, messing, medical, maintenance, and other required support.

Section I
FUNDAMENTALS

RECONNAISSANCE REQUIREMENTS

The special factors that the reconnaissance party must consider are determined by the objective of the survey and the methods, techniques, and equipment that will be employed. Survey methods and techniques are not within the scope of this chapter; therefore, only the more general considerations are given.

Triangulation and Trilateration

Although seldom used, special conditions may arise that make triangulation or trilateration feasible. These two methods make the greatest demand on the reconnaissance party. The mathematical computations place stringent requirements on the size and shape of the geometric figures. For this reason, the location of the stations will normally be dictated to the field reconnaissance party based on results of the office reconnaissance. The reconnaissance party must ensure that all stations to be observed from a proposed station are intervisible. Thorough knowledge of triangulation/trilateration criteria is absolutely necessary.

Transverse

The demands for traverse reconnaissance are less stringent than for triangulation. Care must be taken to ensure that both rear and forward stations are visible from each proposed station. Wherever possible, distances between stations should be uniform. In control surveys that may become part of the national network, the SSGCN must be satisfied. Spacing between stations will be dependent on the EDME available.

Taping. Taping remains a reliable way of determining distance. Terrain between stations must be moderate and uniform. Brush and tree clearing will be necessary in many cases. A tape traverse should follow previously cleared routes such as roads, railroads, power line rights-of-way, or pipelines.

Electronic distance measuring equipment. The EDME traverse reconnaissance requires intervisibility between stations, minimum and maximum allowable distances based on the EDME characteristics, and clearance above possible obstructions. Electro-optical and infrared EDME will be dependent on weather (clouds, fog, and haze). Microwave EDME will be affected by nearby power lines and radio frequency interference (RFI).

Leveling

Leveling reconnaissance will depend on the type of leveling performed.

Differential. Differential leveling should follow routes containing the least amount of change in elevation; between bench marks, and for individual setups. Preferred routes for differential leveling are the same as for taping.

Trigonometric. Trigonometric leveling reconnaissance is accomplished when reconnaissance for traverse is performed. When given a choice between a

relatively level observation or a greatly elevated or depressed elevation, select the relatively level observation. Failure to accurately level the instrument will cause greater error in an elevated/depressed observation.

Other Control Methods

Reconnaissance for other methods of extending control will vary according to the physical characteristics and limitations of the equipment or system used. No matter what system or equipment is being used, the proposed station must be accessible and the proposed station must be able to be included in the local survey control scheme. Stations occupied by satellite receivers (MX-1502, GPS receivers) must be free of surrounding (vertical) obstructions, RFI, and surfaces that will reflect the satellite signal onto the back side of the antenna. The distance between the receivers must meet the minimum distance as computed using the project specifications. Stations occupied by PADS must not exceed the maximum distance and time from the initialing station.

COMPOSITION OF RECONNAISSANCE PARTY

The reconnaissance party will vary in disposition and number according to the method of survey, type of terrain, transportation, extent of the survey, and density of control required. The chief of the reconnaissance party is normally the section chief or the survey technical sergeant. The reconnaissance party usually varies from three to five personnel. The reconnaissance party will include the survey party chief and personnel who will be instrument operator, recorder, computer, and rodman (some duties can be combined). The most qualified members of the unit should be assigned to reconnaissance, because a properly designed reconnaissance will result in a survey project that is accurate, complete, and performed expeditiously. Reconnaissance party personnel should be thoroughly briefed on the project instructions and the specifications of the survey mission.

Reconnaissance is accomplished in three phases: office, field, and reporting the gathered information.

Section II
OFFICE RECONNAISSANCE

EXISTING DATA

During the office reconnaissance phase, the first step is to gather all existing data on the area to be surveyed. Depending on the area, there maybe a number of sources which maintain some type of reliable survey data. The existing data will usually consist of trig lists, station description cards, and aerial photographs or maps. Trig lists come in many forms, depending upon the publishing agency. They may be compiled *DA Form 1959 (Description or Recovery of Horizontal Control Station)* cards, horizontal control data booklets from the National Geodetic Survey (NGS), or a computer printout of coordinates. The sources of information are –

- Local Army units, including: map depots, field artillery target acquisition units, SIC, survey units.
- National Geodetic Survey and US Geologic Survey.
- US Army Corps of Engineers District Offices.
- US Department of the Interior, Bureau of Land Management (BLM).
- State and local surveyors.
- When working in other nations, the existing data are sometimes received from the national agency charged with the mapping of that nation. However, approval must be received from the appropriate higher headquarters before direct contact is established with a foreign government.

Regardless of the source of information, all trig lists, officially classified or not, must be safeguarded. Once secured, this information should be maintained as a data base for that area. At some later date it may be necessary to conduct additional surveys in the same area or an adjacent area.

MAP AND PROFILE STUDY

While the existing material is being assembled, it should not be evaluated. The evaluation cannot take place until all material has been assembled and annotated on the available maps or aerial photographs. The required survey control points (SCP) from the project directive are also plotted and an evaluation of the usability of existing controls can be conducted. The required control is compared with the existing control to determine whether the existing control meets requirements or additional basic control is needed. It is possible that many stations that are required may be eliminated because adequate control exists. For those required stations that must be established, a tentative route of survey is anotated on the maps and profiles of the lines of survey are made. These profiles can normally be drawn by two methods:

Hand and Eye Interpretation

Hand and eye interpretation is laborious and should only be undertaken when time permits. Each proposed line is followed, picking out distances and elevations on the line. The result is a **cross-section** of the line that is plotted and drawn. Refer to *FM 21-26,* Paragraph 10-8 (Profiles), for the procedure.

Analytical Photogrammetric Position System (APPS)

The APPS also has the capability to determine profiles, using data base and aerial photographs of the area in question.

No matter which method is used, the tentative results for intervisibility between proposed stations must be confirmed by field reconnaissance.

Section III
FIELD RECONNAISSANCE

Each survey project will be different. The party chief must be able to use knowledge of previous projects and apply the lessons learned. The methods and procedures can be changed to suit the conditions of the current project. A successful party chief will also use the knowledge and ingenuity of his personnel.

INSPECTION

When time permits, a preliminary field inspection of the area is conducted by the party chief and one other person (survey technical sergeant, if available). When gathering information concerning the area to bc surveyed, include types of terrain, heights of trees, road width, road surface type, spacing between roads, microclimate (fog, haze, and heat waves), and any other factors that will affect distance measuring and intervisibility between proposed stations. The inspection may be conducted using vehicles, helicopters, or airplanes, depending on what may be available. The results of the inspection will affect the scheme and route for the survey.

RECOVERY AND VERIFICATION OF EXISTING CONTROL STATIONS

In areas where control is to be extended or established, there frequently are control stations (from earlier surveys) that must be recovered and verified. These stations will serve as the starting points for proposed triangulation nets, traverse lines, or level lines, and should have been identified and annotated on overlays during the office reconnaissance phase. The existing stations will be located on the ground, described, and verified for accuracy, prior to using them for extending control.

Locating Existing Control Stations

Existing control stations (and their establishing surveys) follow patterns that will vary very little from one area to another. Recognizing the patterns and associating the patterns with the terrain types will assist the surveyor in locating the existing stations.

Triangulation stations are usually found on the highest point of a hill or mountain. In areas of little relief, the stations may be located at prominent points or sites where a tower could be easily erected.

Bench marks and traverse stations are typically located along roads, railroads, pipelines, or other transportation routes which permit intervisibility and accessibility. Bench marks and traverse stations will also be found along waterways, rivers, canals, and coastlines.

Sources and Use of Available Information

In some areas, urbanization has changed road or drainage patterns. In rural areas, new land may be cleared and cultivated, while older fields become overgrown or reforested. When searching for a station, gather and consider all available information.

Trig lists, control cards, and control bulletins contain brief descriptions and sketches of stations. The information may be outdated or insufficient for a final product, but will permit the surveyor to locate the general vicinity and search for the station. The final location of the station will involve the use of distances and azimuths from the reference marks to the station.

Previous survey data will include survey schemes, overlays, or plots depicting the relative position of the stations in the general area. After one or more stations have been recovered, the other stations may be roughly plotted and located using magnetic compass and either intersection or resection methods.

Aerial photographs may be used if the station to be recovered can be identified on the photographs. Using features that are permanent and prominent on both the photograph and the ground will permit the surveyor to reach the station site. Aerial photographs can be used with the APPS and data base of the area in question.

Maps with the plotted coordinates of the station will permit the surveyor to identify the route of travel to the

station. The map will also assist the surveyor in determining the accessibility of the station.

Local sources of information include local surveyors, police or public service officials, construction companies, and landowners. Local sources may be the only means of locating a station if the area has dramatically changed since the other sources of information have been published.

Station Verification

Verification of a station must be performed before using the station. Where only one other station is intervisible, a check distance measurement will be performed. Where two or more stations are intervisible, check angle observations will be performed. After the measurements and observations have been performed and reduced, they will be compared to the published computed information. If the results agree within the overall specifications for the survey project, the stations may be used.

SELECTING STATION SITES

New Stations

New station sites will be selected after all existing stations have been recovered, described, and verified. The new stations will be placed where required to complete the scheme of the survey.

Factors to Consider

Correct selection of a site for a new station will result in time and expense saved and will prolong the life of the new station. The following factors must be considered when selecting a site for a station:

Permanency. If the proposed site may experience disturbance or land development, another site should be considered. If the proposed site must be used, the station should have guard or witness posts placed around the station.

Intervisibility. Intervisibility of stations is mandatory. The reconnaissance party must consider lines of sight and possible obstructions to those lines. Growth of trees and brush must be considered when determining intervisibility between stations. The adjoining stations must be positively identifiable, and surrounding features cannot be mistaken for the adjoining stations. Vertical clearance of the line of sight will also be included during the intervisibility determination.

Marking of Stations

Marking of stations will assist in the positive identification of stations. This maybe accomplished using a beacon target, a tripod wrapped with high visibility cloth, a rock cairn built adjacent to the station, or any other marking device that is visible and identifiable from long distances. Just prior to starting observations, the location and identity of a station may be verified through the use of colored smoke grenades, or in conjunction with radios, by the survey teams at that station and the adjoining stations.

CAUTION

Smoke grenades are HOT and when incorrectly used will obscure the survey target. Make sure the smoke grenade is downwind of the station and on bare ground to prevent fires.

Naming the Stations

Names for the new stations will normally be controlled by the customer (project name or number followed by the sequence number of that station in the scheme of control extension). In the absence of guidance from the customer, the following rules will be adhered to:

1 Use the name of a nearby geographical feature. If that is not possible, use the name of a local political subdivision.

2 Use short names, as opposed to long names.

3 Do not duplicate names or designations.

4 Make sure the station name is correctly spelled on all documents.

5 DO NOT USE ANY OF THE FOLLOWING:

- Names of party personnel.
- Nicknames.
- Names without meaning.
- Names arising from incidents during the project.

Old stations that are reestablished will be given the same name with a numerical suffix such as Boulder #2.

Landowners

Permission must be obtained prior to conducting a survey on any private land. The survey technical sergeant or the party chief, working through the local military legal office, will contact and negotiate with landowners for access to prospective station sites before entering the land. Written permission is highly preferred to oral permission, because the permission to enter the land is documented. The local Staff Judge Advocate will assist you in this matter, and will help keep you out of potential trouble.

United States. The reconnaissance party and all survey parties should have a **right-of-entry** letter to the overall area from their headquarters. The right-of-entry letter should be prepared in accordance with *AR 405-10,* Paragraph 13. This letter does not entitle the survey team to have access to private property or

into restricted areas without further permission. When the landowner is contacted, a full explanation of the work to be done is given. Do not attempt to conceal any inconveniences or damage that may arise. Government regulations concerning damage claims should be explained when necessary. A letter explaining the work and asking consent should be mailed to the property owner in the case of an absentee owner who cannot be reached in person or who is not at home when contact is attempted.

Other nations. When working in other nations, the right-of-entry letters for overall areas within a country are generally negotiated by the appropriate officer of the US Embassy within that country. However, a right-of-entry letter or approval from the host nation is not always sufficient for access to all public lands within the national boundaries. It sometimes becomes necessary to contact the local officials where the work is to be performed. Agreements will be conducted in accordance with local customs. Some countries consider an oral agreement, or any statement that could be construed to be an oral agreement, to be contractual and binding. If assets, material or otherwise, are transferred, close coordination with the Staff Judge Advocate is required.

CURVATURE AND VERTICAL REFRACTION

A factor entering into many field calculations is the correction introduced by the earth's curvature and the atmospheric refraction. Due to the earth's curvature, distant points will appear to fall below a level line of sight from the point of observation. Vertical refraction, on the other hand, causes the line of sight to curve downward and makes the distant point appear higher than its true elevation.

Vertical Refraction

The vertical refraction is about one-eighth of the curvature and opposite in sign. In survey work, the two are generally combined and the approximate resultant correction is given by the formula –

h (meters) = K (horizontal distance in kilometers) squared times 0.0676.

Where:

h = height in meters that a line horizontal at the point of observation will be above a level surface at K.

K = distance between points in kilometers.

Where h is known:

K = square root of h times 3.8478.

Table 3-1 gives the corresponding values of K and h.

Table 3-1. **Correction for earth's curvature and refraction**

Distance km	Correction m	Distance km	Correction m	Distance km	Correction m
1	0.1	21	29.8	41	113.5
2	0.3	22	32.7	42	119.1
3	0.6	23	35.7	43	124.8
4	1.1	24	38.9	44	130.7
5	1.7	25	42.2	45	136.7
6	2.4	26	45.6	46	142.8
7	3.3	27	49.2	47	149.1
8	4.3	28	52.9	48	155.5
9	5.5	29	56.8	49	162.1
10	6.8	30	60.8	50	168.8
11	8.2	31	64.9	51	175.6
12	9.7	32	69.1	52	182.5
13	11.4	33	73.5	53	189.6
14	13.2	34	78.0	54	196.8
15	15.2	35	82.7	55	204.2
16	17.3	36	87.5	56	211.7
17	19.5	37	92.4	57	219.3
18	21.9	38	97.5	58	227.1
19	24.4	39	102.7	59	235.0
20	27.0	40	108.0	60	243.0

Intervisibility

The general problem for intervisibility is determining how much a line of sight between two stations will clear or fail to clear an intervening obstruction. The formula is –

$$h = h_1 + (h_2 - h_1) \frac{d_1}{d_1 + d_2} - 0.0676 \; d_1 \, d_2$$

Where

h = elevation of line at obstruction, in meters.

h_1 = elevation of lower station, in meters.

h_2 = elevation of higher station, in meters.

d_1 = distance from lower station to obstruction, in kilometers.

d_2 = distance from higher station to obstruction, in kilometers.

The frost two terms of the above formula are a solution of similar triangles. The last term is the curvature and refraction correction. If the two stations are at the same elevation, the obstruction can be cleared using signals of equal height and the above formula becomes simply –

$h = h_{1,2} - 0.0676 \; d_1 \, d_2$

and the height of signal at each end is –

$h_{1,2} = h + 0.0676 \; d_1 \, d_2$

For a given length (K) between stations, the elevation required at one station to see the other across a level surface such as water is K squared x 0.0676. If both stations are raised to the same elevation, the height (h_1, h_2) required at each station is (K/2) squared x 0.0676, or one-fourth that at one end only.

In the field, the method generally amounts to a determination of an equal signal height for both stations so that the line of sight will clear the obstruction. Signal heights are nearly always computed in this way. Sometimes, a higher signal is specified at one station for some other line than the one under consideration. This permits a lower signal at the opposite end of the line. The amount one signal may be reduced in height for a given increase of the other is proportional to the distance of the two stations from the obstruction. The station nearer to an obstruction will require the least height to clear the line (Figure 3-1). To see station A, a high tower would be needed at station B, whereas a lower tower at station A would see station B. The amount that one instrument elevation may be reduced in height for a given increase in the height of the other is proportional to the distances of the two stations from the obstruction. If the distances A to H and B to H were 1.3 kilometers and 8.7 kilometers respectively, the ratio would be about 1:7.

Obstructions

Sometimes a series of obstructions occurs along a line of sight. It may not be possible to pick out by inspection the one that the line must clear. A lower obstruction near the middle of the line may require higher signals to clear than a higher obstruction near

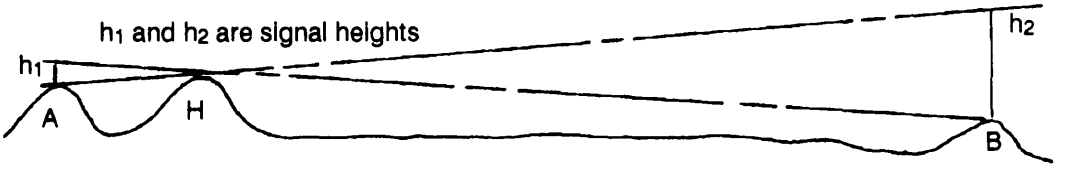


Figure 3-1. **Clearance of obstruction**

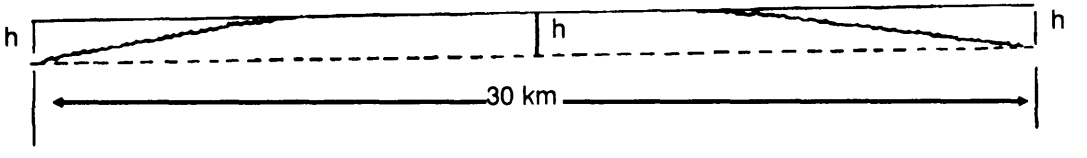


Figure 3-2. **Signal heights for line over water**

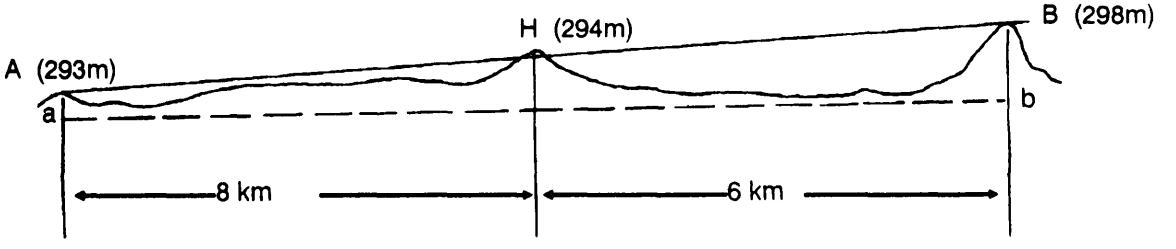


Figure 3-3. **General formula solution**

either end. The simplest way to determine the critical obstruction is to compute the signal heights for each one in turn. The following example of corrections illustrates a typical problem. Two stations are at water level on opposite shores of a bay 30 kilometers wide. What is the required height (h) of equal signals to make the line of sight clear the surface? According to the formula on page 3-6 –

$h = (K/2)^2 x\ 0.0676 = (30/2)^2 x\ 0.0676 = 15.2$ meters

Figure 3-2 shows has the distance that a line joining the stations passes below the earth's surface. Because the obstruction is equidistant from the two stations, h will also be the required height of equal signals at the two ends needed to clear the line of sight.

Elevation of the Line of Sight

The problem when two end stations are not at the same elevation and/or the obstruction is not at the point midway between them (Figure 3-3) can be solved by the use of the **general formula** or the **computation of similar triangles** as discussed below. Either method is acceptable.

Applying the **general formula** in the Intervisibility paragraph, page 3-6 –

$$h = h_1 + (h_2 - h_1)\ \frac{d_1}{d_1 + d_2} - 0.0676\ d_1\ d_2$$

$$h = 293.0 + (298.0 - 293.0)\ \frac{8}{8 + 6} - 0.0676\ (8)\ (6)$$

$$h = 293.0 + (5)\ 0.57 - 3.25$$

$$h = 293.0 + 2.85 - 3.25 = 292.60$$

Therefore, the amount of the obstruction at H = 294.0 -292.6 = 1.4 meters.

The computation of obstruction is the solution of **similar triangles.** In Figure 3-4, the elevations of the points are: A = 293 meters, B = 298 meters, and obstruction H = 294 meters. The distance from A to H = 8 kilometers and from B to H = 6 kilometers. Use Table 3-1, page 3-5, to first determine the effective elevation of points H and B. The effective elevation of H = 294.0 – 4.3 = 289.7 meters and of B = 298.0 -13.2 = 284.8 meters. The effective elevation of the line at the observation H is now computed. In b, Figure 3-4, we form the similar triangles using the effective elevation of B and H. Then, solving for x –

$$x : 6 = 8.2 : 14,\ \frac{x}{6} = \frac{8.2}{14} \text{ or } x = \frac{(6)\ (8.2)}{14} = 3.5\text{m}$$

Therefore, the effective elevation of the line at the obstruction H = 284.8 + 3.5 = 288.3 meters, Then, the effective elevation of the line at H = 288.3; hence 288.3 -289.7 = - 1.4 meters. Therefore, the line fails to clear the obstruction at H by 1.4 meters.

HORIZONTAL REFRACTION

Some lines are affected by abnormal horizontal refraction. Therefore, the reconnaissance party should try to avoid lines likely to give refraction trouble. Horizontal refraction is caused by layers of air or air currents of unequal temperature and density along the lines of sight. Lines passing near the base of a mountain range or bluff will be affected by the air currents flowing down side canyons and ravines

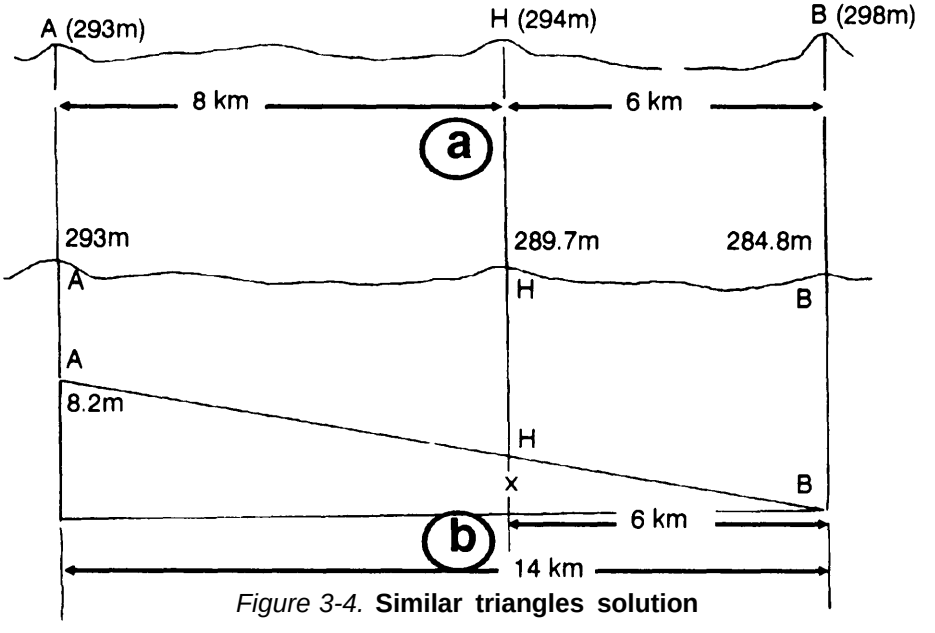


Figure 3-4. **Similar triangles solution**

(Figure 3-5). These varying air densities produce a condition similar to that of a beam of light passing through a series of very flat prisms. The kind of cover or vegetation, the range in temperatures between day and night, the direction and velocity of the wind, and the humidity are important factors. Another example of serious refraction trouble is a valley through an open plain and bordered by bluffs on either side. When it is impossible to avoid such a condition, the stations should be placed back on the tablelands as far as possible (Figure 3-6). Lines between the headlands and parallel to the valley will give the least accurate results and should be avoided. Horizontal refraction is much greater in barren or open country than in built-up areas. Over heavy timber the effects of air currents are small. The party chief may generally ignore the refraction effects in such areas.

On calm nights the atmosphere tends to stratify into layers of different temperatures and densities. The coefficient of vertical refraction then becomes larger than normal, lifting distant objects above the horizon. This abnormal nighttime refraction may vary between three and five minutes of arc. A **refraction line** is one that is normally obstructed but becomes visible at night. Directions observed over refraction lines are not unduly affected horizontally and their use is sometimes permissible, although they should be used only as a last resort.

Stormy or windy nights may break up the air strata and the abnormal vertical refraction may disappear entirely. Over sloping ground, the air strata may be inclined, in which case there will be a horizontal component of the refraction. Lines should always be kept well clear of bare ground.

HEIGHT OF OBSTRUCTIONS

Locating Stations to Miss Obstructions

It is often necessary to locate stations so the lines of sight will miss obstructions requiring signals to impractical heights. Blocks of unusually high timber will often be seen in heavily wooded areas. Plot the blocks on the map and ensure that all lines miss them, Intersections from water tanks, section corners, and other established stations will give the positions of the obstructions.

Determining Tree and Building Heights

Heights of trees in wooded areas and the heights of buildings in urban areas must be determined. The most direct method is to physically measure the obstruction, but this is not always easily or conveniently accomplished. There are many and various instrumental and improvised methods that can be used. Two such methods are the shadow and vertical angle methods.

Shadow method. This method of determining the height of trees employs the similar angle method, where the height of the tree equals a known height times the length of the tree's shadow, divided by the length of the known height's shadow (Figure 3-7).

Vertical angle method. This method employs a theodolite and a tape. Measure the distance from the base of the tree to a point where the top of the tree is visible; then, with the theodolite observe the vertical angle or zenith distance to the top of the tree. The height of the tree above the telescope axis will be **d** tan **a = h,** where **d** is the distance measured and a is the vertical angle. The height of the telescope above the base of the tree is added to the computed height to obtain the height of the tree (Figure 3-8, page 10). The angle need only be observed to the nearest degree and the distance measured to the 0.5 foot or 0.1 meter, It is usually desirable to use only full tape lengths when using this method.

CLEARING LINES OF SIGHT

The required clearance of lines of sight to avoid excessive refraction and dispersion of light will vary with the type of vegetation cover and with other physical conditions along the line. Regions combining a bare ground surface with a wide daytime temperature range require the greatest clearance and heavily timbered areas in a humid climate require the least. The following are average minimum values of the amount of clearance required for lines of sight:

Over water – 3 meters,

Over open plains where the sun is hot during the day and the atmosphere dry – 9 to 12 meters.

Over cultivated land interspersed with wooded areas – 4.5 to 6 meters.

Over treetops – 3 meters.

Special conditions may modify the clearance required. Extremes of heat and drought create special problems. Furthermore, the greatest vertical refraction is likely to occur in the regions requiring greatest clearance. In computing signal heights, reconnaissance parties often ignore the effect of the superstructure and this gives an added factor of safety. Microwave measuring instruments are susceptible to reflections from ground or water between stations. However, they can give acceptable measurements despite low obstructions directly within the line of sight. The optical electronic devices require the same line of sight clearance as theodolites.

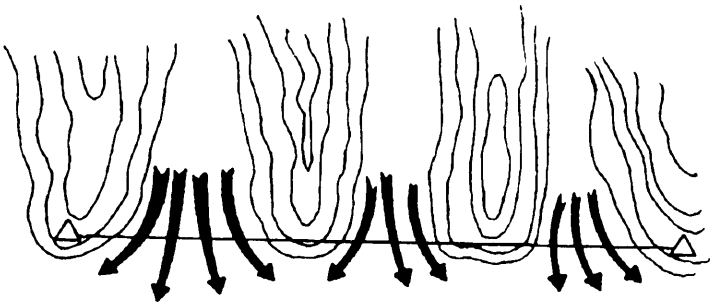


Figure 3-5. **Horizontal refraction due to air currents (ravines)**

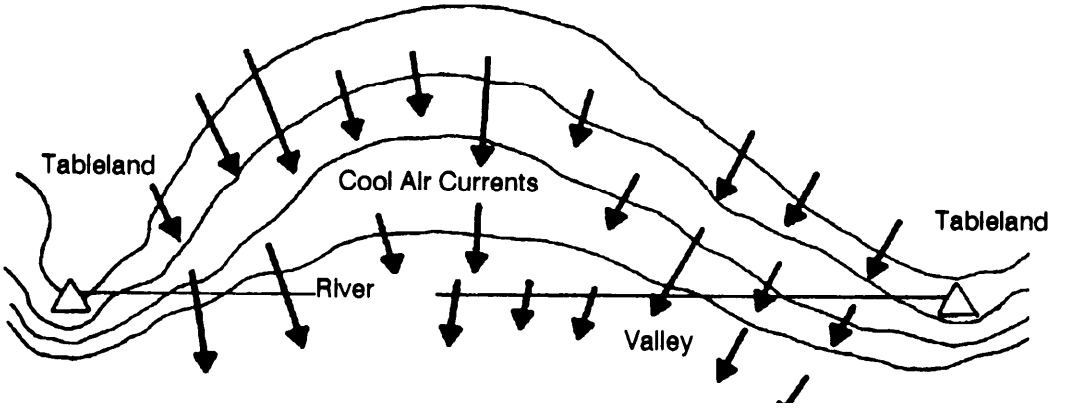


Figure 3-6. **Horizontal refraction due to air currents (hills)**

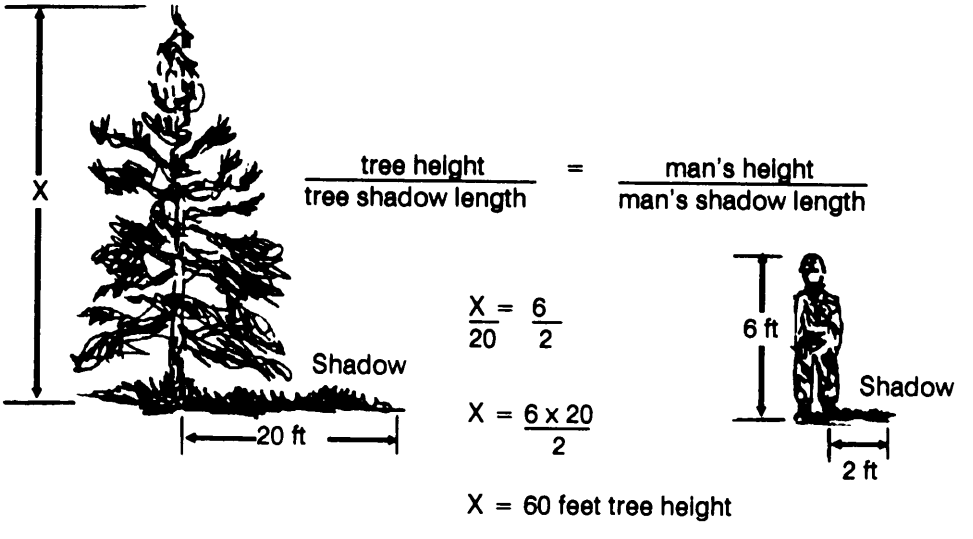


Figure 3-7. **Tree height by shadow method**

MONUMENTING

The monumenting of stations is accomplished during the reconaissance phase of a survey operation.

Surface Station Marks

A variety of standard monuments are currently available for use as station marks. On projects conducted for the Defense Mapping Agency (DMA), standard DMA disks should be used. The disks are set in the top of a concrete post or other appropriate monument. Each method of survey has an individually designated disk. These station marks must be as permanent as possible and be intelligently placed for present and future use and safety from damage. In cultivated fields or in pastures which may later be cultivated, the owner's permission should be obtained to build rock cairns or to set guard or witness posts around monuments.

Subsurface Station Marks

Subsurface marks are mandatory for first-, second-, and third-order stations. They are used for lower-order stations when located in an area where they are likely to be disturbed, such as sandy or marshy ground or in urban areas.

Types of Monuments

The type of monument used depends on the terrain, climate, and soil composition. Monuments can be generally subdivided into two general categories: standard and nonstandard.

Standard monuments. These are monuments that use some form of the standard survey disk. These disks maybe either brass, bronze, aluminum, or other alloys. *Poured concrete.* The classic standard monument is one that must be completely poured concrete with the disk set in the top of the concrete (Figure 3-9). The procedures and dimensions described here are for a second-order or higher monument. For third-order or lower surveys, the dimensions can be reduced. To emplace a standard poured monument, a hole is excavated 1.0 to 1.5 meters deep and 0.4 meter across the top. The depth variance is to ensure the monument is well below the active frost zone. The lower 0.3 meter is belled. This helps ensure the permanence of the finished station. If a subsurface mark is required, an additional 0.25 to 0.3 meter is dug directly in the bottom center of the hole. This chamber is filled with concrete mixed at a ratio of one part cement, two parts sand, and three parts aggregate. The subsurface mark – either a proper stamped disk, a nail, or bolt – is placed in the center of the concrete. After this concrete has set for 24 hours, a plumbing bench is erected. This will ensure the subsurface mark and the surface

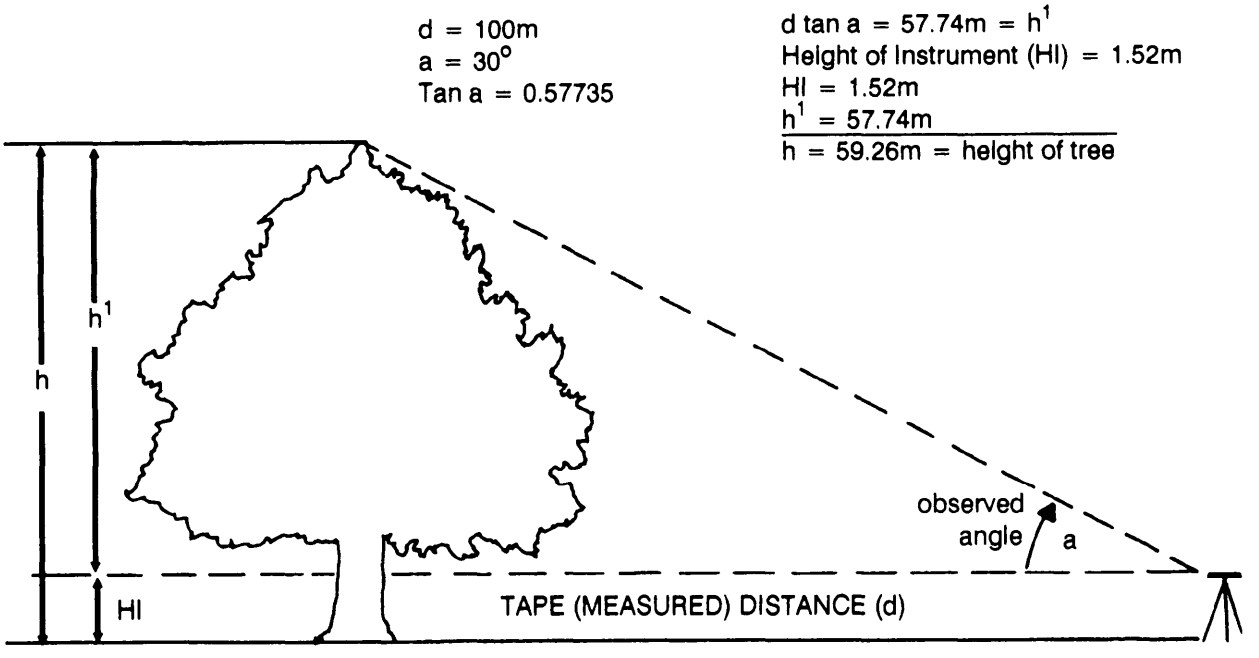


Figure 3-8. **Tree height by vertical angle method**

mark are in line vertically. The subsurface mark is covered with a thin board and 0.05 to 0.1 meter of sand to prevent disturbance. Unless otherwise directed, stations should be set flush with ground level. The top form may be in the shape of a square or cylinder. After the top form is poured and tamped, the top of the monument is smoothed and the surface disk is plumbed into position and set in the concrete. The concrete should be mixed in proportions of one part cement, two parts sand, and three parts aggregate, except for the top 0.30 meter of the monument which should be slightly richer. Where only cement and sand are available, the lower part should be proportioned one part cement to three parts sand and the upper part should be one part cement and two parts sand. No reinforcement rods should be used.

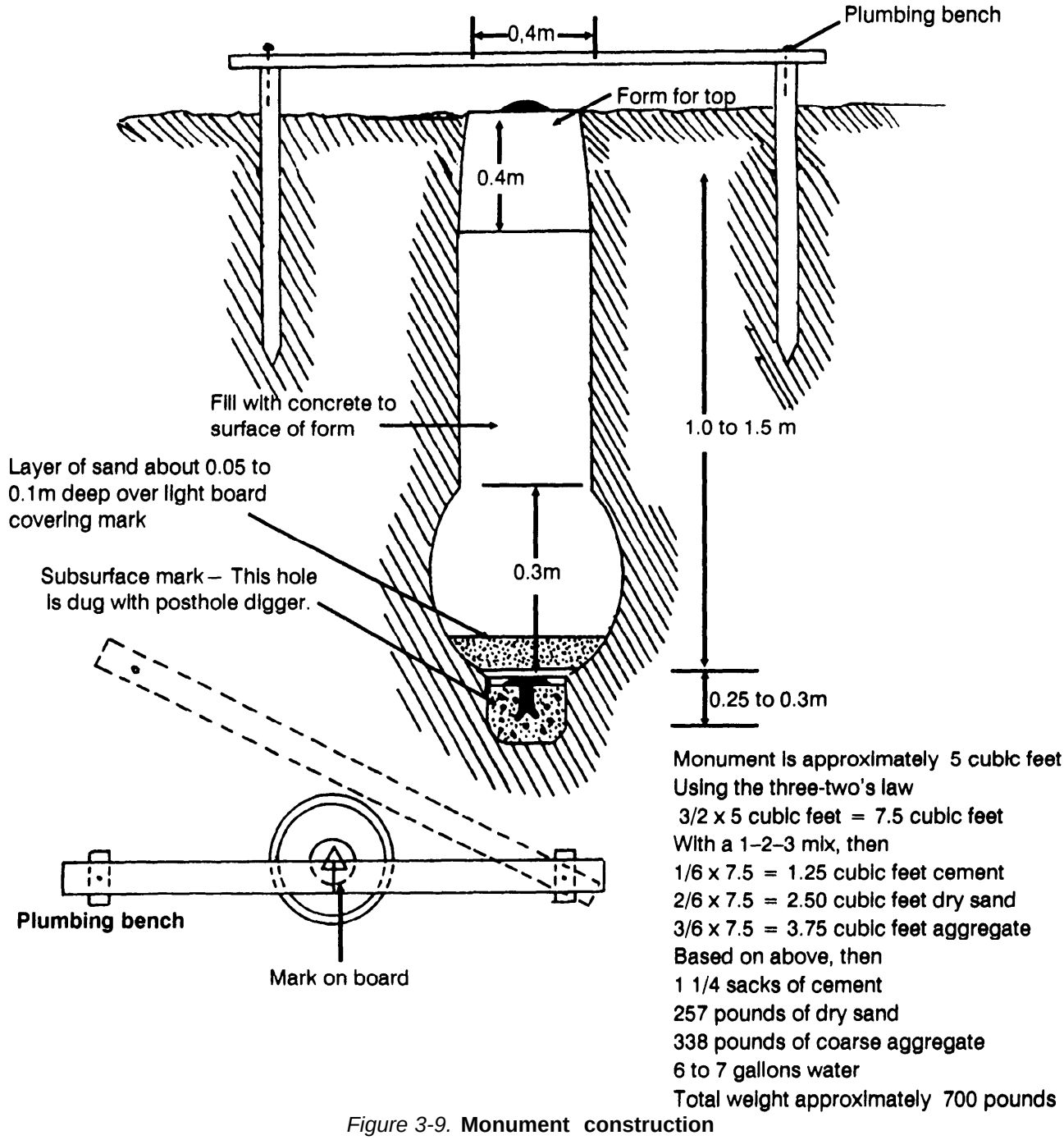


Figure 3-9. **Monument construction**

Precast. To eliminate the need for mixing and pouring monuments at the station site, precast monuments may be used if the project specifications permit. These precast monuments are fabricated at the base station or camp and are constructed with the equivalent dimensions listed for poured concrete, page 3-10. If a subsurface mark is required, it is emplaced as above with the precast monument being carefully plumbed.

Natural rock or boulders. When solid rock outcropping or very large boulders are the station site, monumenting maybe done by using a star drill to make a hole about 0.06 meter (2.5 inches) deep to receive the shank of the marker. The hole is filled with epoxy resin and the disk is inserted with the resin slightly built up around the edge. When a solid bench or ledge is covered with a few feet of top soil, the subsurface mark should be in the ledge and a concrete monument should be set above it to protrude above the surface.

Permafrost. In areas of permafrost, a wrought iron water pipe 0.05 to 0.10 meter in diameter and 1.22 meters or more in length is desirable. The pipe should extend through the active (freeze and thaw) layer into a good bond with the permafrost layer. Holes should be drilled in the lower end of the pipe and the lower part should be filled with water for an ice bond with the permafrost. The standard disk is brazed to the upper end of the pipe.

Marsh. Tile forms are used for monuments in marsh areas. After firmly bedding the tile into the marsh, the tile is cleaned out and filled with concrete and a disk is set in the top,

Reference marks (RM). The RMs are usually set in the same type of monument as the main station, but they can be made smaller. The number of RMs set depends upon the method of survey being used. In the triangulation and traverse methods of survey, at least two and normally three RMs will be set for each station. These marks should be located within 30 meters of the station and at intervals of about 120 around the station. No subsurface marks are used with these marks. Marks should be located where they are least liable to be disturbed. It is also necessary that marks be placed where direct measurements can be made to them from the station. It is permissible to use drill holes or chiseled marks in rock outcrops.

Azimuth marks. Azimuth marks are established in connection with SCPs to furnish an azimuth which will be available to local surveyors from an ordinary ground level instrument setup without requiring the building of a tower. This mark is used in the extension of control from the station. Readings to azimuth marks are observed as part of the triangulation procedure. The azimuth mark is a permanent monument, more than 400 meters but less than 3 kilometers from the triangulation station, and placed in a prominent and safe location. Prominent and permanent man-made strutures may also be used as azimuth marks. Some good examples of these would be the light on the top of a water or radio station tower or the cross on a church in a nearby town.

Commercial monuments. A number of commercial monuments are available that can be considered standard monuments. These are generally metal or plastic rods that are driven into the ground with a disk affixed to the top.

Nonstandard monuments. These monuments can take many forms and, if properly installed, provide for a good permanent control station. Some examples are –

- Shell casings, ranging from 7.62-millimeter to 105-millimeter expended shell casings embedded into a concrete post as prepared for standard monuments.
- Sections of rebar or pipe driven into the ground with a concrete collar poured around the upper 0.3 meter.

Witness Posts and Guard Posts

In order to aid in the preservation and to serve as a means of easy recovery of monuments, a witness post and/or guard posts may be established.

Witness posts. A witness post is no more than a sign or stake driven into the ground next to the station or reference mark.

Guard posts. Guard posts are emplaced around stations that are susceptible to damage from ground traffic. They are generally large wood stock 8 by 12 by 8 feet or expended steel such as sections of railroad rails or heavy pipe. Guard posts are usually set 1.0 to 1.5 meters into the ground and secured with concrete. Both guard posts and witness posts are marked in such a fashion as to be readily seen and identified.

DESCRIPTION AND SKETCH OF STATION

The reconnaissance party will prepare a description and sketch of all newly established permanent and temporary stations as well as all stations recovered (Figure 3-10). Stations recovered but not used still must have a description completed. The description and sketch will be on *DA Form 1959,* or in appropriate current field books such as *DA Form 4648, Station Description Book.* The field record will be freehand using vertical gothic lettering. The final *DA Form 1959* should be typed.

COUNTRY	TYPE OF MARK	STATION	
UNITED STATES	Bronze disk	Cotton, 1962, AMS	
LOCALITY	STAMPING ON MARK	AGENCY (CAST IN MARK)	ELEVATION 1179.1 (FT) 359.42 (M)
Maricopa, Arizona	1962, Army Map Service	Corps of Engineers	
LATITUDE	LONGITUDE	DATUM	DATUM Sea Level Datum of 1929
33 03 15.771 N	112 01 32.659 W	1927 NAD	
(NORTHING)(EASTING) (FT) 3 657 591.90 (M)	(EASTING)(NORTHING) (FT) 404 234.41 (M)	GRID AND ZONE UTM 12	ESTABLISHED BY AGENCY AMS
(NORTHING)(EASTING) (FT) (M)	(EASTING)(NORTHING) (FT) (M)	GRID AND ZONE	DATE 1962 ORDER Third

TO OBTAIN GRID AZIMUTH, ADD ° ' " TO THE GEODETIC AZIMUTH

TO OBTAIN GRID AZ (ADD)(SUB) ° ' " TO THE GEODETIC AZIMUTH

OBJECT	AZIMUTH OR DIRECTION (GEODETIC)(GRID) (MAGNETIC)	BACK AZIMUTH	GEOD DISTANCE (METERS) (FEET)	GRID DISTANCE (METERS) (FEET)
R.M. # 2	90° 46' 50.0"	° ' "	11.412	
TT M-31 (AZ MK)	136 46 25.1		553.1709	
R.M. # 1	180 46 25.0		6.828	
Base Station 'A'	283 54 08.51	83 59 53.69	16505.6605	16500.6268

Recovered as described

The station is located near the town of Maricopa, Arizona.

To reach the station, from the Southern Pacific Rail Road grade crossing in Maricopa, Arizona, proceed in a northerly direction on Maricopa-Phoenix Highway for approximately 0.1 mile (0.16 km) to a '+' intersection; turn right and proceed in a easterly direction for approximately 1.3 miles (2.1 km) to a '⊢' intersection to the right; turn right and proceed in a southerly direction for approximately 0.25 miles (0.4 km) to a '⊢' intersection of a road to the right and the site of the station.

The station is located 4.2 meters south of the centerline (℄) of a paved road to the west; 7.6 meters west of the centerline (℄) of a paved road to the north; 1.7 meters north of the north edge of a concrete irrigation headwall; 1.1 meters east of a wooden 4x4 inch white witness post.

The station is marked by a Corps of Engineer's U.S. Army bronze disk stamped: 'COTTON, 1962, ARMY MAP SERVICE', in a 10 inch (23 cm) round concrete post 4 inches (9.2 cm) above the ground.

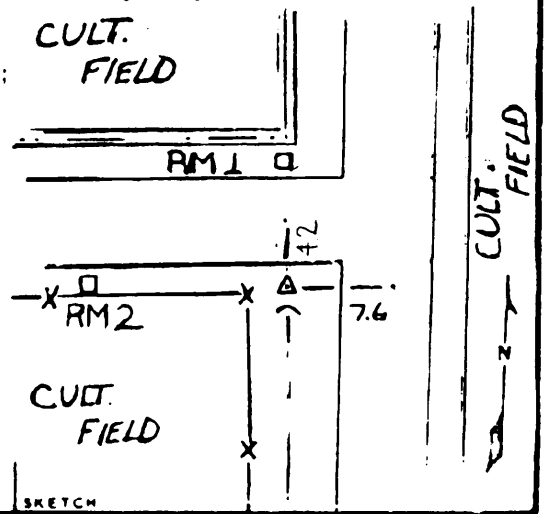
Reference Mark (RM) #1 is a Corps of Engineer's bronze disk stamped; 'COTTON, R.M. #1, 1962, ARMY MAP SERVICE', in a 10 inch (23 cm) round concrete post flush with the ground at 6.8 meters, 180 degree Magnetic Azimuth to the station mark.

Reference Mark (RM) #2 is a Corps of Engineer's bronze disk stamped; 'COTTON, R.M. #2, 1962, ARMY MAP SERVICE', in a 10 inch (23 cm) round concrete post 4 inches (9.2 cm) above the ground at 13.3 meters, 91 degree Magnetic Azimuth to the station mark, and 13.3 meters, 64 degree Magnetic Azimuth to R.M.#1.

Azimuth Mark (AZ MK) is a Corps of Engneer's bronze disk stamped; 'TT M-31, ARMY MAP SERVICE, 1961', in a 10 inch (23 cm) round concrete post flush with the ground at 3.2 meters north of the north edge of the road bank, 4.3 meters west-northwest of a wooden powerpole, and 1.0 meters northeast of a metal fencepost.

Visibility at tripod height is clear in all directions.

(Miscellaneous Information) to include hazards to survey party and special access requirements.



DA FORM 1 OCT 84 1959 REPLACES DA FORMS 1958 AND 1959, 1 FEB 57 WHICH ARE OBSOLETE

DESCRIPTION OR RECOVERY OF HORIZONTAL CONTROL STATION

For use of this form, see TM 5-237, the proponent agency is TRADOC.

Figure 3-10. **Station description card**

Description

The description is a narrative report compiled at the station site containing all the information necessary to expeditiously locate the station. It should enable someone totally unfamiliar with the area to go with certainty to the immediate vicinity of the station. In conjunction with the sketch, a positive identification of the station and reference marks should be possible. Repetition must be avoided where possible. A station description should be brief, to the point, and uniform in order of statement. All descriptions will contain —

Recovery note. The two- or three-word phase describes the general condition of the monument. The only recovery notes are –

New station. This is a newly established station for which no description exists.

Recovered as described. When a station is recovered exactly as described, all marks are in good condition, the distances and directions are verified, and the sketch and description are adequate. The statement alone is sufficient for the reconnaissance recovery card. The old sketch and description are transcribed onto the new control card.

Recovered. When a station is recovered but changes have occurred which make the old sketch and description inaccurate or inadequate, a new card should contain a new sketch and/or description of the station. Alterations to the station or reference marks are to be reported, with a description of the altered marks and new measurements of the referenced distances and directions. A definite effort should be made to improve all sketches and descriptions.

Not recovered. This is a station for which no positive evidence of existence can be found after a diligent search has been made.

Destroyed. This is a station at which there is positive evidence that the station did exist, but the station and its reference marks have been so mutilated that it cannot be replaced within 1 centimeter of its original position. The individual making the recovery and writing the description must use judgment in determining the status of a station. It must be remembered that a station may be destroyed for precise purposes but still be valuable for surveys requiring less accurate control; for example, gravity, magnetic, or astronomic surveys.

Reset. This is a station at which the monument and/or station marks have been replaced so that the mark is within 1 centimeter of its orginial position. A station is reset only from subsurface and/or reference marks that have not been moved from their original positions. The task of resetting monuments maybe assigned to the reconnaissance party.

Disturbed This notation is generally used only with reference to vertical control points. It is a station at which the monument is physically present, but it has been so moved that it has lost its value as a vertical control point within the accuracy to which it was orginally established.

General location. This follows the recovery note. It locates the station area on a map, in relation to cities and towns, bridges, and other major landmarks. The political subdivision should also be stated.

Route description or "to reach" statement. This describes the route to follow in order to reach the station site. This should start from an easily located point such as a public building, park, main road intersection, or any other permanent landmark identifiable both on the map and on the ground. Distances between checkpoints on the route are given in miles and tenths or kilometers and tenths. Changes in direction of route are given as both left/right and east/west/north/south.

Station site description. This describes the exact location of the mark in relation to readily identifiable reference marks. The magnetic azimuth and the distance are listed from the reference point to the station mark.

Description of the station mark. This describes the actual mark (drill hole, bronze disk, chiseled mark in stone) and the exact stamping on the mark (agency, year, type of station). It must be noted if the station mark is above or below the ground surface.

Reference marks. These describe the reference marks in the same manner as the station mark, with distances and directions measured from the station mark.

Azimuth mark. This describes the azimuth mark in the same manner as reference marks, except that the distance is usually approximated rather than measured.

View from tripod height. This is a description of field of view from tripod height. For example, "view is unobstructed in all directions except south" and "trees, 60 feet high, 300 feet from the station, obstruct the view between the magnetic azimuths of 170 and 215 degrees."

Miscellaneous information. Any important information about the station site that is not covered in

any other section can be listed at the bottom of the description. This may include the photo number and mission (if applicable), danger areas, notes concerning access, or any other pertinent information.

Sketch

The sketch should be clear and simple, and should contain only the detail required for positive identification of the station, In general, it should contain –

Features of permanent nature. The features around the station are shown with enough detail so that they will not be confused with similar features. For example, many road intersections and hilltops look alike. It is only when the sketch is extended slightly that the characteristic features become evident. When there is little detail available, a rough contour sketch should be made. All symbols used on the sketches should be standard topographic and military symbols as listed in *FM 21-31* and *FM 101-5-1.*

Scope and scale of sketch. Judgments on what features are actually required to identify the station and the individual's ability to draw usually govern the scope of a sketch. Normally a sketch should include the area within a radius of 200 feet to 1/2 mile. Sketches covering an area of several miles should be avoided. In all cases, the termination point of the **to reach** description must be on the sketch. The sketch need not be drawn to scale.

Orientation. The sketch must be oriented to north; it will be the preprinted arrow on *DA Form 1959.*

TRANSPORTATION

The reconnaissance party will use transportation that is organic to the unit, in accordance with the unit TOE and unit SOP. When available, due to project requirements or customer support, the use of aircraft will enhance the project reconnaissance. Helicopters will greatly assist and speed reconnaissance by checking routes of travel. lines of sight between stations, selection and identification of stations (existing and proposed), as well as determining the scheme for extending surveying control. If aircraft are used, it is mandatory that the pilots be thoroughly briefed on the survey project and the reason for it. Complete knowledge of the entire project by the pilots will expedite the field reconnaissance and probably accelerate the progress of the project.

COMMUNICATIONS

The reconnaissance part y has access to radios, in accordance with the unit TOE and unit SOP. The radios will be used by the surveyors to confirm lines of sight when stations are separated by great distances. Prior to using the radios on a survey project, the party chief will obtain authorized frequencies from the local (customer's) signal officer. The surveyors will use the radios in accordance with the local CEOI and communications-electronics standing instructions (CESI), The surveyors will also adhere to the unit's standing signal instructions (SSI), signal operation instructions (S0I), and radio communications procedures. In the event of a conflict, the procedures of the local (customer's) signal office will take precedence. *FM 24-1* is the authority for signal security.

MISCELLANEOUS INFORMATION

Fuel and Maintenance

The party chief will make arrangements with the customer to ensure that both fuel and maintenance are available for the vehicles he signs for.

Equipment and Office Space

The party chief will ensure that adequate space is available to secure equipment. Adequate space for project administration and field office computing must also be obtained.

Section IV
REPORTS

Upon completion of the field reconnaissance of the area to be surveyed, the party chief will submit a reconnaissance report. If the area or the project is large, the project will be divided into phases, with a report required at the completion of each phase.

The reconnaissance report is discussed in Chapter 8, Section I.

Chapter 4
Targets and Signals

A target is generally considered to be a nonilluminating signal. Target requirements can be met by three general types: tripods, bipeds, and poles, all of which may incorporate variations. The targets are constructed of wood or metal frameworks with cloth covers.

Section I
TARGETS

SIZE, SHAPE, AND COLOR OF TARGETS

For ready bisection, the target should be as narrow as possible without sacrificing distinctness. The easiest of targets to bisect are triangular in shape, with square- and rectangular-shaped targets being next. Targets that are round are the poorest of targets due to problems in pointing during repeated observations. These targets should be avoided whenever possible, A target which subtends an angle of four to six seconds of arc will be easy to bisect. Since one second of arc equals 0.5 centimeters at a l-kilometer distance, an angle of six seconds requires a target 3 centimeters wide at that distance or 30 centimeters at 10 kilometers. Under adverse lighting conditions, the target width will have to be increased. To make a target readily visible against both light and dark backgrounds, it should be constructed of alternating bands of red and white or orange and yellow. Flags of an appropriate size may be added to aid in finding the target or by filling the background with blaze orange cloth to contrast the target. All cloth used on the targets should be slashed after construction to minimize wind resistance and to avoid pilfering in areas where cloth may be valuable.

LOCATION OF TARGETS

The location of targets by observers is sometimes a difficult and tedious task, depending upon the type of terrain and foliage in the area. In jungle-type areas where the targets are not profiled or silhouetted, they are very difficult to locate without direct sunlight shining on them. To expedite the location of targets, it sometimes becomes necessary to use some method of illuminating the target area. Five of the generally accepted methods are –

- The lighting of highway-type flares
- The use of a handheld flashing mirror
- The use of a strobe light unit, if available
- The use of colored smoke grenades during daylight hours
- Vehicle headlights

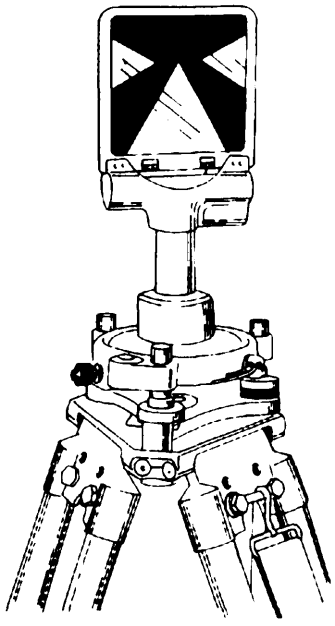
Once the area of the target is located, it becomes a simple task to find the exact location of the target. The use of iridescent cloth on the target in place of regular signal cloth is recommended if the cloth can be interchanged, especially in jungle areas.

TYPES OF TARGETS

Target Set

The target set is a precise survey target device generally used for short traverse lines (approximately 4 kilometers). The target set assembly (Figure 4-1) consists of a lower and upper group *(TM5-6675-244-15).* The lower group is a tribrach with a three-screw leveling head, circular bubble, and optical plumbing device. The upper group contains a plate with three triangles, a long level vial, and a lighting attachment. The upper group is removable and interchangeable with the theodolite.

Figure 4-1. **Target set assembly**



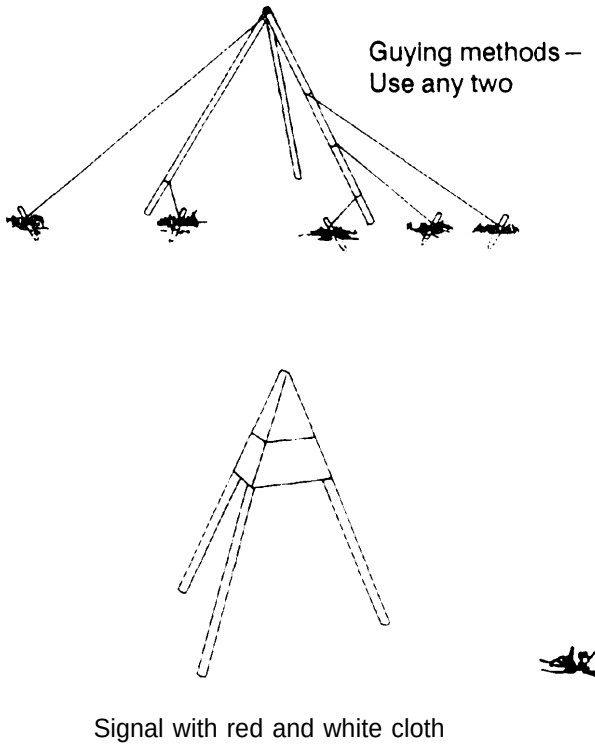
Use. In traverse operations where continual backlights and foresights are needed and where distances are not excessive, the target sets can be used in a leapfrog technique. The actual distance the target can be seen depends on background, lighting, and weather conditions,

Pointing. Care must be taken in pointing the target at the observer in order to eliminate the appearance of distortion of the target when viewed through the telescope. A disadvantage of the target set is that only one at a time maybe set at a station.

Tripod Target

The tripod-type target is the most satisfactory from the standpoint of stability, simplicity of construction, durability, and accuracy. It ranges from a simple hood of cloth, cut and sewn into a pyramid shape and slipped over the instrument tripod, to the permanent tripod with the legs embedded in concrete, sides braced, vertical pole placed at the top, and the upper part boarded up and painted. Temporary tripod targets may be constructed of 2-inch by 2-inch lumber, pipe, poles, or bamboo joined at one end by wire, or bolts threaded through drilled holes. The tripod must be guyed and plumbed (Figure 4-2) and the legs should be set in depressions to prevent lateral movement. On uneven ground, one leg may have to be shortened or dug in to maintain a symmetrical appearance from all directions. Signal cloth wrapped around the tripod should be used only on lower-order (fourth-order) work, as it is almost impossible to make it symmetrical around the station.

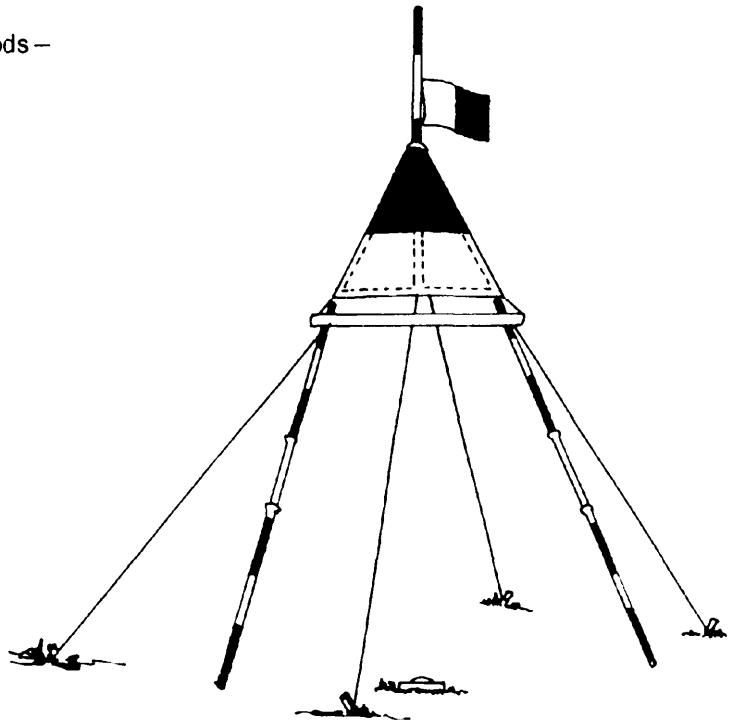
Figure 4-2. **Tripod targets**



Biped Target

Biped targets are more simply constructed than tripods, but are less stable and must be strongly guyed. Figure 4-3 shows an issued surveying beacon. It is a biped target and is carried disassembled in a canvas case about 53 inches long. It can be assembled, erected, and plumbed by two people in 15 minutes or less and can be dismantled and packed in 5 minutes, If this target must be left standing in the weather for any extended period, the rope guys should be replaced with wire and two more guys added at each end of the crossbar. In soft ground, the pointed legs will sink unevenly because of wind and rain, and should be set in holes bored in the end of wooden stakes driven flush

Figure 4-3. **Biped target**



with the ground or in a short piece of 2-inch by 4-inch lumber laid flat in a shallow hole.

Pole Targets

Pole targets (Figure 4-4) are seldom used because the station cannot be occupied while the target is in place. In certain cases. as when a picture point is to be intersected or an unoccupied station must be used and the cutting of lines of sight is extremely difficult or impossible, a pole target which can be seen above the medium-sized trees may be erected. The staff may be constructed of 2-inch by 2-inch lumber or cut poles, varying from about 2 inches (5 centimeters) to 6 inches (15 centimeters) in diameter. The method of joining sections of 2-inch by 2-inch lumber and the construction of a panel target are shown in Figure 4-4. The target must be plumbed by manipulating the guy wires or ropes. Special care must be taken when warped or crooked boards are used to construct pole targets, and they must be checked for eccentricity.

CENTERING AND PLUMBING TARGETS

When setting a target, it must be plumbed exactly over a station. A target is said to be eccentric when the vertical center is not on the vertical line passing through the station mark. The proper correction can always be made for eccentricity by remembering the approximation **a second is a foot at 40 miles** (actually 39.065 miles) or that an inch represents about 3 1/4 seconds at a distance of 1 mile. Always check a target or signal that has been observed for eccentricity. Any eccentricity found must be recorded so that the computer can be certain of the facts when correcting the observations.

PHASE

When observations are made on targets in the daylight, errors in the horizontal angle measurements due to unequal lighting of a target are referred to as phase (Figure 4-5). When one side is brightly lighted and the other is in the shadows, the observer tends to favor the sunlit side. Sometimes, with a skylined white target, the reverse is true and the dark side is favored. Phase is an eccentricity which could be corrected for, if its exact amount were known. The observer is rarely able to measure its amount accurately, since influencing factors such as the angle of the sun with the line of sight, the opacity of the signal, the shape of the

Figure 4-4. **Pole targets**

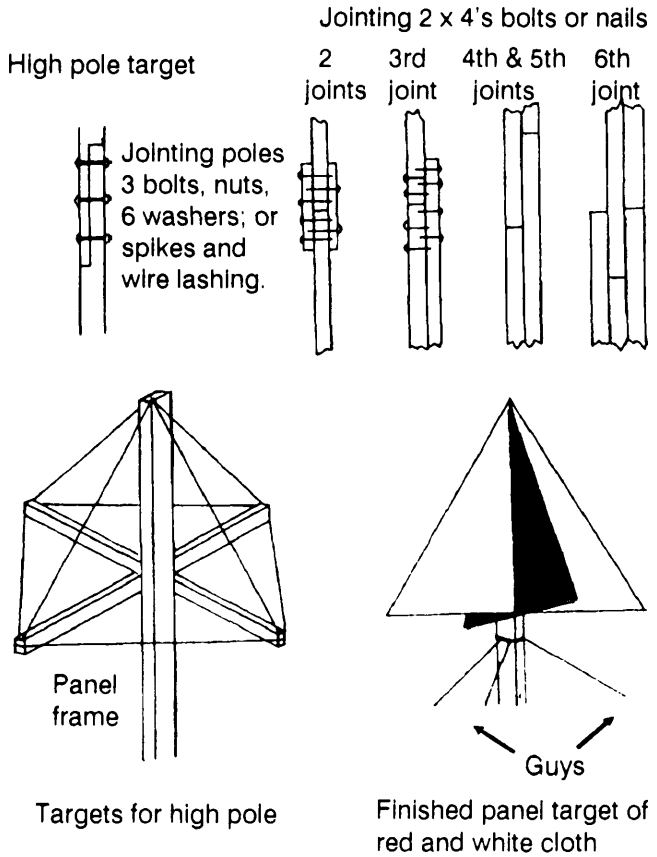
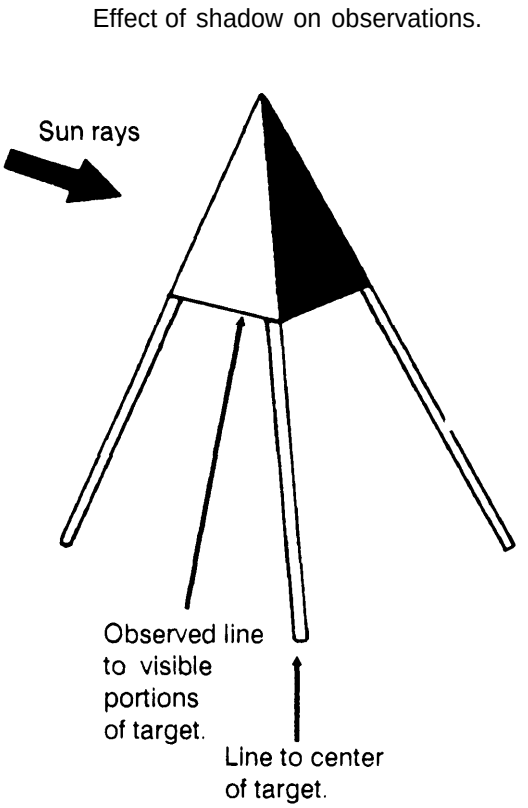


Figure 4-5. **Phase**



object sighted upon, and the intensity of the sunlight change rapidly. Trigonometric formulas for the correction of phase based upon the direction of the sun have appeared in some textbooks, but are rarely practical. It is usually best to delay observations until poor conditions improve or no longer exist.

Section II
SIGNALS

Signals are those survey targets that are either illuminated by natural sunlight (heliotrope) or are electrically lighted by use of wet or dry cell batteries. The observations for all second-order, Class I triangulation and traverse are usually done at night by using signal lights because of more stable atmospheric conditions which allow for better pointings. Observations may be made during daylight hours using lights, but for high accuracy surveys this is done only under extreme conditions.

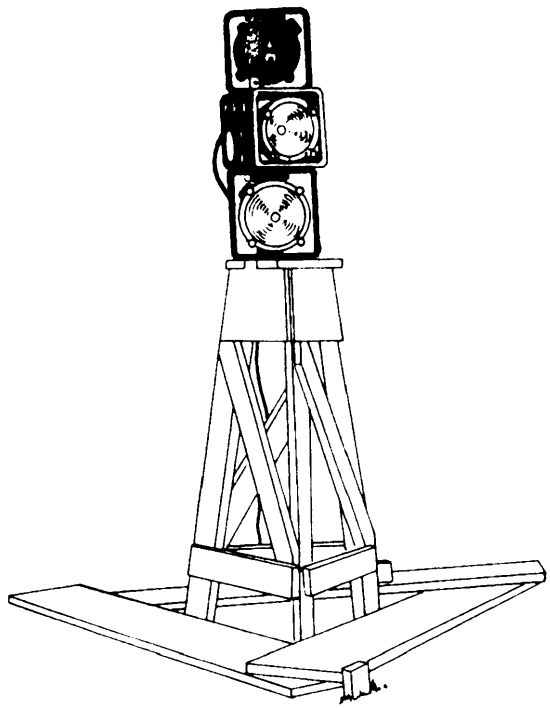
SIGNAL LIGHTS

The most commonly used signal light has a 5-inch reflector. These signal lights (Figure 4-6) are used as illustrated for lines of sight in excess of 8 kilometers, but by masking the face of the light they can be used for shorter lines of sight. A 5-inch light should **not** be used on lines of sight shorter than 5 miles (8 kilometers). This rule of thumb (no more than 1-inch diameter per mile observed) should be applied to other sizes of lights.

Pointing

The exact horizontal and vertical pointing of the light is very important. If the light is not pointed exactly toward the instrument, only a portion of the reflector will be observed and in some cases this portion will not be plumbed over the station mark. The instrument operator must check the pointing prior to starting the observations by viewing the light through the telescope. During hazy weather and especially on long lines of sight, the view through the telescope may appear as a bright spot surrounded by a flare. The instrument operator should request the lightkeeper to swing the light slightly in a horizontal and vertical are while it is being viewed through the telescope until the best pointing can be determined. The best pointing will be when the light is the brightest. The light is then stopped and locked into position. The bottom light, if lights are stacked, must be pointed first as shown in Figure 4-6. It can be adjusted for brightness by adding or removing batteries. The light should never be improperly pointed to reduce its brilliance as this will create an eccentric light.

Figure 4-6. **Stacking of 5-inch lights**



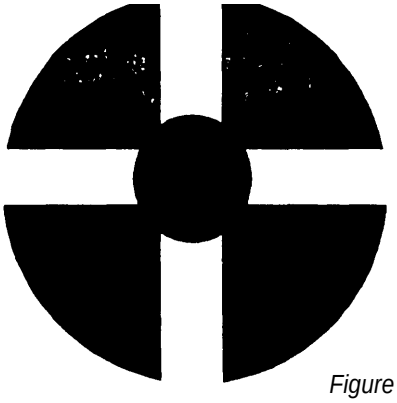
Masking

The light can be masked to reduce the size and brilliance by covering equal portions of the lens both above and below and to the right and left of the center of the glass face. When masking a light, opposite sides of the glass must be masked equally to eliminate eccentricity. One method of masking is shown in Figure 4-7. This type of masking is very good for distances between 6 to 10 kilometers on normal nights. A sheet of orange scribe paper is required but any other color would work almost as well. When using the orange paper as a masking material, the light will present an orange glow with a brilliant white cross for pointing on by the observer. At maximum ranges, the orange glow is practically invisible through the telescope and at minimum ranges the glow will help in identification of the light.

Focusing

The light is focused by means of a screw at the rear of the bulb socket. By turning this screw, the position of the bulb is changed in relationship to the reflector. If the light is not properly focused, it will appear as a fuzzy ball in the telescope. The light maybe focused at night by shining it on a flat surface about 50 meters away and adjusting until the beam is slightly larger than the light. When no distant object is available, afield expedient is to hold one's hand about 6 inches in front of the light and adjust until a dark spot the size of a quarter appears in the center of the beam.

Figure 4-7. **Masking of 5-inch light**



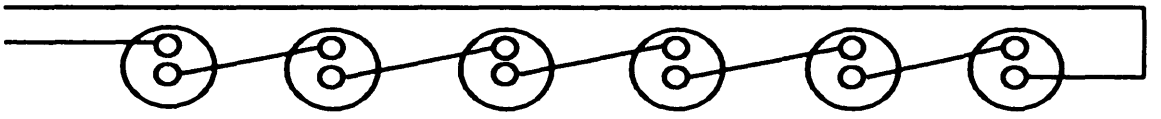
Brilliance

The brilliance of the light is determined by the type of light bulb and the amount of voltage being used. The light is issued with two different bulbs: the standard 3.7-volt bulb and a 6.0-volt bulb. The amount of voltage needed will vary with the lighting requirements. The various battery arrangements are shown in Figure 4-8. If dry cell batteries are not available or are too weak, a field expedient is to connect two lights with 6-volt bulbs in series and then connect them to a 12-volt wet cell battery. Never apply more voltage to the bulbs than their rated value.

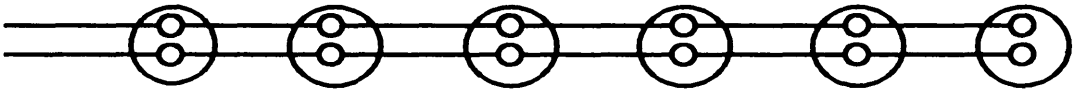
Stacking

When lights to several observers from the same station are needed, the lights are stacked, generally on a range pole tripod as shown in Figure 4-6. If lights are stacked over a station, they must be leveled and plumbed over that station mark. The first (lowest) light must be leveled and plumbed, then the other lights are attached and individually checked for level. Care must be taken when attaching additional lights to the pole not to knock the other lights out of plumb.

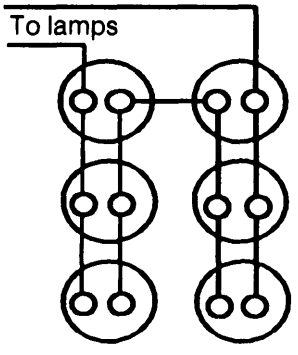
Figure 4-8. **Battery wiring diagram**



① Cells connected in series. Output 9 volts, 24 amperes.

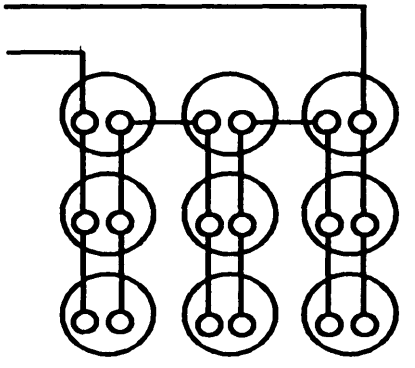


② Cells connected in parallel. Output 1 1/2 volts, 144 amperes.



③ Series-parallel connection.
Output 3 volts, 72 amperes.

Outputs are based on the assumption of dry cells with an average of 1 1/2 volts and 24 amperes each.



④ Series-parallel connection.
Output 4 1/2 volts, 72 amperes.

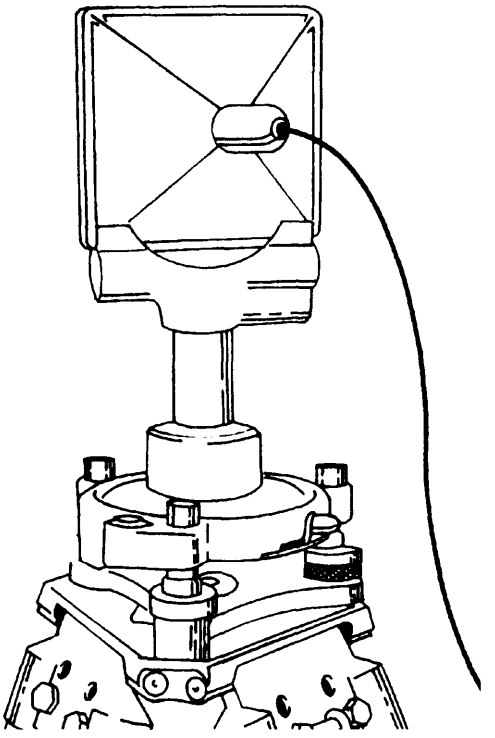
Ranging

When observations are made from a small (low) instrument stand, it is sometimes impossible to plumb the lights directly over the station mark. If this occurs, it is acceptable to use lights on range. The lights must be lined in on range to all stations with a theodolite. The standard theodolite tripod or range pole tripod is used as a stand and should be from 4 to 30 meters from the station. Care must be taken to avoid introduction of eccentricities when using lights on range.

TARGET SET

As previously mentioned, the target set is a precise survey target device. It is also a precise survey lighting device (Figure 4-9) used for short traverse lines (approximately 4 kilometers). When the target set is used for night observations, it requires the attachment of an accessory lighting unit on the back of the target. The lighting unit consists of a metal hood with a light bulb mounted in the center. For the older target sets, the hood hangs on two small metal studs mounted at the top rear of the target. For the newer target sets, the hood slides down over the sides of the target from the rear.

Figure 4-9. **Lighting assembly for target**



Use

The target set is used as a signal in the same way as when it is used as a target, as discussed in Section I.

Pointing

Extreme care must be taken in the pointing of this device. The lighting attachment must be pointed directly at the observer in order to eliminate the appearance of uneven lighting of the target's triangles.

HELIOTROPES

The heliotrope is a device which reflects the sun's light through a pair of mirrors set over a station mark and pointed toward the observer on another station mark.

Characteristics and Procedures

The issued heliotrope consists of a flat base to which are attached two plane mirrors and a pair of sights (Figure 4-10). The base may be mounted on any standard tripod and plumbed directly over a station mark. It can be fitted in the wild-type tribrach and mounted on the tripod. One mirror is fixed to the base; it may be rotated and tilted, and it directs the reflected sunlight through the sights to the observer. If the sun is in the direction of the observer, the fixed mirror is all that is needed. The second mirror is on a movable arm for use when the sun is shining toward the observer. It serves to direct the light into the fixed mirror and from there to the observer. No provision is made for adjusting the pointing in a vertical plane: however, flat wood chips or folded cardboard shims between the bottom of the heliotrope and the tripod head will solve this problem. The main point to remember is that all fittings must be tight, since any play or looseness will cause trouble when the observer sights on the heliotrope. Whichever mirror is receiving the direct sunlight must be attended at all times. Due to the apparent motion of the sun, the sunlight will stop hitting the receiving mirror about every three minutes. Thus, the receiving mirror must be moved with the sun in order to maintain the light source for the observer. The receiving mirror should be just tight enough so that light taps with the fingertip or a pencil will maintain the correct angle. The two sights are seldom aligned perfectly with the light apertures, and tests should be made prior to use so that the proper allowances can be made.

Use

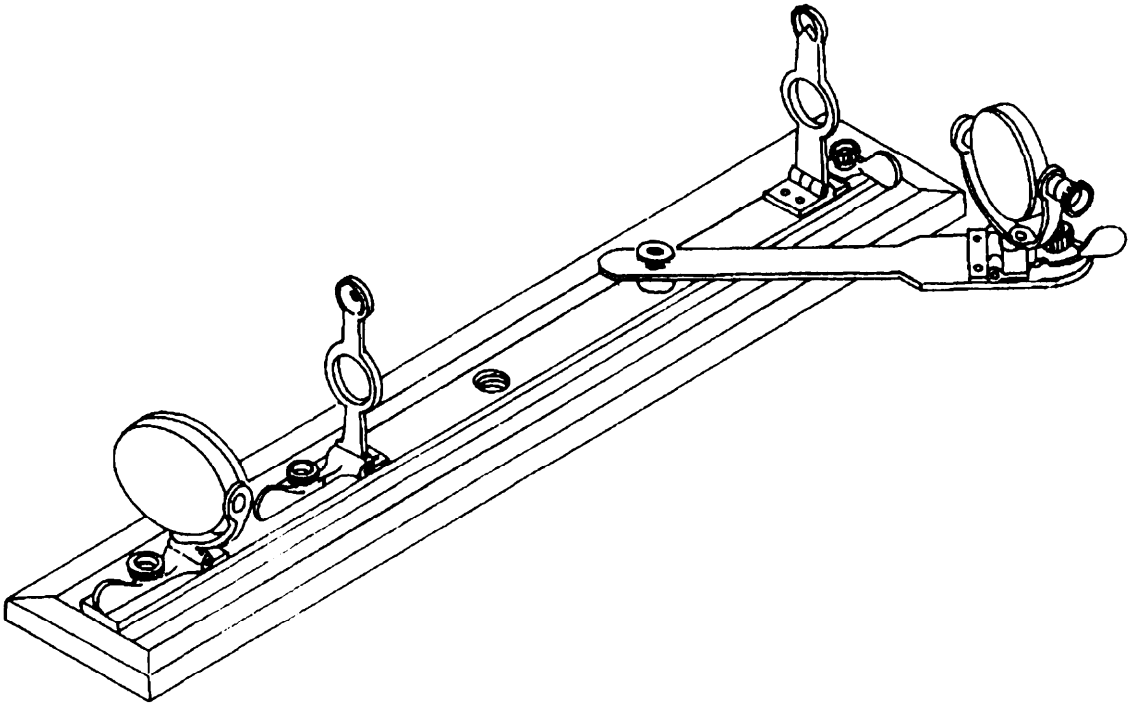
Many surveyors tend to shy away from using the heliotrope because they have not been able to get good results due to faulty pointing techniques. There are times when use of this instrument is the only way to solve a line of sight problem. The intense rays of the

reflected sunlight are visible through hazy and smoky atmosphere when no other signals can be detected and the range is essentially unlimited. The heliotrope's use is limited by: first, the necessity for sunlight; second, the difficulty in using it as a target while making simultaneous observations from the same ground station; and third, the difficulty of aligning without radio communications. The second difficulty can be solved by placing the heliotrope to one side of the station and making careful measurements of its eccentricity. It can also be used in this position for simultaneous vertical angle measurements by measuring the difference of elevation from the true station. The third difficulty is not often present, since most survey parties are equipped with radio. The observer, while sighting through the telescope and with the radio in hand, gives a running stream of one-way directions to the heliotrope attendant until the observer has a steady light in the telescope. At this time, the heliotrope attendant needs only to note the position of the sun's image on the sight and periodically adjust the sun mirror. When occupying a station with a heliotrope, the signal tender must continually adjust the mirror to maintain a steady light.

EXPEDIENT LIGHTS

There are many types of expedient lights or signals that can be used when standard equipment is not available or is inoperative. No attempt will be made here to list or illustrate all the different types of expedient lights or signals that can be used. These include the headlight of a vehicle, a masked lantern, a boxed light bulb, or chemical illumination lights. The survey party chief must use experience gained in the field and ingenuity to determine the proper expedient for a particular condition or problem.

Figure 4-10. **Heliotrope**



Chapter 5
Field Procedures

OBSERVATION PRECAUTIONS

Because of the high standards of accuracy required for second-order observation, constant precautions are necessary to counteract as much as possible all sources of error. The party chief should periodically inspect the performance of all observing parties. A good observer achieves the full potential of his instrument at all times. He precisely bisects signals and targets and consistently obtains very little spread (three or fewer of the smallest increments marked on the micrometer) between his direct and reverse pointings. Proficiency can be attained only by a careful study of all factors affecting the accuracy of theodolite observations. Efforts should be made to eliminate all known sources of error. Observation precautions can be summarized as follows:

Instrument Check

Check the instruments and signals for stability. If an instrument is not stable, all other refinements are useless.

Instrument Adjustment

Pay careful attention to parallax and inclination of the horizontal circle plate. Errors introduced by these cannot be eliminated. Since the effects of an inclined horizontal circle plate increase with the inclination of the line of sight, the plate level of the T-3, or the striding level of the T-2, is read for second-order observations.

Plumb Signals and Targets

Plumb signals and targets directly over the SCP. Carefully aim targets and signals towards the observing station.

Other Precautions

Other operational precautions for accurate observations are —

- Repainting on the initial after each circle setting.
- Checking the plate level frequently.
- Protecting the instrument from wind, sun, and weather, by using an observing tent.

Do not disturb the instrument during observation of a position by releveling or by lateral thrust on a clamp, tangent screw, or electric switches, or by striking the instrument or its support.

When all other known precautions have been taken, one of the principal causes of reobservation is horizontal refraction. Sometimes elevating the signal will reduce the effects of horizontal refraction, but often the only solution without altering the traverse is to reobserve under different atmospheric conditions.

FIELD CHECK PROCEDURES FOR STARTING AND TERMINATING STATIONS

The starting and terminating stations for a traverse are usually recovered and adjusted stations from a previous triangulation or traverse survey. These stations may be established during the current survey by astronomic observations of the appropriate order of accuracy. These stations must be of the same or a higher order of accuracy as that of the traverse being established. When previously established stations are used, they must be positively identified and a line or angle check must be made. The required limits of these checks (ties) to existing stations will depend upon the order of the survey being accomplished.

Distance Check

When only two intervisible stations of the required order can be recovered, their accuracy can be checked by measuring a check distance between the two. The measured distance is reduced to grid and compared to the computed distance between the stations. Measure the distance between the two stations using the method that is prescribed for the equipment being used. The check distance consists of at least two complete measurements: one concentric, the second eccentric (offset). The amount of offset is carefully measured and will not be greater than 0.5 meters. Reduce the measured distance to grid distance and compare with the computed grid distance. If the measured distance compares to the computed distance within the specifications of the project, then the stations are usable.

Angle Check

When three or more intervisible stations of the required order exist, they can be checked by turning check angles between them. The corrected field angles are then compared to the computed angles.

1. With the theodolite pointed at the target and with the horizontal clamp tightened, the circle is set as follows: Set micrometer scales to read the unit minutes and seconds of the given value. Then, using the horizontal circle drive knob, turn the circle until coincidence (or as near as possible) is obtained at the degree and tens of minutes value of the given reading. After setting the circle in this manner, the actual reading is determined. This setting should normally be accurate to ± 05.0".
2. When measuring a predetermined angle, the instrument is first pointed along the initial line from which the angle is to be measured and the circle is read. The value of the angle is added to the reading to determine the circle reading for the second pointing. Set the micrometer scale to read the unit minutes and seconds of the value to be set on the circle. Then, turn the instrument in azimuth and make coincidence (or as near as possible) at the degrees and tens of minutes value that is to be set. The horizontal slow-motion screw is used to obtain coincidence. After setting the value in this manner, the actual reading is determined. The predetermined value can usually be set on the circle in this way to ± 02.0".
3. It is seldom necessary to set a predetermined value on the vertical circle, except when adjusting the instrument or when locating a preselected star for azimuth. Set the micrometer scale to the unit minutes and seconds of the given zenith distance. Then the telescope is elevated (or depressed) to make coincidence at the predetermined degrees and tens of minutes value. The telescope clamp and vertical slow-motion screw are used to make this coincidence. After setting the value in this manner, the actual reading is determined. The predetermined zenith distance can usually be set on the circle in this way to ± 02.0".

TRAVERSE ROUTE SELECTION PROCEDURES

The party chief usually selects a tentative route from a map and aerial photographs, if available, and plots the proposed station on the reconnaissance map. The lines of sight and all previously established controls (both horizontal and vertical) should also be plotted on the map. The final route is selected during the field reconnaissance. The route that will provide the most rapid means of extending the control with the least effort is usually selected. Often this route will bypass some of the required control points and these points can be connected to the main scheme by separate loop traverses or by side shots if the required order of accuracy is low enough. Full advantage should be taken of previously cleared lines in laying out the traverse. All control stations from previous surveys that exist along the traverse route should be connected whenever possible, to include bench marks.

Reconnaissance Specifications

There are some reconnaissance specifications pertinent to the route selection that are based on the order of accuracy required:

- Minimum distance between stations,
- Maximum number of traverse legs permitted before being required to extend vertical control (direct leveling) from an existing bench mark to the traverse.
- Maximum number of traverse legs permitted before an azimuth check must be made.
- Maximum permitted change in direction of the traverse before an azimuth check must be made, The change in direction is based on the computed deflection angle at the station during the forward run of the traverse.

These specifications are spelled out in the Federal Geodetic Control Committee's publication, *Standards and Specifications for Geodetic Control Networks,* and will be strictly adhered to when supporting National Geodetic Survey or its Control Networks. In all other cases, comply with the project requirements of the using organization while observing correct surveying procedures.

Type of Distance Measuring Equipment

Consideration must be given to the type of distance measuring equipment when planning a traverse route, In most cases, EDME is available and the distances between intervisible stations are limited only by the maximum effective range of the EDME. If taping must be used, limit the distances between the stations to ten lengths of the tape. The ten-length limit will minimize alignment, leveling, and taping errors.

PROCEDURAL SPECIFICATIONS FOR THIRD-ORDER TRAVERSE SURVEY

The following procedures will be performed when extending horizontal control by traverse methods and third-order accuracy is to be obtained:

ALL third-order traverses will have TWO **station angles** observed at each occupied SCP. The sequence for observing station angles is as follows:

1. The observer places the instrument in the direct position (vertical circle on the observer's left) and points the instrument at the rear station. The observer bisects the rear target, sets the initial plate setting (if required), and reads the micrometer.
2. In the direct position, the observer turns the instrument clockwise to the forward station, bisects the target, and reads the micrometer.
3. The observer plunges the telescope, and turns the instrument clockwise to the forward station, with the vertical circle on the observer's right (reverse position). The observer bisects the target, and reads the micrometer.
4. In the reverse position, the observer turns the instrument clockwise until the instrument is pointing at the rear station, bisects the target, and reads the micrometer.

Steps **1** through **4** constitute the **first station angle.**

5. The instrument remains in the reverse position and pointed at the rear station. The observer bisects the target, advances the horizontal plates to the new initial plate setting (if the theodolite so requires), and reads the micrometer.
6. In the reverse position, the observer turns the instrument clockwise until the instrument is pointing at the forward station, bisects the target, and reads the micrometer.
7. The observer plunges the telescope and turns the instrument clockwise until the instrument is pointing at the forward station in the direct position. The observer bisects the target and reads the micrometer.
8. In the direct position, the observer turns the instrument clockwise until the instrument is pointing at the rear station, bisects the target, and reads the micrometer.

Steps **5** through **8** constitute the **second station angle.**

ALL third-order traverses will have TWO **explement angles** observed at each occupied SCP, The sequence for observing explement angles is the same as the sequence for station angles, except that the explement angles are initiated on the forward station.

The **mean of the station angles** will be shown on the recording form.

The **mean of the explement angles** will be shown on the recording form.

The **horizon closure** will be calculated and shown on the recording form. The horizon closure is the sum of the mean station angle and the mean explement angle.

The **error** will be shown on the recording form, The error is the horizon closure minus 360 degrees. The error will not exceed ± 05.0".

The **corrections** will be shown on the recording form. The corrections are the error divided by two, and the algebraic sign reversed. When a 1-second theodolite is used, the corrections will be rounded to 0.1 second, If one correction is rounded up, the other correction will be rounded down. The larger correction will be applied to the larger angle.

The **corrected mean station angle** will be calculated and shown on the recording form (see Figure 6-1, page 6-2).

Traverse lines (legs) will have zenith distances observed **in both directions** within one hour. Reciprocal zenith distances are mandatory for compliance with third-order traverse specifications.

SPECIFICATIONS FOR THIRD-ORDER DIFFERENTIAL LEVELING

The terms differential leveling, direct leveling, geodetic leveling, and spirit leveling describe the same activity: the determination of differences in elevation by direct observation. The terms will be interchangeable in this publication. When performing differential leveling and third-order accuracy is to be obtained, the following procedures will be adhered to:

1. Each day, just before the leveling begins, and immediately following any instance when the level is subjected to unusual shock, the error of the level (C factor) must be determined. The C check will be recorded and kept in the records of the project.
2. The leveling will start from and end on bench marks of third-order accuracy or higher.
3. The method of observation will be three-wire readings.
4. No observation will be made closer to the ground than one-half (0.500) meter. No observation will be made on the rod or precise meter board higher than project specifications require.
5. The rods will be leapfrogged forward.
6. There will be an even number of setups between the starting and ending bench marks.
7. The sequence of observing the rods will be the red rod first sequence: rod # 1 or A of a matched pair of rods will be marked (the foot of the rod is painted or flagging is attached to the rod) to distinguish it from the other rod. The marked rod will be observed and the readings recorded first for each setup.
8. Sections will be double run: from the first bench mark out to the next bench mark and return.

9. The maximum allowable disclosure will be the lesser of the two computed values:
- Twelve millimeters times the square root of the shorter distance run between the bench marks in kilometers, or;
- Twelve millimeters times the square root of the perimeter of the loop (front and back runs combined) in kilometers.

10. Actions not specified above will comply with the specifications set forth by the Federal Geodetic Control Committee.

11. In no instance will proper leveling methodology and procedures be abandoned. Procedures 1 through 10 will be complied with at all times unless the customer sets forth specific methodology, standards, and specifications for performing the differential leveling in his request for survey support.

Chapter 6
Recording and Abstracting Procedures

RECORDING HORIZONTAL DIRECTIONS

Recording horizontal directions will be the same for all orders of accuracy, Horizontal directions will be recorded in *DA Form 4253, Horizontal Direction or Angle Book,* authorized single sheet recording forms, or appropriate media when operating automated integrated survey instruments (AISI). In all cases, complete documentation will be performed in the field, Each time an SCP is occupied, the following will be recorded:

1 **Instrument make, model, and serial number.**
2 **Instrument operator's name.**
3 **Recorder's name.**
4 **Weather description** – three words describing –
   ŽTemperature.
   ŽGeneral atmospheric condition.
   ŽWind.
5 **Complete designation of the station occupied–**
   ŽFull station name.
   ŽYear the monument was installed.
   ŽName of agency on the disk.

Each station observed will, when first listed on a page or form, be identified by full station name, year monumented, and name of agency on the disk, If an instrument, signal, or target is set eccentric to a station (not plumbed directly over the station mark), that item will be sketched on the recording form, showing –

1 Distance of the item from the station.
2 Relative directions of the item to –
   ŽStation is set eccentric from.
   ŽFirst distant station in a clockwise direction.
   ŽIncluded angle.

Where intersection stations are observed, the exact part of the object sighted upon must be recorded and shown in a sketch.

Numbers and letters should be approximately half the height between lines, The recording should be centered in the block and on the bottom line of the block. All figures must be neat and legible. There will be no erasures or obscuring of the original figures. Original numbers may be crossed out using a single diagonal line through the numbers. The corrected numbers will be written above the original entry. The person making the correction will place his initials above and to the right of the original entry and within the block. The person making the correction will explain the reason for the correction in the Remarks column when he makes the correction. No position will be voided or rejected on any recording media, except in the case of bumping the instrument or stand, causing the instrument to become unlevel. If the instrument is observed to be unlevel, make a note on the recording media in the Remarks column stating that the instrument was not level, and why. All recordings will be done with a dark reproducible ink, preferably black or blue-black, Directions in degrees, minutes, and seconds will be entered in the Remarks column. A note will be entered in the Remarks column for the first position of each set, describing the general condition: "No eccentricity of instrument or target," "Eccentric target shown to all stations." or other appropriate entry.

Every computation on each page or sheet will be checked by the observer, The observer will verify the computation with a light, visible tick mark to the upper right of the computed numbers, or will correct the numbers (as described above). The observer will confirm that he has checked all computed numbers on the page by placing his initials at the bottom right corner of the page.

On the appropriate page in the front of the recording book, an index will be made of the stations from which observations were made and recorded within the book. An index will also be required for all other recording media, listing where to locate observations from any occupied SCP.

Refer to the appropriate illustration for the following types of observations:

1 **Traverse** (using l-second theodolite) (includes determining horizon closure and corrected station and explement angles for third-order accuracy projects) – Figure 6-1.
2 **Triangulation** (using 0.2-second theodolite) – Figure 6-2.
3 **Zenith distance** (using l-second theodolite) – Figure 6-3.
4 **Vertical angle** (using 0.2-second theodolite) – Figure 6-4,
5 **Side shot** (used for airfield obstruction positioning and reporting) – Figure 6-5.
6 **Astronomic azimuth** – Figures 6-6a and 6-6b.
7 **Two-point intersection** – Figure 6-7.
8 **Plane table** – Figure 6-8.

STATION LEWIS (30TH ENGR BN) 68 DATE 2 JUNE 19 88

INSTRUMENTMAN SFC J. DOE INSTRUMENT WILD T-2 # 1012

RECORDER SFC K. SMOE WEATHER COOL, CLEAR & CALM

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	CHRON TIME M	CHRON TIME S	STOP WATCH	TEL D/R	CIRCLE	
1	KING 30TH ENGR BN					D	00	00
	68					R	180	00
	ET-1 USC+GS 68					D	325	10
						R	145	10
2	KING 30TH ENGR BN					R	210	02
	68					D	30	02
	ET-1 USC+GS 68					R	175	12
						D	355	12
1	ET-1 USC+GS 68					D	00	00
						R	180	00
	KING 30TH ENGR BN					D	34	51
	68					R	214	51
2	ET-1 USC+GS 68					R	210	02
						D	30	02
	KING 30TH ENGR BN					R	244	52
	68					D	64	52

MICRO. / VERN. 1ST / A( )	MICRO. / VERN. 2D / B( )	MEAN	MEAN D / R	DIR / ANG	REMARKS	LEVELS W	LEVELS E
52							
58		55.0		00.0			
31					STA #		
35		33.0		38.0	325° 09' 38.0"		
32							
28		30.0		00.0			
12					STA #		
07		09.5		34.5	325° 09' 34.5"		
					MN STA # 325° 09 38.8		
48							
53		50.5		00.0			
15							
19		17.0		26.5	EXP # 34° 50' 26".5		
27							
26		26.5		00.0			
56							
48		52.0		25.5	EXP # 34° 50' 25".5		
					MN EXP # 34° 50' 26".0		
					MN STA # 325° 09' 38.8		
					HC 360 00 04.8		
					CORR -04.8 -2.4 +-2.4		
	JCO		CORR		STA # 325° 09' 36.4		

DA FORM 1 JUN 74 4253 (Blue)

Figure 6-1. **Recording procedures for horizontal directions using 1-second theodolite**

STATION LEWIS 30TH ENGR BN 68 DATE 2 JUNE 19 88

INSTRUMENTMAN SFC J. DOE INSTRUMENT WILD T-3 1012

RECORDER SFC SMOE WEATHER CALM, COOL, & CLEAR

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	CHRON TIME M	CHRON TIME S	STOP WATCH	TEL D/R	CIRCLE		MICRO. / VERN. 1ST / A(')	MICRO. / VERN. 2D / B(')	MEAN	MEAN D / R	DIR / ANG	REMARKS	LEVELS W	LEVELS E
1	Δ JAMES USC+GS	01	18			D	00	00	06.8	06.6	06.7			NO ECC. OF LIGHT		
	68					R	180	00	05.4	05.4	05.4	06.0	00.0	OR INSTR.		
	Δ WILLIS USC+GS					D	67	14	54.9	54.7	54.8					
	68					R	247	14	55.0	54.8	54.9	54.8	48.8	67° 14' 48".8'		
	Δ KING 30TH ENGR BN					D	123	39	06.9	06.6	06.8					
	68					R	303	39	06.3	06.2	06.2	06.5	00.5	123° 39' 00".5'		
2	JAMES USC+GS					R	191	00	22.9	23.1	23.0					
	68					D	11	00	22.7	22.5	22.6	22.8	00.0			
	WILLIS USC+GS					R	258	15	11.2	11.0	11.1					
	68					D	78	15	10.7	10.6	10.6	10.8	48.0	67° 14' 48".0'		
	KING 30TH ENGR BN					R	314	39	23.0	22.8	22.9					
	68					D	134	39	22.5	22.4	22.4	22.6	59.8	123° 38' 59".8'		
	THE REMAINING POSITIONS ARE SIMILAR TO THESE, EXCEPT THAT THE PLATE IS ADVANCED TO THE PROPER INCREMENT.													JCB		

DA FORM 1 JUN 74 4253 (Blue)

Figure 6-2. **Recording procedures for horizontal directions using 2-second theodolite**

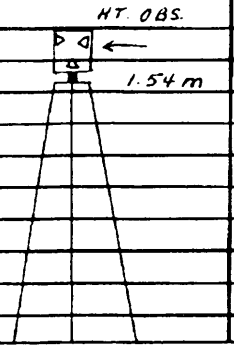
Zenith Distance/Vertical Angle

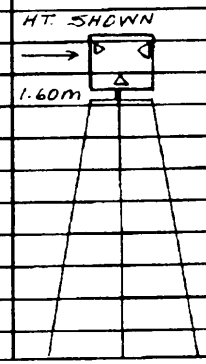
For use of this form, see FM 5-232, the proponent agency is TRADOC.

STATION LEWIS (USC + GS) 29 DATE PM 14 OCT 19 68 INSTRUMENTMAN SFC J. DOE INSTRUMENT WILD T2 #52119

RECORDER SP4 W. ROE WEATHER BREEZY COOL CALM

OBJECT OBSERVED	CHRON TIME H	M	S	STOP WATCH	TEL D/R	CIRCLE		MICRO. 1ST	2D	MEAN	ZEN DIST	REMARKS	LEVELS W	E
1. LEWIS (USC+GS) 29	14	25			D	90	04	51	-03.5	= 47.5		HT. = 1.60m		
					R	269	55	16	-03.5	= 12.5		HT. = 1.54m		
					℄	359	59	67	-07.0	= 60.0	90° 04' 41" 5			
2	14	30						52	-03.5	= 48.5				
								15	-03.5	= 11.5				
								67	-07.0	= 60.0	90° 04' 48" 5			





DA Form 5817-R, AUG 89

Figure 6-3. **Recording procedures for observing zenith distances using 1-second theodolite**

Zenith Distance/Vertical Angle

For use of this form, see FM 5-232, the proponent agency is TRADOC.

STATION LEWIS (USC & GS) 29 DATE PM 14 OCT 19 68

INSTRUMENTMAN SFC J. DOE INSTRUMENT WILD T-3 # 1852

RECORDER SP4 W. ROE WEATHER CALM, COOL, & CLEAR

OBJECT OBSERVED	CHRON TIME H	CHRON TIME M	CHRON TIME S	STOP WATCH	TEL D/R	CIRCLE		MICRO. 1ST	MICRO. 2D	MEAN	ZE N DIST	REMARKS	LEVELS	
△ WILLIS	23	40			D	93	33	32.0	32.2	32.1		H.I. = 1.85 meters		
(30TH ENGR BN) 68					R	86	26	26.6	26.6	26.6				
				VERT ∡ = +		07'	07'			05.5	82° 52' 54.5"	H.S. = 1.60 meters		
					D	93	33	33.8	34.0	33.9				
OBSERVED:					R	86	26	27.6	27.8	27.7				
					+	07'	07'			06.2	82 52 53.8			
CENTER OF LIGHT														
					D	93	33	33.9	33.9	33.9				
					R	86	26	28.6	28.8	28.7				
					+	07'	07'			05.2	82 52 54.8			
					D	93	33	30.2	30.4	30.3				
	23	55			R	86	26	26.7	26.7	26.7				
					+	07'	07'			03.6	82 52 56.4			
								TOTAL		=	219."5			
								MEAN		=	82° 52' 54."88			

jed

DA Form 5817-R, AUG 89

Figure 6-4 **Recording procedures for vertical angle using 0.2-second theodolite**

STATION LAGUNA-A SIDE SHOT DATE 8 MAR 19 86

INSTRUMENTMAN SPC HOWSIE INSTRUMENT WILD T-2 # 51735

RECORDER SPC POTTS WEATHER WARM, BREEZY, CLOUDY

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	CHRON TIME M	CHRON TIME S	STOP WATCH	TEL D/R	CIRCLE		MICRO. 1ST / A(')	VERN. 2D / B(")	MEAN	MEAN D / R	DIR / ANG	REMARKS	LEVELS W	LEVELS E
1	COMPASS ROSE					D	00	00	11		12.0					
						R	180	00	13							
	BERM					D	305	10	11							
						R	125	10	21		16.0		STA	305 10 04.0		
2	COMPASS ROSE					R	225	00	21							
						D	45	00	19		20.0					
	BERM					R	170	10	23							
						D	350	10	25		24.0		STA	305 10 04.0		
												MN	STA	305 10 04.0		
1	BERM					D	00	00	23							
						R	180	00	22		22.5					
	COMPASS ROSE					D	54	50	04							
						R	234	50	11		07.5		EXP	54 49 45.0		
2	BERM					R	225	00	22							
						D	45	00	18		20.0					
	COMPASS ROSE					R	279	50	15							
						D	99	50	06		10.5		EXP	54 49 50.5		
												MN	EXP	54 49 47.8		
												MN	STA	305 10 04.0		
													HC	359 59 51.8		
													CORR	+08.2 +04.1 +04.1		
										CRH		CORR	STA	305 10 08.1		

DA FORM 1 JUN 74 4253 (Blue)

Figure 6-5. **Recording procedures for side shot**

STATION LIFT (USAES 79) DATE 24 JULY 19 79

INSTRUMENTMAN SGT HOWARD INSTRUMENT WILD T-2 # 50101

RECORDER PFC MAYO WEATHER CLEAR, COOL, CALM

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	M	S	STOP WATCH	TEL D/R	CIRCLE		MICRO. / VERN. 1ST / A(')	2D / B(")	MEAN	MEAN D / R	DIR / ANG	REMARKS	LEVELS W	E
	WWV 15 MHZ UT		LOT													
	03 26	23	25	47												
	03 27	23	26	47												
	03 28	23	27	47												
1	LIFT AZ MK					D	00	00	12							
	(USAES 79)					R	180	00	08			10.0				
	POLARIS	00	46	32		D	212	09	03							
		00	48	09		R	32	08	50			08/56.5		212° 08' 46".5		
	Δ		01	37												
	MN	00	47	20.5												
2	LIFT AZ MK					R	225	02	30							
	(USAES 79)					D	45	02	34			30.0				
	POLARIS	00	54	35		R	77	13	43							
		00	55	45		D	257	14	01			13/52.0		212° 11' 22".0		
	Δ		01	10												
	MN	00	55	10												
3	LIFT AZ MK					D	90	05	20							
	(USAES 79)					R	270	05	24			22.0				
	POLARIS	01	00	43		D	302	17	17							
		01	02	07		R	122	16	50			17/03.5		212° 11' 41".5		
	Δ		01	24												
	MN	01	01	25												

JEH'

DA FORM 1 JUN 74 4253 (Blue)

Figure 6-6a. **Recording procedures for astronomic azimuth using 1-second theodolite**

STATION LIFT (USAES 74) DATE 24 JULY 19 79

INSTRUMENTMAN SGT HOWARD INSTRUMENT WILD T-2 # 50101

RECORDER PFC MAYO WEATHER CLEAR, COOL, CALM

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	M	S	STOP WATCH	TEL D/R	CIRCLE		MICRO. / VERN. 1ST / A(')	2D / B(')	MEAN	MEAN D / R	DIR / ANG	REMARKS	LEVELS W	E
4	LIFT AZ MK					R	310	07	51							
	(USAES 74)					D	130	07	53			52.0				
	POLARIS	01	06	51		R	162	21	20							
		01	08	29		D	342	22	04			21/42.0		212° 13' 50".0		
	Δ		01	38												
	MN	01	07	40												
	WWV 15 MHZ UT															
	05 20	01	19	47												
	05 21	01	20	47												
	05 22	01	21	47												

JEH

DA FORM 1 JUN 74 **4253**
(Blue)

Figure 6-6a. **Recording procedures for astronomic azimuth using 1-second theodolite (continued)**

STATION DEC. STA. #1 (USC+GS) DATE 1 JUNE 19 88

INSTRUMENTMAN SGT JACK INSTRUMENT WILD T-3 # 72063

RECORDER PFC DANIELS WEATHER CLEAR, CALM, HOT

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	M	S	STOP WATCH	TEL D/R	CIRCLE		MICRO. / VERN. 1ST / A(')	2D / B(')	MEAN	MEAN D. R	DIR / ANG	REMARKS	LEVELS W	E
	WWV 15 MHZ		LST													
	23 29	05	07	51.5												
	23 30	05	08	51.5	←											
	23 31	05	09	51.6												
1	DEC.STA. AZ.MK.					D	00	00	10.0	10.1	10.0					
	(USC+GS) 75					R	180	00	09.6	09.8	09.7	09.8'				
														W E		
	POLARIS	11	23	41.8		D	14	15	14.1	14.2	14.2			03.9 30.9		
		11	25	27.0'		R	194	15	36.4	36.6	36.5	25.4'		31.4 04.4		
	Δ		01	45.2'										27.5 26.5		
	MN	11	24	34.4'										+1.0		
2	DEC.STA. AZ.MK.					D	191	00	25.6	25.8	25.7					
	(USC+GS) 75					R	11	00	32.4	32.6	32.5	29.1'				
														W E		
	POLARIS	11	27	57.1		D	205	16	23.6	23.8	23.7			31.5 04.5		
		11	30	11.1'		R	25	16	50.6	50.8	50.7	37.2'		04.0 31.0		
	Δ		02	14.0'										27.5 26.5		
	MN	11	29	04.1'										+1.0		

DA FORM 1 JUN 74 4253 (Blue)

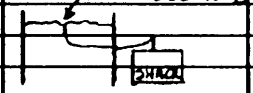
Figure 6-6b. **Recording procedures for astronomic azimuth using 0.2-second theodolite**

STATION HANCHEY (30TH ENGR BN) 81 DATE 6 MAY 19 88

INSTRUMENTMAN SP4 FISH INSTRUMENT WILD T-2 #72071

RECORDER WEATHER CLEAR, CALM, COOL

POS. / REP.	OBJECT OBSERVED	CHRON TIME H	CHRON TIME M	CHRON TIME S	STOP WATCH	TEL D/R	CIRCLE	
1	HANCHEY AZ MK					D	00	00
	(30TH ENGR BN) 81					R	180	00
	NDB					D	97	21
						R	277	21
2	HANCHEY AZ MK					R	270	00
	(30TH ENGR BN) 81					D	90	00
	NDB					R	07	21
						D	187	21
1	NDB					D	00	00
						R	180	00
	HANCHEY AZ MK					D	262	39
	(30TH ENGR BN) 81					R	82	39
2	NDB					R	270	00
						D	90	00
	HANCHEY AZ MK					R	172	39
	(30TH ENGR BN) 81					D	352	39

MICRO. / VERN. 1ST / A(')	MICRO. / VERN. 2D / B(')	MEAN	MEAN D / R	DIR / ANG	REMARKS	LEVELS W	LEVELS E
30					POINT OBSERVED		
31			30.5				
03							
02			02.5				
				STA #	47° 20' 32".0		
31							
29			30.0				
04							
02			03.0	STA #	47° 20' 33".0		
			MN	STA #	47° 20' 32".5		
31							
30			30.5				
57							
58			57.5	EXPL #	262° 39' 27".0		
32							
31			31.5				
59							
58			58.5	EXPL #	262° 39' 27".0		
			MN	EXPL #	262° 39' 27".0		
			MN	STA #	47° 20' 32".5		
			H°	R LOG.	359° 59' 59".5		
				ERROR	-00.5		
				CORR.	+00.2 +00.3		
				CORR. STA #	47° 20' 32".7		

JEF

DA FORM 1 JUN 74 4253 (Blue)

Figure 6-7. **Recording procedures for airfield two-point intersection**

General Survey Notes

For use of this form, see FM 5-232; the proponent agency is TRADOC.

Project FAIRFAX COMMO		Weather HAZY			Wind CALM		Instrument ALIDADE, ICE #4671			Date 15 SEP 84
Designation		Location FAIRFAX, VA			Temp WARM		Organization 99th ENG CO			Page no. 17 | No. of Pages 41
Point	H Dist	H Scale	RI	V Scale	Prod ±	RC −	DE ±	HI	Elev.	Remarks
		↑	STATION A				+4.4	170.1	165.7	ELEV STA. A
A1	95	99	0.86	45	−4.3	−2.6	−6.9		163.2	℄ DITCH
A2	135	100	1.35	50	—	−4.3	−4.3		165.8	NE CORNER BLDG
A3	140	100	1.40	48	−2.8	−6.8	−9.6		160.5	TOE OF SLOPE
A4	94	99	0.95	55	+4.8	−2.0	+2.8		172.9	TOP OF BANK

sample

DA Form 5818-R, AUG 89

Figure 6-8. **Recording procedures for plane table**

ABSTRACTING OF HORIZONTAL DIRECTIONS

Second-order horizontal observation specifications require that an abstract of horizontal directions be compiled for every station at which horizontal directions have been observed. *DA Form 1916, Abstract of Horizontal Directions,* will be completed before leaving the SCP. (Third-order horizontal observations require the determination of horizon closure, corrected station angle, and corrected explement angle on the recording form. This will be accomplished prior to leaving the SCP.) Readings will be entered opposite the proper circle position, as indicated in the field notes, The degrees and minutes for each direction are entered only once, at the top of each column, and the seconds are entered for each circle position (Figure 6-9). The following is a summary of requirements when abstracting and rejecting horizontal directions.

Record all positions observed onto *DA Form 1916.* If two or more observations have been made for the same circle setting (position), list all the observations in the same box and determine the mean for that position.

Examine the list of the form. For all positions which appear to vary greatly from the apparent mean of all the positions, check the computations in the field recording book or recording media. Be alert for a change in the minutes of the computed directions (angles) in the field data. Reject any positions which vary widely from the mean and reobserve the positions, Values that are rejected will be enclosed in parentheses, and followed by "R_0." "R_0" indicates that the value was rejected by observation.

Determine (compute) a mean of the observed positions. The mean value of a direction will be rounded off to the nearest 0.01 second if a T-3 theodolite was used for observations. The mean value of a direction will be rounded off to the nearest 0.1 second if a l-second instrument was used for observations. Reject all observations which differ from the mean by more than the rejection limit (from *Standards and Specifications for Geodetic Control Networks).* Enclose any rejected observations with parentheses, and annotate with "R1." "R1" indicates that the value was rejected using the first mean value. The rejection limit will be applied to each observation with the same amount of accuracy as when the mean was determined (0.01 second for 1/10-second instruments, 0.1 second for 1-second instruments).

Reobserve any rejected positions and redetermine anew mean. Reapply the rejection limit. Any positions still exceeding the rejection limit will be enclosed in parentheses and annotated with "R2." "R2" indicates that the value was rejected using the second mean value. Ensure that sufficient positions remain acceptable (from *Standards and Specifications for Geodetic Control Networks).*

No value (reading) should be rejected if it is within the rejection limits, unless it was rejected at the time of observation, If a value was rejected at time of observation, check the field notes for the observer's reason for rejection.

Once a value is rejected, it cannot be used again.

If one of two or more readings on a position is outside the rejection limits, do not use the mean of the readings. Use only the reading which is within the rejection limits.

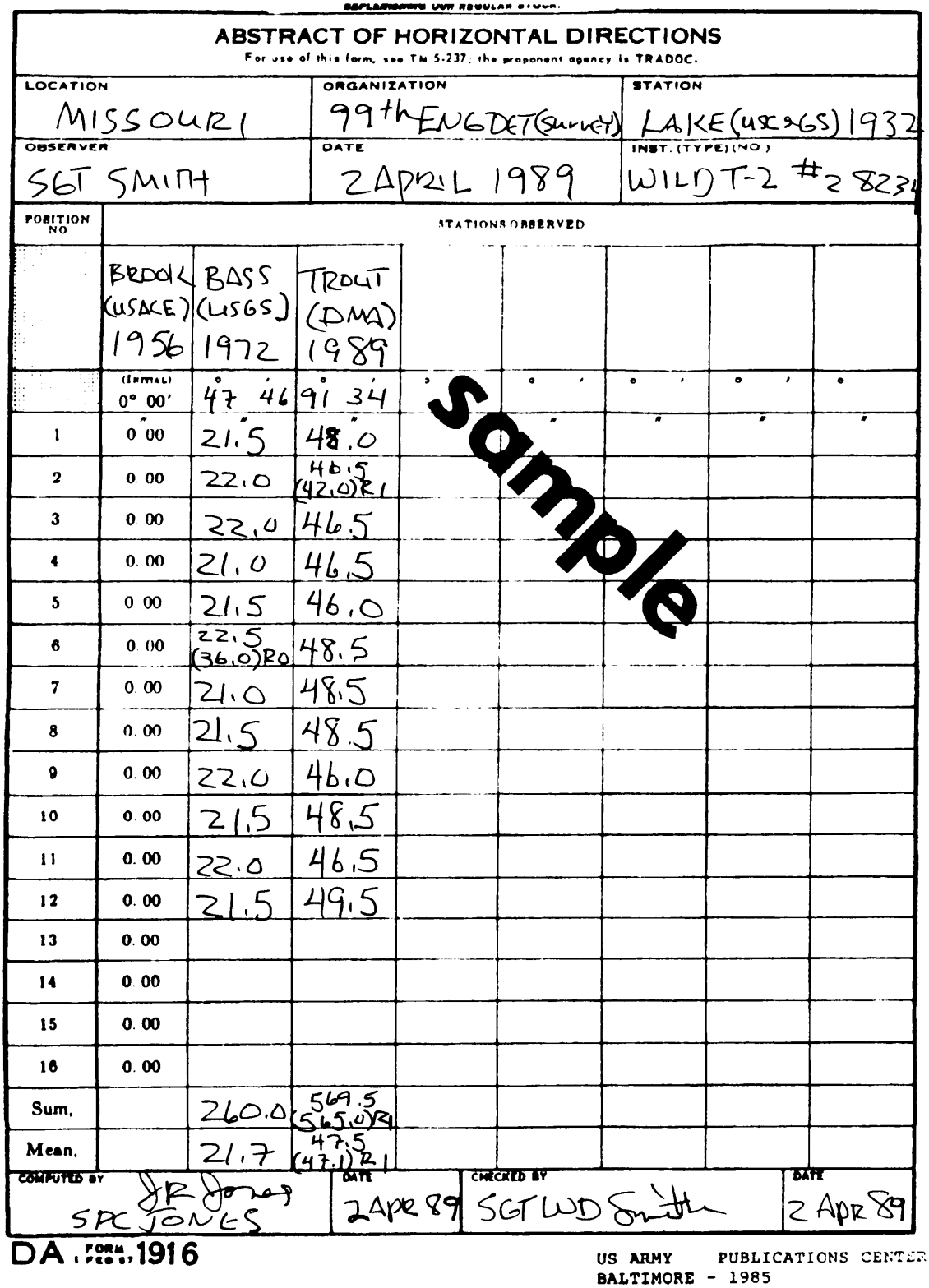
If two readings are outside the rejection limits (one high, the other low, and the mean is within the limits), the readings must be rejected.

If there is a progressive change in the values of the positions of a direction, or if the mean of the first half of the positions differs appreciably from the mean of the last half of the positions, attempt to observe another complete set of positions before leaving the SCP.

If repeat positions are observed at any circle setting during the same occupation of a station, combine the result of each additional observation with that of the original circle position. If, on second-order Class I triangulation, 12 or more additional positions are observed, they should be meaned separately and combined by sets.

On second-order Class I triangulation, two or more sets of 12 or more positions must be given equal weight, regardless of whether they are observed on the same or different nights. When two sets of 12 or more positions differ by more than 1 second, the set which best closes the triangle(s) is retained and the other set is rejected. In the case of three sets, sometimes two sets which agree with each other must be rejected and the third retained. Usually, the set or sets retained are those which are observed under the least harmful conditions of horizontal refraction. When there are more than two sets, any set which falls within 0.5 second of the individual or mean value which best satisfies the triangle(s) should also be meaned with that value.

If it appears that the initial is causing a large number of rejections, the observations can be listed by positions and directions on the abstract form, with some other station as the zero initial. In this case, the angle between the new initial and the original initial should be added to the listed circle settings to obtain the correct values to use when reobserving rejections, unless a complete new set of observations is to be made with anew initial. (See Table 6-1, pages 6-14 and 6-15.)



REPLACES EDITION OF 1 JAN 57 WHICH MAY BE USED.

ABSTRACT OF HORIZONTAL DIRECTIONS

For use of this form, see TM 5-237; the proponent agency is TRADOC.

LOCATION	ORGANIZATION	STATION
MISSOURI	99th ENG DET (SURVEY)	LAKE (USACE & GS) 1932
OBSERVER	**DATE**	**INST. (TYPE) (NO.)**
SGT SMITH	2 APRIL 1989	WILD T-2 # 28231

POSITION NO	STATIONS OBSERVED								
	BROOK (USACE) 1956	BASS (USGS) 1972	TROUT (DMA) 1989						
	(INITIAL) 0° 00′	° ′ 47 46	° ′ 91 34	° ′	° ′	° ′	° ′	° ′	°
1	0 00	21.5	48.0	"	"	"	"	"	
2	0. 00	22.0	46.5 (42.0)R1						
3	0. 00	22.0	46.5						
4	0. 00	21.0	46.5						
5	0. 00	21.5	46.0						
6	0. 00	22.5 (36.0)R0	48.5						
7	0. 00	21.0	48.5						
8	0. 00	21.5	48.5						
9	0. 00	22.0	46.0						
10	0. 00	21.5	48.5						
11	0. 00	22.0	46.5						
12	0. 00	21.5	49.5						
13	0. 00								
14	0. 00								
15	0. 00								
16	0. 00								
Sum,		260.0	569.5 (565.0)R1						
Mean,		21.7	47.5 (47.1)R1						

COMPUTED BY	DATE	CHECKED BY	DATE
SPC JONES JR Jones	2 APR 89	SGT WD Smith	2 Apr 89

DA FORM 1916, FEB 57

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sample

Figure 6-9. **Abstracting horizontal directions**

Table 6-1. **Circle settings**

Two positions of circle	10-minute micrometer drum		
1	0°	00′	10″
2	90	05	40

Four positions of circle	5-minute micrometer drum			10-minute micrometer drum			Circle	Wild T-3*	Micrometer
1	0°	00′	40″	0°	00′	10″	0°	00′	15″
2	45	01	50	45	02	40	45	02	45
3	90	03	10	90	05	10	90	04	15
4	135	04	20	135	07	40	135	20	45
Six positions of circle									
1	0°	00′	10″	0°	00′	10″	0°	00′	15″
2	30	01	50	30	01	50	30	02	35
3	60	03	30	60	03	30	60	00	50
4	90	00	10	90	05	10	90	04	15
5	120	01	50	120	06	50	120	00	35
6	150	03	30	150	08	30	150	20	50
Eight positions of circle									
1	0°	00′	40″	0°	00′	10″	0°	00′	10″
2	22	01	50	22	01	25	22	00	25
3	45	03	10	45	02	40	45	02	35
4	67	04	20	67	03	55	67	00	50
5	90	00	40	90	05	10	90	04	10
6	112	01	50	112	06	25	112	00	25
7	135	03	10	135	07	40	135	20	35
8	157	04	20	157	08	55	157	00	50
Twelve positions of circle									
1	0°	00′	40″	0°	00′	10″	0°	00′	10″
2	15	01	50	15	01	50	15	00	25
3	30	03	10	30	03	30	30	02	35
4	45	04	20	45	05	10	45	00	50
5	60	00	40	60	06	50	60	00	10
6	75	01	50	75	08	30	75	00	25
7	90	03	10	90	00	10	90	04	35
8	105	04	20	105	01	50	105	00	50
9	120	00	40	120	03	30	120	00	10
10	135	01	50	135	05	10	135	00	25
11	150	03	10	150	06	50	150	20	35
12	165	04	20	165	08	30	165	00	50
Sixteen positions of circle									
1	0°	00′	40″	0°	00′	10″	0°	00′	10″
2	11	01	50	11	01	25	11	00	25
3	22	03	10	22	02	40	22	00	35
4	33	04	20	33	03	55	33	00	50
5	45	00	40	45	05	10	45	02	10
6	56	01	50	56	06	25	56	00	25
7	67	03	10	67	07	40	67	00	35
8	78	04	20	78	08	55	78	00	50
9	90	00	40	90	00	10	90	04	10
10	101	01	50	101	01	25	101	00	25
11	112	03	10	112	02	40	112	00	35
12	123	04	20	123	03	55	123	00	50
13	135	00	40	135	05	10	135	02	10
14	146	01	50	146	06	25	146	00	25
15	157	03	10	157	07	40	157	00	35
16	168	04	20	168	08	55	168	00	50

Table 6-1. **Circle settings (continued)**

Sets	Instrument** 10″ setting			Instrument*** 20″ setting			Instrument*** 30″ setting		
1	0°	00′	00″	0°	00′	00″	0°	00′	00″
2	90	05	30	90	10	20	90	10	30
1	0	00	00	0	00	00	0	00	00
2	60	03	30	60	06	20	60	06	30
3	120	07	00	120	13	00	120	13	00
1				0	00	00	0	00	00
2				45	05	20	45	05	30
3				90	10	00	90	10	00
4				135	15	20	135	15	30
1				0	00	00	0	00	00
2				36	04	20	36	04	30
3				72	08	00	72	08	00
4				108	12	20	108	12	30
5				144	16	00	144	16	00
1							0	00	00
2							30	03	30
3							60	07	00
4							90	10	30
5							120	14	00
6							150	17	30
1							0	00	00
2							25	02	30
3							51	05	30
4							76	08	00
5							102	10	30
6							128	14	30
7							153	17	00
1							0°	00′	00″
2							22	02	30
3							45	05	00
4							67	07	30
5							90	10	00
6							112	12	30
7							135	15	00
8							157	17	30

The Kern DKM-3 theodolite is an example of an instrument with a micrometer drum range of 5′. The Wild T-2 and the Kern DKM-2 theodolites are examples of instruments with a micrometer drum range of 10′.

* For Wild T-3 theodolites, with a 2′ micrometer graduated to 0.″2, the micrometer readings shown in the table as units would be in seconds.

** Repeating theodolite with a 10′ circle.

*** Transit with a 20′ circle.

RECORDING VERTICAL OBSERVATIONS

Recording vertical observations will be the same for all orders of accuracy. Vertical observations will be recorded in *DA Form 4446, Level, Transit, and General Survey Book;* authorized single sheet recording forms; or appropriate media when operating AISI. In all cases, complete documentation will be performed in the field. In addition to the recording requirements stated on page 6-1, the following information will be recorded:

1 The HI above the station will be measured and recorded to the nearest 0.01 meter.

2 The target observed will be sketched in the bottom of the Object Observed column, and the point of the target observed will be indicated.

3 The height of target observed (HT) above the station being observed will be measured and recorded to the nearest 0.01 meter.

4 If the observer and recorder show a target to adjoining stations, the target shown will be sketched at the bottom of the Remarks column. All possible points that may be observed on the target will be measured and recorded to the nearest 0.01 meter as heights above the mark at the station. If the observer and recorder change the the target shown, they will remeasure all possible points, and record the new heights above station and the time of day when they changed the target.

5 If the target shown is not plumbed over the station, whether on line or eccentric, the recording requirements on page 6-1 will be strictly complied with.

During vertical observations, the time of the first observation of the first position and the time of the last observation of the last position will be recorded. The times will be recorded to the nearest whole minute.

The recording formats for the more commonly used instruments are shown at Figures 6-3 and 6-4 (pages 6-4 and 6-5). The T-2 theodolite and similar 1-second instruments observe zenith distances (Figure 6-3). The T-3 theodolite observes half-angles (Figure 6-4). The reverse (position) observation is subtracted from the direct (position). The difference is a vertical angle, with the algebraic sign indicating whether the vertical angle is elevated or depressed.

ABSTRACTING VERTICAL OBSERVATIONS

Vertical observations will be abstracted on *DA Form 1943, Abstract of Zenith Distances* (Figure 6-10), at the station site by the observing party.

Targets or signals shown to other stations will be sketched and dimensioned at the bottom of the form. If a target or signal is changed during the day, the time of change and the new dimensions will also be entered.

Vertical observations recorded as vertical angles will be converted to zenith distances prior to abstracting, The zenith distances will be abstracted, including the times of the observations. The abstracted zenith distances will be meaned, The mean zenith distances will be reduced to corrected zenith distances, by applying the **reduction to line-joining stations.** The formula is –

$$\text{Reduction (in seconds)} = -\frac{(t - o)\sin \text{mn Zenith Distance}}{T \sin 1''}$$

Where:

t = height of telescope above the station (HI)
o = height of object (point) observed above station
T = slope distance between stations (in kilometers)

This computation will also be applied to the vertical observations performed at the station at the other end of the line observed (reciprocal observations). The length of the line (T) will be multiplied by 0.46. Sum the two corrected zenith distances and subtract 180 degrees. Compare the product (T x 0,46) to the difference (corrZD1 + corrZD2 - 180 deg) (express as minutes of arc). If the two values differ by more than one minute of arc, perform a second set of reciprocal zenith distance observations. Differences exceeding one minute of arc are normally due to errors in observations, or unusual refractions in the atmosphere (poor observing conditions).

RECORDING HORIZONTALLY TAPED DISTANCES

Horizontally taped distances will be recorded *in DA Form 4196, Horizontal Distance Book,* or authorized single sheet recording form (Figure 6-11, page 6-18). The recorder will compute the horizontal distance in the recording book or form.

RECORDING ELECTRONICALLY MEASURED DISTANCES

Distances measured by EDME will be recorded on authorized single sheet recording forms (Figure 6-12, page 6-19). If the AISI is used, the appropriate recording media is authorized.

RECORDING DIFFERENTIAL LEVELING

Recording differential leveling is the same for all orders of accuracy. Differential leveling is recorded in *DA Form 4446* or authorized single-sheet recording forms (Figure 6-13, page 6-20). In addition to the

ABSTRACT OF ZENITH DISTANCES

PROJECT: 99E/99/TRA 3		
LOCATION: MISSOURI	INSTR. (TYPE) (NO.): WILD T2 #52119	STATION: LAKE (USC&GS) 1932
ORGANIZATION: 99th ENG DET (SURVEY)	OBSERVER: SGT SMITH	HEIGHT OF STAND: —

Date 1989	Hour	Object Observed	Object Above Station = o (Meters)	Telescope Above Station = i (Meters)	Diff of Heights i − o (Meters)	Reduction to Line Joining Stations	Observed Zenith Distance	Corrected Zenith Distance
2 Apr	1425	BROOK	1.54	1.60	+0.04		90 04 47.5	
	1430	(USACE) 1956					48.5	
		OBS CENTER of				MA	90° 04' 48.0"	
		TARGET						

sample

Date	Light Shown to Station	Height of Light* Above Station (Meters)	Date	Light Shown to Station	Height of Light* Above Station (Meters)
2 Apr 89		1.60 m at CENTER			

*Height of Light (or object above station) should also be entered on Abstract of Zenith Distances of station to which light was shown.

COMPUTED BY	DATE	CHECKED BY	DATE
SFC [illegible]	2 Apr 89	SGT [illegible] Smith	2 Apr 89

DA, FORM 1943, FEB 87 ☆U.S. GPO: 1986—491-083/60457

For use of this form, see TM 5-237; the proponent agency is TRADOC.

Figure 6-10. **Abstracting zenith distances**

FROM STATION TP-4 TO STATION TP-5

CHIEF TAPEMAN SP5 ORTON TAPE NOS. LUFKIN # 5216 LUFKIN # 3114

DATE 14 JUNE 19 85 WEATHER CALM, CLEAR, COOL

STATION FROM	STATION TO	TEMP FRONT	TEMP REAR	DISTANCE	% OF SLOPE FWD	% OF SLOPE BKWD	SET-UP	SET-BACK	TAPE SUPPORT	INCL CORR	TEMP CORR	CAL CORR	REMARKS
TP4		54	56	30.000	2.5				2	-0.013	-0.002	+0.021	
		55	55	30.000	3.0				2	-0.015	-0.002	+0.021	
		55	56	30.000	1.5				2	-0.008	-0.002	+0.021	
		54	56	30.000	1.5				2	-0.008	-0.002	+0.021	
		55	55	30.000	1.5				2	-0.008	-0.002	+0.021	
	TP-5	55		4.774	0				2	-0-	-01	+0.003	
				$154.774						-0.052	-0.010	+0.108	
TP-5		55	56	30.000	1.5				2	-0.008	-0.002	+0.021	
		56	55	30.000	1.5				2	-0.008	-0.002	+0.021	
		54	55	30.000	1.5				2	-0.008	-0.003	+0.021	
		55	55	30.000	3.0				2	-0.015	-0.002	+0.021	
		54	55	30.000	2.5				2	-0.013	-0.003	+0.021	
		54		4.802	0				2	-0-	-0-	+0.003	
				$154.802									E.C = 0.021
													MN DIST = 154.8355
													RC = 1.7300

DA FORM 1 JAN 74 4196 (Blue)

Figure 6-11. **Recording horizontal, taped distances**

Field Sheet, Infrared
For use of this form, see FM 5-232; the proponent agency is TRADOC.

PROJECT	WEST RANGE ARTY 3.79						
ORGANIZATION	99th ENGR CO.		DATE	16 MAR 89	APPROX DISTANCE	1500 m	
ZERO CORRECTION *	−0.004	CALIBRATION DATE 7MAR 89	OBSERVER	SPC WILSON	RECORDER	PFC WHITE	
INSTRUMENT STATION	ELKHORN (99th ENGR) 89	H.I. 1.54M	ELEVATION	ELEVATION INSTRUMENT	ECCENTRICITY * TOWARD / AWAY 0.000M	INST NO 1268	
REFLECTOR STATION	BULLRUSH (99th ENGR) 89	H.I. 1.60M	ELEVATION	ELEVATION REFLECTOR	ECCENTRICITY * TOWARD / AWAY 0.000M	PRISM NO R-1268	

METEOROLOGICAL READINGS

	TIME	PRESSURE (Hg)	TEMP. (DRY)
		~~IN~~ mm	°C
INSTRUMENT	0819	762	16
REFLECTOR	0817	761	
SUM		1523	
MEAN		762	16
CORRECTION FACTOR (PPM)		+5	

PRODUCT = UD × PPM
RC = PRODUCT × 10^{-6}
T = UD ± Z ± RC
H′ = $(T)^2 - (d)^2$
H′ = SIN ZD × T
H_{FT} = H′ × 3.280840

ZD INSTRUMENT TO REFLECTOR

DISTANCE (meters)

1	1527	308
2	1527	306
3	1527	311
4	1527	306
5	1527	306
6	1527	307
7	1527	304
8	1527	310
9	1527	310
10	1527	307
SUM	15273	075

UD	1527.308	MEAN UNCORRECTED SLOPE DISTANCE (UD)	157.7	308
PPM	+5	ZERO CORRECTION° (Z)	0	004
PRODUCT	7636.540	REFRACTIVE INDEX CORRECTION (RC)	0	008
RC	+ 0.008	CORRECTED SLOPE DISTANCE (T)	1527	312
DIFF. OF ELEV. (d)		UNCORRECTED HORIZON. DISTANCE (H′)		
		ECCENTRIC CORRECTION * (EC)		
		HORIZON DISTANCE (H_M) / (H_{FT})		

° Obtained from Instrument Calibration.
* Toward Eccentricity must be ADDED.
Away Eccentricity must be SUBTRACTED.

REMARKS

COMPUTED BY	DATE	CHECKED BY	DATE	PAGE OF

Sample

Figure 6-12. **Recording procedures for electronically measured distance (infrared)**

Three-Wire Leveling

For use of this form, use FM 5-232; the proponent agency is TRADOC.

Project	Location	Organization
99/US/324/5/89	FT BELVOIR, VA	99th ENG (TOPO)

Observer	Recorder	Instrument	Sun	Wind	Weather
SGT J DOE	SPC W. ROE	WILD N-3 #1268	CLEAR	CALM	WARM

From	To	Date	Time	Line or Net	Page no.	No. of pgs.
RM 5-1	TBMS-1	25 Apr 89	0900	MAINLINE, NET "S1"	42	79

Station	Backsight Face of rod (+)	Mean (+)	Back of rod	Interval	Sum of intervals	Foresight Face of rod (−)	Mean (−)	Back of rod	Interval	Sum of intervals	Remarks
RM 5-1	1.292					3.031					
	1.019	1.0193		273		2.750	2.7503		281		
	0.747			272	545	2.470			280	561	
	3.058					8.251					
	0.715					2.779					
	0.487	0.4873		231		2.556	2.5563		223		
	0.257			230	461	2.334			222	445	
	4.520	1.5066			1006	15.920	5.3066			1006	
	3.001					0.955					
	2.692	2.6917		309		0.619	0.6193		336		
	2.382			310	619	0.284			335	1671	
	12.595	4.1983			1625	[illegible]	5.9259			1677	
	2.896					[illegible]					
	2.536	2.5360		360		1.502	1.5020		368		
	2.176			360	720	1.134			368	736	
	20.203	6.7343			2345	22.284	7.4279			2413	
	2.977					0.861					
	2.612	2.6117		365		0.530	0.5300		331		
	2.246			366	731	0.199			331	662	
	28.038	9.3460			3076	-23.874	7.9579			3075	TBMS-1
						+28.038	9.3460			3076	
						+ 4.164	+1.3881			15.1	
						+1.3880					

INST OP INT [signature]

1st COMP INT _____

2nd COMP INT _____

DA Form 5820-R, AUG 89

Figure 6-13. **Recording procedures for three-wire leveling**

sample

requirements on page 6-1, the names of the rodmen (and umbrellaman, when applicable) will be recorded.

Determining and recording mean centerwire reading to four decimal places –

- If the top interval is LARGER than the bottom, ADD the correction to the recorded centerwire reading to obtain the mean centerwire value to four decimal places.
- If the top interval is SMALLER than the bottom, SUBTRACT the correction from the recorded centerwire reading to obtain the mean centerwire value to four decimal places.

Maximum permissible
interval imbalance = 3 (third-order)

Difference in Intervals	Centerwire Correction
0.000	0.0000
0.001	0.0003
0.002	0.0007
0.003	0.0010

Maximum permissible
interval imbalance = 2 (second-order)

Difference in Intervals	Centerwire Correction
0.000	0.0000
0.001	0.0005
0.002	0.0010

DETERMINATION OF C FACTOR

Each day, just before differential leveling begins or immediately following any instance when the instrument is subjected to unusual shock, the error of the level (C factor) must be determined. The determination of C may be performed as a part of a leveling line or separately. In all cases, the C factor determination recordings must be separate from other recordings and comply with all requirements for note keeping.

It is desirable to determine the C factor under the same conditions that the leveling will be performed, including length of sight, slope of ground, and elevation of the line of sight above the ground.

If C is determined during the first setup of the leveling, perform the following sequence of events:

1. After the regular foresight observations are recorded for the level line, record the foresight readings on the C factor note sheet.
2. Call up the rear rodman to approximately 10 meters behind the level.
3. Observe and record the rear rod readings on the C factor note sheet,
4. Move the level to approximately 10 meters behind the front rod.
5. Read and record the front rod on the C factor note sheet.
6. Read and record the rear rod on the C factor note sheet.

Ensure that the circular bubble is carefully centered and that the observed ends of the bubble in the tubular level vial are in coincidence (when applicable) prior to reading the three wires.

The C factor is determined using the formula:

$$C = \frac{(\text{sum of near rod mean readings}) - (\text{sum of corrected far rod mean readings})}{(\text{sum of far rod intervals}) - (\text{sum of near rod intervals})}$$

The total correction for curvature and refraction (Table 6-2) must be determined for each far rod reading, using the distance from the instrument to the far rod as the argument. Distances equal the product of the sum-of-the intervals (for a single set of three-wire readings) times the stadia interval factor (SIF). The two corrections for curvature and refraction are algebraically added to the sum of the mean wire readings for the distant rod. The maximum permissible C factor varies with the SIF. Instruments with an SIF of 1:100 may not have a C factor of greater than ± 0.004. Instruments with a SIF of 1:200 may not have a C factor of greater than ± 0,007. Instruments with a SIF of 1:333 may not have a C factor of greater than ± 0.010. If the C factor is determined to be greater than what is permitted for the instrument's SIF, the instrument must be adjusted and the C factor redetermined before performing differential leveling operations. The notes for the C factor determination become a part of the administrative notes for the leveling operation (Figure 6-14, page 6-23).

CENTERWIRE ADJUSTMENT

If the C factor exceeds the limits (as established by the SIF), a correction to the centerwire must be made.

The correction to the centerwire is determined by multiplying the total rod interval of the last foresight (distant rod) by the computed C factor. Compute the correction to three places to the right of the decimal point and include the algebraic sign of the C factor.

The correction to the centerwire is algebraically added to the last foresight mean wire reading. The result will be the corrected centerwire reading, Compute the corrected centerwire reading to three places to the right of the decimal point (Figure 6-14).

Following the manufacturer's manual, adjust the level until the corrected centerwire reading is observed on the distant rod. Perform the C factor

determination again to ensure that the new C factor is within the acceptable limits.

DETERMINATION OF STADIA INTERVAL FACTOR

The SIF is required to compute the length (horizontal distance) from the stadia intervals and to determine the maximum allowable error for a level line. The SIF must be determined if the reticle (which contains the etched stadia wires) is replaced or changed in the level. The notes from the SIF determination become a permanent part of the records kept with the level, as well as being kept with the project files (Figure 6-15, page 6-24).

The SIF determination is made by comparing the stadia intervals observed over a course of known distances. Lay out the course on a reasonably level track, roadway, or sidewalk. Place nails or other marks in a straight line of measured distances of 0, 25, 35, 45, 55, 65, and 75 meters. Plumb the optical zero point of the level over the zero marker on the ground and level the instrument. The optical zero point of the level will be found in the manufacturer's manual. Read the rod at each of the six points and record the intervals. Compute the half-wire intervals as a check against erroneous readings. Compute the sum of the total intervals for the six readings. The SIF will be the sum of the measured distances (300 meters) divided by the sum of the six total intervals.

To check for errors, compute the SIF for each of the six readings and divide the measured distance by the total interval observed for that distance. The average of the six computations will serve as a numerical check. A tendency for the six computed values to creep in one direction indicates an error in plumbing the optical zero point of the level over the zero point on the ground.

Table 6-2. **Correction for curvature and refraction (leveling)**

This table of total correction for curvature and refraction is for use in computing "C" and in general wherever the total correction is required. In computing this table, the refraction was assumed to equal one-eighth the curvature.

Distance (meters)	Correction to rod (mm)	Distance (meters)	Correction to rod (mm)	Distance (meters)	Correction to rod (mm)
0 to 27	0.0	125 to 130	–1.1	210	–3.0
28 to 47	–0.1	131 to 136	–1.2	220	–3.3
48 to 60	–0.2	137 to 141	–1.3	230	–3.7
61 to 72	–0.3	142 to 146	–1.4	240	–4.0
73 to 81	–0.4	147 to 150	–1.5	250	–4.3
82 to 90	–0.5	160	–1.8	260	–4.7
91 to 98	–0.6	170	–2.1	270	–5.0
99 to 105	–0.7	180	–2.3	280	–5.4
106 to 112	–0.8	190	–2.6	290	–5.8
113 to 118	–0.9	200	–2.8	300	–6.2
119 to 124	–1.0				

Three-Wire Leveling

For use of this form, use FM 5-232; the proponent agency is TRADOC.

Project	Location	Organization
99/FLW/7802	FLW MISSOURI	99th Engr Det

Observer	Recorder	Instrument	Sun	Wind	Weather
SFC J. DOE	SPC W. ROE	WILD N3 #96866	CLEAR	CALM	COOL

From	To	Date	Time	Line or Net	Page no.	No. of pgs.
		13 FEB 78	0830	"C" CHECK		

Station	Backsight Face of rod	Mean	Back of rod	Interval	Sum of intervals	Foresight Face of rod	Mean	Back of rod	Interval	Sum of intervals	Remarks
	1.568					2.169					STADIA
A.	1.508	1.5080		60		1.837	1.8370		332		CONSTANT=
	1.448			60		1.505			332		0.100
	4524				120	5511		Ref.=	-0.3	664	
	1.636					1.606					
B.	1.587	1.5870		49		1.263	1.2630		343		
	1.538			49	98	0.920			343	686	
	9285	30950			218	9300	31000	Ref.=	-0.3	1350	
							-0.6	Tot Ref		-218	
							30994			1132	
							-30950				
							4.4	÷ 1132 =	.0039	= C	
											ROD # 100A
											ROD # 100B

INST OP INT J. D.

1st COMP INT _____

2nd COMP INT _____

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Figure 6-14. **Determination of C factor and centerwire adjustment**

Three-Wire Leveling

For use of this form, use FM 5-232; the proponent agency is TRADOC.

DESIGNATION 51F DATE 25 APR 19 76

☒ SP5 S. DOE WILD N-3 #1268
☐ SP4 W. ROE CLEAR, CALM, WARM

STATION		ROD READING		INTERVAL	SUM OF INTERVALS
		1355			
25		1230		125	
		1106		125	250
		1425			
35		1250		175	
		1075		175	350
					600
		1486			
45		1260		226	
		1034		226	452
					1052
		1505			
55		1230		275	
		0955		275	550
					1602
		1545			
65		1270		325	
		0945		325	650
					2252
		1675			
75		1300		375	
		0926		374	749
300 =	TOTAL				3001

	CHECK		REMARK
	25/250	= 0.100	
	35/350	= 0.100	
	45/452	= 0.100	
	55/550	= 0.100	
	65/650	= 0.100	
	75/749	= 0.100	
	300/3001	= 0.100	
	SUM 0.600	÷ 6 = 0.100	
	CHECK		

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Figure 6-15. **Determination of stadia interval factor**