

NOAA Manual NOS NGS 4



Geodetic Operations

National Geodetic Survey
Rockville, Maryland
April 1984



U.S. DEPARTMENT OF COMMERCE
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National Geodetic Survey

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U .S. DEPARTMENT OF COMMERCE

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Preface

The purpose of this manual is to provide personnel of the National Geodetic Survey (NGS) with guidance and instructions for geodetic field operations. This material supersedes the action and information memoranda formerly provided to field personnel, and supplements information in other NGS publications that is sketchy or obsolete.

The text is divided into two parts: Part 1 contains information on field party management. Part 2 provides details on specific surveying operations.

To maintain an up-to-date manual, recommendations for proposed changes or suggestions are solicited from the users. Please send your comments to the Chief, NGS Operations Branch, N/CG16.

Acknowledgment

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NOAA Manual NOS NGS 4

GEODETIC OPERATIONS

ABSTRACT: This manual furnishes guidance and instructions for geodetic field operations performed by the National Geodetic Survey. It presents general specifications and detailed information on (1) geodetic field management, (2) monumentation and mark maintenance, (3) horizontal control, (4) vertical control, (5) satellite geodesy, (6) astronomic surveys, (7) gravity surveys, and (8) establishment of calibration base lines.

PART 1

General Party Management



1.1 MANUALS AND HANDBOOKS

Many publications contain information applicable to geodetic field operations. Table 1.1-1 lists the documents that are to be at the disposal of field personnel. Geodetic advisors and mark maintenance personnel should have copies of all the publications listed. A source of supply is given for each publication. To requisition publications from the NOAA Logistics Supply Center (NLSC) in Kansas City, Missouri, use NOAA Forms 37-4, Stores Requisition, and 37-4A, Continuation Sheet. Information on publications not listed below can be obtained by contacting N/CG17x2. Geodetic advisors and mark maintenance personnel should have copies of all the publications listed.

Table 1.1-1—Reference materials used by NGS Operations Branch

Title	Party Application	Source	Title	Party Application	Source
NOAA Directives Manual (NDM)	All	NLSC	The State Plane Coordinate Systems, C&GS		
NOAA Forms Catalog	All	NLSC	Special Publication 235, revised		
NOAA Travel Handbook	All	NLSC	June 1974	Horizontal	N/CG17x2
NOAA Finance Handbook	All	NLSC	Horizontal Control, NOAA Technical		
NOAA Cashier's Handbook	All	NLSC	Report NOS 8 NGS 19 (1980)	Horizontal	N/CG17x2
NOAA Safety Handbook	All	NLSC	Fundamentals of the State Plane		
NOAA Personnel Handbook	All	NLSC	Coordinate Systems, 1974	Horizontal	N/CG17x2
NOAA Small Purchase Guide	All	NLSC	Understanding the State Plane Coordinate		
NOAA Timekeeper's Handbook	All	NLSC	Systems, 1977	Horizontal	N/CG17x2
FTS Telephone User's Guide	All	N/CG16	Bilby Steel Tower for Triangulation,		
NOAA Organization Directory	All	NLSC	C&GS Publication 62-3, 1929	Horizontal	N/CG17x2
NOAA Address Handbook	All	NLSC	Manual of Reconnaissance for Triangulation,		
Definitions of Terms Used in, Geodetic and			C&GS Special Publication 225, 1941	Horizontal	N/CG17x2
Other Surveys, C&GS Special Publication			Specifications for Horizontal Control Marks,		
242, 1948	All	N/CG17x2	ESSA Technical Memorandum C&GS		
Classification, Standards of Accuracy, and			TM-4, 1968	Horizontal	N/CG17x2
General Specifications of Geodetic Control			Geodetic Leveling, NOAA Manual NOS		
Surveys, 1974	All	N/CG17x2	NGS 3, 1981	Vertical	N/CG17x2
Specifications to Support Classification,			Manual of Leveling Computation and		
Standards of Accuracy, and General			Adjustment, C&GS Special Publication		
Specifications of Geodetic Control			240, 1948	Vertical	N/CG17x2
Surveys, Federal Geodetic Control			Observing and Automatic Recording		
Committee, Revised June 1980	All	N/CG17x2	Procedures for Leveling	Vertical	N/CG13
National Geodetic Survey Data: Availability,			Input Formats and Specifications of the		
Explanation, and Application, NOAA			National Geodetic Survey Data Base,		
Technical Memorandum NOS NGS-5,			Volume II, Federal Geodetic Control		
1979	All	N/CG17x2	Committee, 1980	Vertical	N/CG17x2
NGS Reference Library Bibliography	All	N/CG17x2	Geodetic Bench Marks, NOAA Manual		
Inventory Handbook for the NGS	All	N/CG161	NOS NGS 1, 1978	Vertical	N/CG17x2
Publications of the National Geodetic			Control Leveling, NOAA Technical Report		
Survey, current date	All	N/CG17x2	NOS 73 NGS 8, 1978	Vertical	N/CG17x2
Superwylbur Text Editing Manual	All	N/CG164	The Zeiss Apparatus for Crossing Water		
	w/terminals		Spans in Precise Leveling, U.S. Lake		
Superwylbur Workbook: Six Sessions			Survey Misc. Paper 69-6, 1969	Vertical	N/CG17x2
on Superwylbur	All	N/CG164	Manual of Geodetic Astronomy, C&GS		
	w/terminals		Special Publication 237, rev. 1952	Astronomic	N/CG17x2
Manual of Geodetic Triangulation, C&GS			Apparent Place of Fundamental Stars	Astronomic	N/CG142
Special Publication 247, Revised 1959	Horizontal	N/CG17x2	Astronomical Almanac, U.S. Naval		
Manual of Triangulation Computations,			Observatory, current date	Astronomic	N/CG142
C&GS Special Publication 138, 1928	Horizontal	N/CG17x2	Input Formats and Specifications of		
the National Geodetic Survey Data Base,			the National Geodetic Survey Data Base,		
Volume I, Federal Geodetic Control			Volume III, 1983	Gravity	N/CG17x2
Committee 1980	Horizontal	N/CG17x2	Establishment of Calibration Base Lines,		
			NOAA Technical Memorandum NOS	Base Line	
			NGS-8, 1982	Horizontal	N/CG17x2

<i>Title</i>	<i>Party Application</i>	<i>Source</i>
Use of Calibration Base Lines, <i>NOAA</i> <i>Technical Memorandum</i> NOS NGS-10,	Base Line	
rev. 1980	Horizontal	N/CG17x2
The Preservation of Triangulation Stations	Mark Maint.	N/CG17x2

<i>Title</i>	<i>Party Application</i>	<i>Source</i>
Coastal Mapping Handbook	Mark Maint.	N/CG17x2
NGS Doppler Operations Manual	Doppler	N/CG14
Field Operations Manual Doppler Geodetic Positioning, <i>DMA Technical Memorandum</i> T-2-52220	Doppler	N/CG14

1.2 PROJECT DIRECTOR'S RESPONSIBILITIES

Traditionally, the head of each NGS field party was titled "Chief of Party." The person who was formerly chief of a NGS horizontal or vertical control party is now called "Project Director" because he or she has more responsibilities than a "Chief of Party" in other areas of the Federal Government. These additional responsibilities include contract field work, subparty operation, and cooperative work with States and other Federal agencies.

The heads of all other field parties are still called "Chief of Party." The term "Chief of Party," as used throughout this chapter, is meant to include both Project Director and Chief of Party. This chapter supersedes all previous instructions regarding responsibilities and duties of the Chief of Party.

1.2.1 General

The Chief of Party is responsible for the efficient and economic operation of the party while carrying out instructions issued by NGS Headquarters. The Chief sees that the party is governed in accordance with all applicable regulations, that the technical specifications for the surveys are rigidly adhered to, that expenditures are properly executed and reported, that records of personnel and property management are maintained, and that Government property is protected from loss or damage.

The Chief of Party is fully responsible for the entire project and must correct any omissions or poor practices, regardless of the person assigned primary responsibility.

1.2.2 Specific Duties

Some specific duties and responsibilities of the Chief of Party follow:

1. The Chief of Party is responsible for the efficient disposition of personnel and scheduling of operations to accomplish the field work, process the data, and report the results to Headquarters in a timely manner.

2. The Chief will make a field inspection of each unit of the party at least once per month. This will include an inspection of mark setting and, where concrete marks are used, the Chief will periodically (at least every 6 months) expose the side of a mark. The Chief will report on these inspections in the Monthly Report and Journal.

3. During each project, the Chief of Party will periodically examine field records before they are transmitted to Headquarters. On horizontal and vertical control parties, this record examination will include, at the very least, a complete inspection of 2 days' work for each theodolite, level, or EDM observer. The data inspected will be noted in the project report.

4. In the absence of rated recorders, observers, and computers, the Chief of Party will provide training for a sufficient number of personnel to perform these functions. The Chief will completely review the records of new recorders,

observers, and computers for the first several days they perform these functions and at frequent intervals thereafter.

5. On horizontal control parties, the Chief of Party will assure that technical specifications are adhered to, especially those for check angles, triangle closures, and side and length checks. The Chief of Party will assure that stations are established in towns with a population of 2,000 or more, at or within 1 mile of airports, along principal highways or coastal areas (4-5 mile spacing), and at colleges and universities. The Chief of Party will assure that the "20-percent" rule is rigorously followed. The position of all VOR's, VORTAC's, and other aeronautical aids to navigation is to be established. Near navigable waters, the position of all fixed aids to navigation and landmarks that are shown on the largest scale nautical charts will be determined. And finally, where feasible, the horizontal position of vertical control marks in the vicinity of occupied stations will be determined.

6. On vertical control parties, the Chief of Party will assure that technical specifications have been met, especially those for section, line, and loop misclosures. The Chief of Party will assure that the proper type, number, and spacing of bench marks are established. The Chief of Party will assure that bench marks are established as required at airports and at designated tide gages and water level gages. Also, where feasible, horizontal control points along the level line will be connected to the National Geodetic Vertical Network.

7. The Chief of Party is responsible for maintaining a safety program. The Chief will correct any unsafe practice or condition involving personnel, vehicles, and equipment and arrange periodic meetings with personnel to discuss safety procedures and precautions. Safety meetings will be noted in the Monthly Report and Journal. Accidents will be carefully reviewed, and appropriate disciplinary action taken if negligence on the part of an employee contributed to the accident.

8. The Chief will periodically evaluate Government equipment on the party to assure that proper maintenance and repair work are performed, report excess property, and dispose of obsolete and surplus equipment.

9. The Chief of Party will maintain good relations with the public. When and where appropriate, the mission, products, and services of NGS will be discussed with property owners and with State and local officials.

10. The Chief of Party will develop an emergency plan for tornadoes, floods, etc. This plan need not be highly formalized; its purpose is to provide guidance to employees and dependents in case of disaster. Party Chiefs are authorized to construct emergency tornado shelters when no other convenient shelter is available. Anchors and tie-down cables may also be purchased so that individual and

Government trailers can be secured when deemed appropriate.

11. The Chief of Party shall actively attempt to recruit minority employees. The locations of contacts for assistance in this recruiting are listed in the Directory for Reaching Minority Groups, available at the parties. This activity will be reported in the Monthly Report and Journal.

12. The Chief of Party will designate an employee of the party to assume this position in the Chief's absence. Normally, the party computer will serve as the Acting Chief. When this occurs, the Operations Branch is to be notified in writing.

1.3 EMERGENCIES AND SAFETY

1.3.1 National Emergencies

National emergencies are those which jeopardize the security of the Nation. Instructions concerning procedures to be used during national emergencies are contained in the *NOAA Directives Manual* (NDM) 65-52, *NOS Operations Manual* 65-51, and the NOS Contingency Plan for Emergency Operations. The latter is for official use only and hence is of limited distribution.

In the event an enemy attack on the Nation has actually been detected, the public will be alerted by radio and television broadcasts and by the Attack Warning Signal (a 3- to 5-minute wavering tone on sirens) or short blasts on horns or other devices. The signal is repeated as deemed necessary to obtain the necessary response by the population. All field personnel should follow the instructions given in the NOS Contingency Plan for Emergency Operations, appendix G, reproduced below.

NOS Contingency Plan for Emergency Operations Appendix G

GENERAL PERSONNEL INSTRUCTIONS

PURPOSE

This document contains information and instructions on the NOAA Emergency Readiness Program for all personnel. It is included in the NOAA Contingency Plan for Emergency Operations as appendix H and in the NOS Contingency Plan for Emergency Operations as appendix G. It has been prepared in a format for separate printing and distribution to each NOS employee.

NATIONAL POLICY AND CONCEPT OF EMERGENCY PLANNING

The general concept is that each department or agency of the Federal Government will plan for emergency operations from three pre-selected alternate sites to maintain continuous critical functions. Each alternate site will be staffed by a small cadre of key personnel who will also serve as a nucleus for reconstitution of normal government functions when hostilities cease. Three Executive Teams, Alpha, Bravo, and Charlie, have been designated for that purpose. Special instructions for NOS personnel assigned to the Executive Teams are contained in the NOAA Contingency Plan for Emergency Operations. Each team member has been furnished a copy of the plan. NOS personnel not on a cadre have no specific emergency assignment other than to respond to instructions from Federal and local authorities. This applies to all NGS field personnel.

ATTACK WARNING RESPONSE—DUTY HOURS

NOAA Directives Manual 65-70 establishes the requirements for a "Facility Self-Protection Plan" for each NOAA building. Each Facility Self-Protection Plan should contain detailed instructions for immediate personal actions to protect life and property in the event of enemy attack during normal duty hours. Under such conditions, instructions concerning evacuation, mobilization, etc., will be issued by appropriate NOAA officials based on the dictates of the local situation and directives or guidance from higher authorities.

ATTACK WARNING RESPONSE—NONDUTY HOURS

In the event of an enemy attack during off-duty hours, or when in a travel status, NOS personnel who are not designated members of either Team A, B, or C should follow the local government plan for emergency action and instructions issued by National Command or Civil Defense Authorities. Specific instructions for any set of circumstances cannot be presented. Each individual is responsible for taking actions according to his or her best judgment. The following are general guidelines.

During Attack Warning Condition:

- Take shelter immediately and do not leave until it is safe or you are instructed to do so.
- Do not use the telephone. Rely on radio and television broadcasts by stations of the Emergency Broadcast System (EBS) for information and instructions.
- Take all possible action to conserve emergency supplies and maintain health and sanitation.
- Do not attempt evacuation of your area unless instructed to do so by appropriate authority.

Termination of Attack or Hostilities:

- When it is safe to leave your shelter, report your status to appropriate authorities. (See section 1.3.1.1). Follow instructions and guidance broadcast by the EBS in doing so.
- In the absence of any special instructions, report to your normal duty station by telephone or in person.
- If in travel status, report to the nearest Department of Commerce Field Office. The nearest office can be determined by consulting a local telephone directory under the heading "U.S. Government—Commerce."
- If unable to comply with any of the above, complete and mail CSC Form 600 and U.S. Postal Service Forms 809 and 810, which are available at any post office.

SELF-PROTECTION EFFORTS

A nationwide civil defense system now exists in the United States, which is constantly being enlarged and improved. The system offers much assistance designed to save lives through warnings and protective shelters and through emergency lifesaving and recovery capabilities. The effectiveness of the system is dependent in large part on individual initiative. It is incumbent on each person to learn the basic "what," "when," and "how" of personal civil defense actions. Additional information is contained in "In Time of Emergency," a citizen's handbook on nuclear attack and natural disasters, published by the Defense Civil Preparedness Agency, A-14, March 1968. The document is available from the Civil Defense Office in the county or state where you live.

1.3.1.1 NGS Contingency Plan

In case of a national emergency, and upon termination of attack or hostilities, field personnel should notify NGS Headquarters of their location and receive instructions. Notify, in order of importance, one of the following offices:

1. The Chief, National Geodetic Survey,
2. The director of the nearest NOAA Marine Center,
3. The nearest U.S. Department of Commerce office listed in the local telephone directory,
4. The nearest State or local police.

Field personnel who cannot contact the Chief, NGS, should ask the office to which they reported to relay their location and condition to the Chief, NGS.

1.3.2 Natural Disasters

For the purpose of these instructions, a "natural disaster" means any hurricane, tornado, storm, flood, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, drought, fire, explosion, or other catastrophe requiring efforts to save lives, to protect property, public health, and safety, or to avert or lessen the threat of a disaster.

The first line of defense against tragic events of this type should always be measures taken well in advance of an actual incident. Upon relocating, Project Directors and Chiefs of Parties should tap the knowledge of local citizens and authorities to determine what natural phenomena might be peculiar to the area. For example, high winds of brief duration, called "Chinooks," sometimes sweep down the eastern slope of the Rocky Mountains. This may not be known by a new arrival, but a check with the local population would bring it to light. Field personnel should be briefed by the Project Director or Chief of Party on specific measures that should be taken to ensure the safety of themselves and their dependents and to protect personal and Government property. If appropriate, an emergency plan should be developed.

Although a choice is often not available, there are precautions to consider when locating party headquarters. Is there a public shelter located nearby? Is the location under

consideration situated in a flood plain? Is a coastal area subject to inundation in the event of a hurricane? Have personal and Government trailers been provided with anchors and tie-down cables? (These can be purchased at Government expense.) Precautions of this nature should be taken in view of the geographic locality and the season of year.

Upon notification of a disaster "warning" from news media, or the actual occurrence of a disaster, all personnel should take immediate action first to protect themselves and their dependents and then, if possible, to protect Government property. A "warning" means that disaster is imminent. Move to a public shelter or safe ground if time permits. If there is no time, seek the best protection available. Mobile homes and trailers provide poor defense against high winds; permanent structures are safer. During a tornado, if no shelter is available, get into the lowest spot around, a shallow ditch if nothing else. Take protection from flying objects. In a hurricane, storm surge is the major concern. Get out of low-lying areas before a hurricane strikes; then take protection from the high winds.

After providing for their own safety and that of other party members and dependents, Project Directors and Party Chiefs are to consider volunteering party assistance to local authorities where they can contribute to the public health and safety or to the restoration of critical public services. These will include:

1. Search, rescue, and evacuation to save lives, prevent injury, and relieve suffering.
2. First aid and other emergency medical care; provision of water shelter, and food; and public safety measures, including protection of property.
3. Emergency restoration of primary utilities, such as power, water, telecommunications, and sanitation.
4. Provision of emergency transportation.

The use of Government property, such as vehicles, radios, and other tools and equipment, is authorized for such volunteer assistance. This assistance may be provided at any time, including on-duty hours.

Chiefs of Parties, Project Directors, and mark maintenance personnel are to contact the Operations Branch as soon as possible in the event of a natural disaster. Normally this would be after the event occurred, but with sufficient warning it could also be before. Headquarters should be kept informed of the nature and extent of the disaster. The information can be obtained from firsthand observation, the news media, local authorities, and others. With this information, Headquarters might issue instructions for technical operations to be carried out in support of the NGS mission following disaster situations.

1.3.3 Safety

Guidelines pertaining to safety in field operations are contained in the following sections of the *NDM* (chapter 64):

- 01—NOAA Safety Management Program
- 04—Potential Hazards

- 10—Safety Management—The Supervisor's Responsibility
- 11—Loss Control Through Safety Management
- 13—Protective Equipment and Clothing
- 19—Installation and Use of Employee-Owned Hot Plates, Coffee Makers, and Electrical Equipment
- 27—Hearing Conservation Program
- 37—Portable Space Heaters

Guidelines are also contained in the *NOAA Safety Handbook* (chapters 3, 4, 5, 6, and 11). All field personnel should be familiar with these guidelines. In addition, local chapters of the American Red Cross often offer free courses on the administration of first aid. Employees are encouraged to take these courses.

1.3.3.1 Personal Safety

This section contains a few elements of personal safety that particularly pertain to the type of work performed by NGS field personnel.

1. **Back Injury.** Back problems are quite common among people who are physically active in their jobs. Many back problems result from poor habits employed while lifting and are easily avoided by correcting those habits. The proper way to lift objects is with the legs, not the back. Although this is a well-known fact, it is often not practiced. Back injuries not only cost the Government lost time and medical expenses, they cause great discomfort and inconvenience to the individual. Develop a habit of lifting things properly, and do not lift objects that are too heavy to handle.

2. **Eye Injury.** Accidents causing damage to the eyes can happen very easily and quickly. Considering the personal tragedy caused by the loss of sight in one or both eyes, precautions against such accidents are well worthwhile. **EYE INJURY CAN HAPPEN TO YOU.** Particles such as the following can get lodged in the eye:

- a. wind-blown sand and grit
- b. debris falling from masts or observing towers
- c. fragments flung from cutting tools such as grinders, drills, and saws
- d. chips thrown from impact tools such as hammers, chisels, and Cobras

Safety goggles or glasses are to be worn whenever the situation warrants, and it takes judgment to decide when to do so. Obviously, an eye injury could occur under almost any circumstance, but that does not mean that one should always wear eye protection. Where good peripheral vision is needed, when building towers for example, use of safety goggles might actually be inadvisable. Supervisors must exercise good judgment when instructing subordinates to wear eye protection. Employees must always wear protection in the following instances:

- 1. while using rotary shop or hand tools,
- 2. while drilling holes in concrete or rock for survey disks, and
- 3. while driving rod for survey markers.

People who wear glasses would be well advised to purchase glasses with safety lenses for routine use on the job.

Light emitted from arc welders is very harmful to the eyes. NEVER look directly at an arc welder in operation unless you are wearing properly shaded eye protection. To many people, this is second nature, but there are those who are unaware of the danger. Be quick to point it out to anyone who does not appear to know.

Radiation can cause serious damage to the eyes. *NOAA Safety Handbook*, Chapter 11, Laser Geodimeter Safety Standards, contains information relevant to NGS's use of lasers. Two sections of this chapter require updating: In section 1, the Model 8 Geodimeter is not mentioned, but regulations pertaining to the Model 4L Geodimeter also apply to the Model 8. In section 3, the frequency of eye examinations can be reduced to 18 months.

3. **Loss of Fingers.** Loss of one or more fingers can and does happen very suddenly. Exercise great care when working with or around power tools and machinery. Extremities can be cut off, pulled off, or smashed. Do not wear gloves when working around rapidly moving parts. Examples of such equipment include electric saws, rotating equipment that can grab a glove and pull your head into the grindstones, lathes, engines, and electric motors. Exercise caution when working around any machinery capable of smashing your fingers, hands, or feet. This applies especially to mark setters working around drilling rigs. Be constantly aware of where your appendages are. Think ahead about possible accidents that can occur. If an accident occurs where an extremity is dismembered, bring the severed appendage, in a cool 1-percent salt water solution if possible, with the victim to the hospital. Sometimes it can be reattached.

4. **Unsafe Clothing and Accessories.** Loose clothing such as unbuttoned shirts or shirt sleeves, neck ties, and in some cases, gloves, should never be worn around moving machinery or tools. These can get caught in the moving parts of the machinery and pull the operator into it.

Similarly, rings, chains worn about the neck, and similar ornaments should be removed before working around any type of apparatus that can catch them. Though it would not seem likely, jewelry, including rings, can easily get caught on equipment that does not even have moving parts.

5. **Protective Clothing.** Brightly colored vests should always be worn when working near traffic. Level observing units operate under these conditions continuously, but others too are exposed to the hazards of moving vehicles. When vests become faded they should be replaced.

Hardhats can be lifesavers. They must always be worn by personnel on tower building and teardown parties. They must also be worn by mark setters when operating a drill rig or gasoline powered hammer (e.g., Cobra). All field personnel should have hardhats available for their use when the situation warrants.

Steel-toed boots are essential for mark setters who operate drill rigs. The hydraulic power generated by the rigs is tremendous. A foot caught between the end of an auger, which is being lowered, and the ground would be easily crushed. Many of the tools and accessories are quite heavy

and could break bones if dropped on someone's foot. Steel-toed boots should be worn also by people handling steel for horizontal observing towers.

Leather gloves offer excellent protection to the hands of those working with metal or wood with sharp edges or slivers. Wounds from these hazards can be serious. Wearing gloves is well worthwhile, if only for protection against the pain of minor slivers, cuts, and bruises.

Gloves should not be worn when there is a chance they could be caught in moving tools or machinery. In those cases they present a more serious threat of loss of fingers or a hand than the protection they offer against slivers or cuts. Use your judgment. If gloves are worn around drill rigs, the gauntlets should always be removed, because they can easily get caught between the flights of a rotating auger.

6. Poison Ivy and Oak. For many people, dermatitis caused by exposure to poison ivy or poison oak is a miserable experience. Sensitivity to these plants varies with individuals, ranging from none to extreme. Most people will experience at least a mild reaction. Some may be so sensitive that they may become ill.

The first line of defense against such dermatitis is to know the facts about poison ivy and oak. A thin oil found on the leaves and roots of the plants causes an allergic reaction when it contacts the skin. The more oil contacted and the longer the period of contact, the worse the reaction will be. Contact can be made directly with the leaves or roots, or indirectly by touching something else where the oil has been spread. This could be clothing or another person, or even smoke from burning plants. Contact with the oil is the only way of contracting the allergy.

Poison ivy and oak are not contagious; touching another infected person will have no effect unless that person still has some oil on the skin. Poison ivy is a climbing plant with slightly shiny leaves in groups of threes. When blooming, its flowers are pale green. It has greenish-white berries. Poison oak is much the same only its leaves have the familiar shape of a white oak leaf. Remember: "Leaves of three, let it be."

After knowing the facts about poison ivy and poison oak, the precautions to take become common sense. First, learn to recognize the plants and then avoid them. The sketchy description above is not enough. Have someone point the real thing out to you. Second, if working near poison ivy or oak is unavoidable, leave as little of the body exposed as possible. Wear high boots, long trousers held tightly around the ankles, long sleeve shirts buttoned tightly around the wrists, gloves, and appropriate headwear. It is also a good idea to carry extra clothing to change into after exposure. Third, carry extra cans of water for copious flushing of the skin after contact with the plants. Shower thoroughly as soon as possible afterward. And finally, wash all clothing that might have oil on it; then wash your hands again.

Immunization to poison ivy and oak has had varying degrees of success. A preventative may do wonders for one person and have adverse effects on another. It is the opinion of some authorities that oral preventatives are the preferred

method of desensitization. The bottom line is to use whatever works for you if you are so inclined.

For the unfortunate person who has contracted poison ivy or oak, there is no known remedy. The dermatitis will just have to run its course. Calamine lotion or similar products may help relieve the itching. Again, the effectiveness of such products will vary from person to person. Consult a doctor if the condition persists or becomes unbearable. It is important to resist scratching. Scratching can cause other areas of the body to become sensitive. More importantly, it can open lesions, exposing them to bacterial infection.

7. Poisonous Snakes. As with poisonous plants, the most effective precaution to take against poisonous snakes is to learn to recognize them and then avoid them. After relocating in a new region of the country, take time to find out what kinds of snakes are likely to be found there, how to recognize them, and what their patterns of behavior are. Carry a snakebite kit containing a constricting band, a scalpel or sharp knife, and a suction cup.

Several different first aid methods for snakebite have been advocated by various groups. Some are inadvisable. It is not recommended that methods of cold therapy or extensive cutting of the flesh be used. Do not give a snakebite victim alcohol, sedatives, aspirin, or any medicine containing aspirin. (Aspirin can adversely affect blood coagulation.) Under consultation of a doctor, however, some painkillers can be given.

Before first aid is administered, make sure the snake does not have the opportunity to strike again. Snakes can and sometimes do strike repeatedly, ejecting venom with each bite, resulting in a more severe reaction. If the snake can be killed without risk or delay, do so for positive identification at the hospital. It is very important to get the victim to a doctor quickly, but without too much physical exertion on the part of the victim.

First aid treatment recommended by the American Red Cross is given below. The Red Cross leaflet entitled "First Aid for Poisonous Snakebite" details the procedure and should be carried whenever working in regions inhabited by poisonous snakes.

a. Keep the victim from moving around and as calm as possible. Try to keep cool and calm yourself. Panic will make the situation much worse.

b. Preferably, the victim should be kept lying down, with the bitten extremity at or below heart level. If the victim can reach a hospital within 5 hours and if no symptoms develop, no further first aid measures are necessary.

c. If mild-to-moderate symptoms develop—mild swelling or discoloration, mild-to-moderate pain at the site of the wound, tingling sensations, rapid pulse, weakness, dimness of vision, nausea, vomiting, or shortness of breath—apply a constricting band 2 to 4 inches above the bite, but not around an elbow, knee, wrist, or angle joint, and not around the head, neck, or trunk.

The band should be $\frac{3}{4}$ to $1\frac{1}{2}$ inches wide, not thin like a rubber band. It should be snug, but loose enough for a fin-

ger to be slipped underneath. Watch for swelling and loosen the band if it becomes too tight, but do not remove it. Periodically check the pulse in the extremity beyond the bite to ensure that the flow of blood has not stopped.

d. If severe symptoms develop—rapid swelling and numbness followed by severe pain at the site of the wound, and possibly pinpoint pupils, twitching, slurred speech, shock, convulsions, paralysis, unconsciousness, or no breathing or pulse—apply a constricting band, make an incision over each fang mark, and apply suction immediately. Make cuts in the skin through the fang mark, using a sharp, sterilized knife. Cuts should be no deeper than just through the skin and should be about ½ inch long, extending over the suspected venom deposit point (usually lower than the fang mark). Cuts should be made along the axis of the limb. *Do not* make cross-cut incisions, and *do not* make cuts on the head, neck, or trunk.

Apply suction for 30 minutes with a suction cup if available, otherwise use your mouth. There is little risk to the rescuer who uses mouth suction, but it is recommended that the venom not be swallowed and that the mouth be rinsed out.

e. If professional help cannot be obtained within 5 hours and any symptoms at all develop, apply a constricting band, make incisions, and apply suction immediately, as described above. Keep trying to obtain professional care by transporting the victim to a place where it is available. If possible, use emergency communications systems to obtain medical advice or to get a professional to the scene. If it is necessary to leave the victim for any reason, make sure he or she is in a calm state of mind and will remain quiet. Mark a trail well so there will be no difficulty finding your way back.

8. **Government-Supplied Safety Equipment.** Table 1.3.3-1 shows safety equipment that can be purchased with Government funds. Only the primary users are listed. Others may also purchase the equipment if needed.

Table 1.3.3-1—Government-supplied safety equipment

Primarily Use	Safety Glasses	Hard Hats	Safety Boots	Safety Gloves	Safety Vests	Snake Bite Kits	Trailer Tiedown
Mark Maintenance ...	x	x		x	x	x	
Reconnaissance.....					x	x	
Builders	x	x	x	x	x	x	x
BM Setters	x	x	x	x	x	x	x
Observers					x	x	
Level Crews					x	x	x
Astronomic					x	x	
Gravity						x	
Doppler						x	

1.3.3.2 Vehicle Safety

Regulations pertaining to the safe use of motor vehicles are contained in the *NDM* (chapter 39). Additional instructions follow:

1. **Driving.** All Project Directors and Chiefs of Parties will ensure to their personal satisfaction that each employee assigned to drive a Government vehicle is a capable and safe driver under all circumstances. Possession of a Government driver's license is not a sufficient indication. The larger tandem combinations will be assigned only to those employees who have demonstrated safe driving habits for several years. On long moves, issue repeat travel orders if necessary to ensure that only well-qualified drivers are assigned to the trucks.

Additional driving instruction under close supervision in safe areas should be given to employees inexperienced in driving vehicles other than automobiles. Even though a Schedule A or career-conditional employee is adept at the mechanics of driving, if the person demonstrates a lack of responsibility, is accident prone, or there is any doubt as to the employee becoming a good driver, the employee should be released at the earliest opportunity.

Operators are required to make routine checks on their vehicles each day they are driven. These shall include cleanliness of the windshield, a visual check of tire pressure, adjustment of the mirrors, and operation of the horn. At the first opportunity, check the brakes to ensure that they are not pulling to one side, or spongy. Additional checks are required each time the vehicle is fueled. They include oil, water, and operation of the headlights, tail lights, brake lights, turn signals, and running lights. At least once a week, or when a different vehicle is assigned, the battery fluid level, tire pressure, and tire wear shall be checked. Any deficiencies must be corrected immediately. Routine maintenance shall also be performed.

Long drives between the office site and work areas are not uncommon, and an extended trip after a full day's or night's work is hazardous. The driver's senses are dulled by fatigue. In addition, the driver is inclined to increase the driving speed in order to return to the office a little earlier. The supervisor should reiterate appropriate warnings under such circumstances. The speed limit of Government-operated vehicles is 55 m.p.h. When towing, follow the limits set by the States.

2. **Accidents.** All Government vehicles must carry NOAA Form 397, Packet—Vehicle Accident Forms. This packet contains step-by-step instructions on what to do if involved in an accident. It also contains all the forms that must be filled out if an accident has occurred.

If traumatic injury has occurred, the injured employee (if able) and the immediate supervisor shall complete and submit Form CA-1 in accordance with the instructions on this form. Forward a copy of the form to NOS Personnel Section, AT/PER15, without delay. All other forms relating to the accident and another copy of the Form CA-1 should be submitted to the Chief, NGS, N/CG1x10, for review and initiation of any claims. Then, N/CG1x10 will forward these forms to the NOS Safety Management Officer.

3. **Equipment.** All equipment carried in Government vehicles must be neatly and securely stowed. This not only promotes efficient operations, but also is an important safety

precaution. In the event of a collision, loose equipment could cause injury or death. Nets or screens may be installed to keep equipment out of the driver and passenger areas.

Vehicles used for work alongside roadways must be equipped with flashing amber lights. The strobe type is better than the rotating type for two reasons: it draws more attention, and it draws less current.

All vehicles that are not international orange in color must be provided with black stripes (either painted or decal) on the bottom half of the rear of the vehicle. The stripes should not be less than 6 inches or more than 1 foot broad and should be from 1 to 2 feet apart, running at a 45-degree diagonal. On vehicles used for night work, it is recommended that white reflective tape, 6- to 12-inches wide, be placed between the black stripes.

Seat belts must be in good working order and must be used without fail. Failure to fasten seat belts is a direct violation of safety regulations by the individual involved and by the Chief of Party for not enforcing the regulations. Any violation of this type will result in disciplinary action ranging from written reprimand to removal of the employee.

All vehicles should be equipped with fire extinguishers. The extinguishers should be suitable for Class A, B, and C fires and should be periodically inspected as per manufacturer's instructions.

West Coast Mirrors or equivalent with a wide view mirror are required on steel trucks, 1-ton trucks with utility beds, and vehicles that tow Government trailers.

Portable signs warning of a survey crew ahead must be displayed for all crews working along roadways. The signs must be visible to traffic from both directions and should be placed between ½ and 1 mile from the actual location of the crew.

Flares must be carried for use when the vehicle is disabled alongside the roadway. Vehicles must also be equipped with an appropriate jack.

Special instructions regarding the use of vehicles equipped with catalytic converters are contained in *NOAA Circular 78-59*.

1.3.3.3 Tower Safety

1. **Other Guidelines.** *C&GS Publication 62-3*, Bilby Steel Tower for Triangulation (1929: ch. VII), contains safety precautions to observe while building and tearing down Bilby towers. The information also applies to other kinds of towers and masts.

2. **FAA Regulations.** When a tower or mast is to be put up in the vicinity of an airport, the Administrator of the Federal Aviation Administration (FAA) must be notified by submitting FAA Form 117. The FAA Advisory Circular 70/7460-2G gives details on when and how to do so. All reconnaissance and horizontal control parties should have copies of this circular. They can be obtained by writing to:

Federal Aviation Administration
HQ438
800 Independence Avenue
Washington, D.C. 20590

3. **Falling Objects.** The danger of objects falling off towers is ever present. Use of hard hats by builders and teardown crews is mandatory. In addition, the building foreman should ensure that builders do not occupy a potentially hazardous position on the ground as towers are being built or torn down. Builders should be reminded to keep alert and to think ahead about where they will run if a warning is shouted. Though the danger of falling objects is more probable during building and tear down, the above precautions should be observed whenever working on or around towers.

4. **Nighttime Hazards.** Observers and recorders must be extra careful on towers when working in the dark because of the increased chance of tripping or losing their footing. Make sure objects are not left where they could be stumbled over. Take extra care to get a firm foothold when climbing up or down a tower.

5. **Ladders on Wooden Towers.** On wooden towers, steps have been known to pull off, causing injury to those climbing them. To prevent accidents of this type, the outer tower of each signal that is higher than 6 feet should be equipped with a ladder. One rail of the ladder can be one of the tower legs. The other rail should be nailed securely to the tower about 12 inches from and parallel to the tower leg. The rail should be made of 2- x 4-inch material. The steps should be made of 1- x 4- or 1- x 6-inch material and should not contain knots large enough to weaken them. They should be about 18 inches apart. Steps should extend to the handrail of the tower, not just to the floorboards. Nails driven into the steps must be far enough from the ends to prevent splitting. Use at least one nail on each end of a step, long enough to project through the rail. All nails that project through the lumber on the ladder shall be bent over so they cannot catch on flesh or clothing. They should be bent across the grain of the wood, not parallel to it.

A newly erected tower must be inspected by the building foreman to see that all the above regulations are complied with. All cleated steps which were used as an aid by the building party must be removed.

6. **Nonskid Material on Observer's Platforms.** Tower platform boards can become slippery under certain conditions. As a precaution, they are to be overlaid with nonskid material. Alternatives include nonskid paint, fresh paint sprinkled with clean sand, or adhesive nonskid strips. If adhesive strips are used, be sure to follow the indicated procedure carefully, especially in regard to surface preparation, or the strips will come off. The recommended layout for the strips is given in *USC&GS Publication 62-3*, Bilby Steel Tower for Triangulation (1929: 86).

1.3.3.4 Miscellaneous Safety

1. **Tools.** Always keep tools in good working order. They will last longer, and be safer to use. In particular, cutting tools should be kept sharp. Contrary to what one may think, sharp tools are safe tools.

2. **Slippery Surfaces.** A person can get seriously hurt by slipping and falling down. Walking surfaces that are normally quite safe can become dangerous if they get wet.

Take extra care under those conditions. Surfaces requiring particular caution include rock (ledges, etc.), metal (towers, etc.), and wood (planks, logs, etc.).

3. **Shipment of Gas Engines.** Gasoline, a flammable liquid with a flash point of -45° to -36° F, is classified as a hazardous material and when shipped by aircraft, must comply with FAA regulations (49 CFR 173.120b). Gasoline-powered equipment must have all gasoline drained, all shut-off valves closed, and all tank caps tightly sealed.

4. **Batteries.** Use proper precautions when working with batteries. When "jump starting" one vehicle with another, make the last connection to a ground on the engine of the vehicle being started instead of the negative post of the dead battery. An electrical spark caused when the jumper cable is attached to the negative post could cause hydrogen gas from the battery to explode.

When using a wet-cell battery on an observing tower, make sure it is secure at all times. Batteries have been known to fall off towers. Their sheer weight is a danger in itself. In addition, a falling battery could break apart on the way down, spewing acid over everything below.

Dry-cell batteries are normally quite safe. However, expended dry cells are never to be left in the field. Not only are they an eyesore, but they pose a hazard to livestock if eaten by them.

1.3.4 Firearms in Government Vehicles

1.3.4.1 Policy

Personally owned firearms and ammunition are not permitted in any Government vehicle or trailer without prior

written permission of the Chief, Field Operations Branch, and the Project Director or Chief of Party. All local and State laws governing firearms, their use, and transportation, must be obeyed. Failure to comply with this policy will result in disciplinary action.

1.3.4.2 Disciplinary Actions

Violation of this policy can result in suspension or dismissal.

1.3.4.3 When Transportation of Firearms Can Be Authorized

A Project Director may request authorization for an employee to carry firearms in Government vehicles under the following circumstances:

1. When traveling to or from remote encampments or station sites at which the firearms may be needed.
2. On moves between project areas.

1.3.4.4 Transporting Firearms

When authorized, firearms may be transported as prescribed by local and State laws. In addition,

- a. the firearm must not be loaded,
- b. the firing mechanism must be disengaged and the weapon must be disassembled,
- c. the firearm must be properly encased, and
- d. ammunition must be carried separately from the firearm.

1.4 PUBLIC RELATIONS

Field parties are the most visible representatives of the NGS. They are in daily contact with the public and should project a neat and professional image.

1.4.1 News Media

Project Directors and Party Chiefs are requested to contact the news media (newspapers, radio, and television stations) in each community in which the party is located. The media should be invited to discuss and photograph the party's activities and equipment. Notify National Geodetic Survey Headquarters of contacts with news media. If possible, field parties should furnish the NGS Field Operations Section, N/CG161, with copies of news articles and radio/television coverage regarding geodetic survey activities. This material will then be forwarded to the NOAA Office of Public Affairs.

1.4.2 Courtesy to Property Owners

In an effort to maintain good public relations, party personnel are to notify the property owners of all possible station sites prior to setting marks or building towers. Permission to enter onto property and to build towers is to

be obtained during reconnaissance and reconfirmed by the party prior to the start of the project. (See also section 1.5.2.3, Third Party Insurance.) Property owners can be supplied with NOAA Form 76-163, which will help explain the purpose of the survey. Party personnel are to comply with the wishes of property owners.

At the close of a project, forward a listing of each station in the project for which a description has been submitted, including the corresponding name and address of the property owner to whom a copy of the description and data sheet is to be mailed, to the National Geodetic Survey Information Center (N/CG17). Mark Maintenance personnel and the Geodetic Advisors should supply the same information but should forward it to the Network Maintenance Section, N/CG162.

Return landscape to its original condition. Where property damage (destruction of trees, shrubbery, lawn, crops, etc.) cannot be avoided, the payment of such damages is to be negotiated and agreed upon before establishing the station. (See chapter 1.5.)

1.5 LEGAL MATTERS

Any claims for damage or loss caused by negligent or wrongful acts or omissions by NGS personnel are governed by the Federal Tort Claims Act, provided the persons who have caused the damage acted within the scope of their employment. Any such claim would have to be considered on its individual merits. There are many factors that are involved in deciding any claim. (See *NOAA Directives Manual* 22-05.)

1.5.1 Accidents

1.5.1.1 Government Vehicle

A Government employee is not liable for damages resulting from an accident while driving a Government vehicle in performance of his or her duties. Under the Federal Tort Claims Act, the Government will consider for settlement any claims for damages caused by negligent or wrongful acts of any Government vehicle operator while acting within the scope of his or her employment under circumstances that would make the United States, if it were a private citizen, liable to the claimant under local law. That is to say, at the time of accident, the employee was acting in the interest of the Government. Ordinarily a slight deviation as to time or place does not constitute a departure from the scope of employment. Conversely, an essential deviation without justification can affect the determination on the employee's status of acting within the scope of employment.

The Federal Tort Claims Act has been made the exclusive legal remedy for claims that arise from the operation of any motor vehicle by any employee of the Government within the scope of employment. For this reason, if an employee is sued in a State court in his/her individual capacity, the Attorney General of the United States defends the suit. He may either have it removed to a Federal Court or settle or compromise it in the same manner as other claims under the Federal Tort Claims Act. For action to take in such instances, see *NOAA Directives Manual* 22-31 dated September 7, 1978.

1.5.1.2 Towing Privately Owned Trailers

NOS extends to its employees the privilege of towing privately owned house trailers with Government vehicles and allows such movement when there are enough vehicles to tow the Government property.

In the event of an accident, payment for damage to the trailer may be precluded either under the Military Personnel and Employees' Claims Act of 1964 or the Federal Tort Claims Act. The facts and circumstances of each claim must be considered. If the employee was negligent, his or her chances of recovery are substantially lessened.

To safeguard against personal liability in the event it is determined that the employee was not within the scope of

his or her liability, and thus outside of the statute providing recovery, Government vehicle operators are encouraged to purchase riders on their personal insurance policies to cover towing privately owned trailers.

The employee is responsible for his or her trailer when "site-parked."

1.5.2 Obligation to Property Owners

1.5.2.1 Contacting Property Owner

At the beginning of each project, the party personnel are to obtain permission from each property owner for the field party to enter the property. The owner should be advised if any property damage is expected. Costs of any damage can be considered as normal site preparation expenses and can be paid from the imprest fund.

1.5.2.2 Reimbursement for Damages

All subvouchers submitted for reimbursement of property damage caused while building or tearing down Bilby towers or setting marks are subject to the following restrictions:

1. The extent of the expected damages and the amount of the reimbursement should be discussed with the property owner before the station is established or the tower is built.
2. The property owner must agree to the settlement.
3. The amount of the settlement must be less than \$500.
4. The subvouchers must be carefully worded. For example:

"Reimbursement for use by NGS during project _____, as a result of normal wear and tear. . ."

or "Site preparation for project _____ . . ."

Do not use words, such as "damage" or "tort," which imply unexpected damages. Tort claims cannot be reimbursed by a subvoucher. Tort claims can only be paid through the Office of General Counsel.

Disputed damages or damages denied by the field party can be resolved as a claim by the property owner under the Federal Tort Claims Act. Damage disputes or claims have been few, but, in all instances, the overwhelming factor prompting the claim was alleged discourtesy on the part of the field party, such as not informing the property owner of

damages or changes in operation, not obtaining permission, and not expressing thanks. This could be avoided to a great extent by the Party Chief or Project Director visiting with the property owner prior to departure, thanking the owner, and inviting him or her to an inspection of the grounds.

1.5.2.3 Third-Party Insurance

Field parties should secure third-party insurance for the property owners before building towers or erecting potentially dangerous structures on private property. This insurance will help protect the property owner from liability suits resulting from bodily injury and property damage. Requests for insurance should be made by telephone to the Field Operations Section, N/CG161. Supply the station name, and the name and address of the property owner.

1.5.3. Liability for Accuracy of Data

All claims for damages resulting from inaccuracies in geodetic data gathered by NGS should be referred to NOAA's Office of General Counsel.

1.5.4 Loaning Government Property

Chiefs of Parties and Project Directors are cautioned not to loan U.S. Government equipment and property to private individuals or firms. Arrangements for storage of Government property *must not* include any provision whereby the use of such property by any private individual or firm is authorized or implied.

Non-Federal requests for the loan or construction of Bilby towers will not be honored. NGS may consider cooperative horizontal control programs which incorporate the use of the towers in overall horizontal control surveys.

Federal requests for the loan or construction of Bilby towers will be honored based on their own merits. Such merits may include contributions to the national network, national defense, and other special use surveys.

All requests for loans of Government property must be submitted in writing to the Chief, National Geodetic Survey. (See *NOAA Directives Manual* 37-17.)

1.6 ADMINISTRATION

1.6.1 Purchasing and Finance

The *NOAA Small Purchase Guide*, the *NOAA Cashier's Handbook*, and the *NOAA Finance Handbook* contain regulations and guidelines for maintaining an imprest fund and for purchasing supplies. These books can be ordered from the NOAA Logistics Supply Center.

1.6.1.1 Purchasing Order, SF-44

NOAA Small Purchase Guide (chapter 4) explains the use of Standard Form (SF) 44, Purchase Order. Exhibits B and C of chapter 4 list the limitations of the SF-44. NGS imposes these additional limitations:

1. All purchases over \$500 must be first approved by the Field Operations Section, N/CG161, at which time they will be registered.

2. All truck repairs in excess of \$500 must be jointly approved by N/CG161 and AT/GSM43.

3. All SF-44's over \$1,000 must be issued by the Chief of Operations Branch, N/CG16.

4. All SF-44's for purchases made by geodetic advisors and mark maintenance personnel must be requested from the Network Maintenance Section, N/CG162, and issued by N/CG16.

5. Purchases in excess of \$2,500 shall not be split between two or more SF-44's. Instead, they should be paid for with a standard purchase order (CD-45) issued by the Plans and Requirements Staff, N/CG1x10.

6. Capital equipment may not be purchased with SF-44's. Read and comply with the guidelines published in *NOAA Small Purchase Guide* (chapter 4). Violating the purchasing guidelines will result in the loss of purchasing authority and possibly disciplinary action.

7. Large purchases should be arranged well in advance to allow N/CG16 to issue an SF-44 or for N/CG1x10 to issue a CD-45. The \$2,500 limit on SF-44's is the maximum limit for NOAA.

Figure 1.6.1-1 shows the authorization for delegating procurement authority. To obtain a current list of authorized purchasing agents, contact the Operations Branch.

1.6.1.2 Imprest Fund

Each party shall maintain its imprest fund according to the regulations in the *NOAA Cashier's Handbook*. Additional guidelines are given in *NOAA Finance Handbook* and the *NOAA Small Purchase Guide*. The NGS Plans and Resources Staff, N/CG1x10, should be contacted to answer any questions about the imprest fund.

NGS imposes a \$500 limit on any single cash purchase. The Field Operations Branch, N/CG161, should be contacted about any cash purchase that is expected to exceed \$500.

1.6.1.3 Supply Requisitions

Most supplies needed for field operations may be requisitioned from the General Services Administration (GSA) or the NOAA Logistics Supply Center (NLSC). All other supplies must be bought on the open market.

1. *GSA*. Procedures for ordering supplies from GSA are given in the *Federal Standards Requisitioning and Issue Procedures (FEDSTRIP) Operating Guide*. This guide and other GSA catalogs may be obtained by writing to the General Services Administration (8FFS), Building 41, Denver Federal Center, Denver, Colorado 80225. Parties should use Standard Form (SF) 344, Multiline Requisition, when ordering supplies from GSA. One copy of this form should also be submitted to N/CG1x10.

2. *NLSC*. The NOAA Stock Catalogs list most of the supplies which can be ordered from the NOAA Logistics Supply Center. Parties should submit NOAA Form 37-4 to NLSC to order supplies. One copy of this form should also be submitted to N/CG1x10.

1.6.2 Personnel

The *NOAA Directives Manual* and the *NOAA Personnel Handbook* list the regulations and operating procedures pertaining to personnel administration. A Department of Commerce booklet entitled "Employee Handbook" contains general information on employment. It is available from the Field Operations Section, N/CG161.

1.6.2.1 Right to Privacy

NOAA Directives Manual (chapter 22-50) outlines NOAA's responsibility under the Privacy Act of 1974, P.L. 93-579 (5 USC 552-a).

NOAA Circular 76-9, dated January 20, 1976, which is filed with NDM 22-50, provides additional information on disclosures of Privacy Act material. Section 11 lists the security and distribution procedures of U.S. Treasury Form W-2 and NOAA Form 34-14 (white cards). Section 12 states what information can be provided by a supervisor when an inquiry is received from rental or credit offices concerning a specific employee.

1.6.2.2 Initiation and Termination of Employment

NOAA Personnel Handbook (chapter 3) lists employment restrictions, recruitment procedures, and special employ-



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Rockville, Md. 20852

Procurement Point 158

DATE: October 1983
TO: See attached list
FROM: N/CG16 - Gerald C. Saladin
SUBJECT: Delegation of Procurement Authority
() New (X) Revised () Cancelled

Pursuant to the authority vested in the undersigned and in accordance with Subpart 1.3 of the Federal Procurement Regulations, you are hereby delegated the responsibility to make small purchases subject to the limitations contained in the Federal Procurement Regulations, Federal Property Management Regulations, Commerce Procurement Regulations, NOAA Directive 36-10, and to any further limitations set forth herein:

	REDELEGABLE	
	YES	NO
SMALL PURCHASES (\$10,000 - 41 USC 252 (c)(3))		
(X) SF-44: Limited to \$ <u>1,000.00</u> per single purchase.	---	<u>X</u>
() Requisitioning Public Utility Service (Regulated Rate).	---	---
() Requisition Actions involving Transfer of Funds under cross-servicing or interagency agreements.	---	---
() CD-45 (or equivalent): Limited to \$ _____ per single purchase. (Delivery orders against existing contracts may be issued up to the maximum order limitation of the contract.)	---	---

OTHER CONSTRAINTS: NOAA Small Purchase Guide Chapter 4 (SF-44 Authority)
NOTE: Exhibit C, Limitations on Use, attached hereto.
See Section 1.6.01.1 of NGS Operations Manual.

This delegation serves to revoke all previous delegations and is necessary:

For efficient operation of NOS-NGS field units which are performing a variety of surveying operations throughout the country.

Authority designated as redelegable may be further delegated to qualified NOAA personnel of not less than 21 years of age. Such redelegations shall be in writing and define the scope and limitations of the authority delegated within the guidelines specified in NOAA Directive 36-10, Exhibit A. Copies of redelegation must be distributed as shown below.

(Signature) (Date)

Attachment
cc: AT/GSM1
AT/GSMx31
AT/GSM42



Figure 1.6.1-1—Sample memorandum delegating procurement authority

ment programs. This section of the manual lists the forms to be submitted for initiation and termination of employment.

Newly hired persons should complete the following forms and submit them to the Field Operations Section (N/CG161). If these forms have not been received by N/CG161 within 10 calendar days after employee enters on duty, employment will be terminated.

SF 61—Appointment Affidavits

SF 61 B—Declaration of Appointee

SF 85—Data for Nonsensitive or Noncritical-Sensitive Position

SF 87—U.S. Civil Service Fingerprint Chart

SF 171—Personnel Qualifications Statement

NOAA 52-10—Statement of Relatives Employed by the DOC

NOAA 55-3—Statement Relating to Employee Responsibilities and Conduct

W-4—Employee's Withholding Exemption Certificate

SF 52 Request for Personnel Action. (See fig. 1.6.2-1.)

CD 133—Application for Operators ID Card

SF 47—Physical Fitness Inquiry for Motor Vehicle Operations ID

A person rehired less than one year after separation must submit all forms except the SF 85 and the SF 87.

On the first day of duty, N/CG161 should be furnished with the employee's name, Social Security number, date

REQUEST FOR PERSONNEL ACTION (SF-52)

NAME:

KIND OF ACTION: Promotion	☐
Reassignment	☐
Appointment (Excepted)	☐
(Career-Conditional)	☐
*Resignation	☐
Retirement	☐
Detail	☐
LWOP	☐
Other: _____	☐

If promotion is requested, give justification (Promotions cannot be requested for grades beyond the career-ladder position).

***Note:** If Resignation is requested, please have employee sign the back of the SF-52 and then send it (incomplete) to N/CG161 along with NOAA Form 55-1, Driver's License, Credentials, etc.

Project Director _____
(Signature/Date)

Figure 1.6.2-1—NGS form used for preparation of SF-52

of birth, date and time entered on duty, organization code, grade, and minority class. This information is needed for payroll purposes.

When retiring or when employment is terminated, employees should submit NOAA Form 55-1, Clearance of Employee Accountability, and the request for personnel action form. (See fig. 1.6.2-1).

1.6.2.3 Performance Ratings

NOAA Personnel Handbook (chapter 18) as amended by NOAA Circular 81-95, describes the General Workforce Performance Appraisal System.

1.6.2.4 Promotions and Within-Grade Increases

The merit promotion system is described in Chapter 6 of the *NOAA Personnel Handbook*, and within-grade or salary increases are discussed in chapter 5.

1.6.2.5 Adverse Action and Discipline

NOAA's policy on adverse actions and discipline is contained in the *NOAA Personnel Handbook* (chapter 13).

1.6.3 Party Moves/Travel

Travel regulations are stated in *NOAA Travel Handbook* (NTH) and in the *NOAA Directives Manual* (chapter 42).

Travel orders should be requested through the Field Operations Section (N/CG161) by using the form shown in figure 1.6.3-1. All claims for reimbursement of travel expenses should be submitted to the NGS Plans and Requirements Staff, N/CG1x10, in accordance with NOAA Travel Handbook, chapter 1, part 11, Claims for Reimbursement.

1.6.3.1 Use of U.S. Government Trucks

The use of Government vehicles in general is discussed in NOAA Circular 75-60 filed with *NDM* (chapter 42-25). This section establishes the policy for use of Government vehicles on party moves.

The first priority is to use Government trucks to move Government trailers and equipment. Any Government vehicle not needed to tow Government equipment may be used to tow privately owned vehicles and house trailers.

A second trip under travel orders can be authorized to move additional Government equipment. Requests for second trips should be made through the Field Operations Section (N/CG161) in advance of party moves. Project Directors and Party Chiefs should carefully schedule second trips to minimize the cost to the Government.

1.6.3.2 Per Diem

Per Diem is paid to field personnel to help offset the cost of travel under orders. Regulations for civilians are prescribed in the *NOAA Travel Handbook*. For commissioned officers, the *Joint Travel Regulations* govern. The present per diem rate is \$23/day plus the average cost of lodging not to exceed \$50/day for enroute travel and the first 30 days

at a temporary duty (TDY) station. After the first 30 days at any TDY station, the per diem is reduced to a flat rate of \$25/day.

Allowable lodging costs for employees with trailers are limited to the following: parking fees; fees for connection, use, and disconnection of electricity, gas, oil, water, and sewage; shower and bath expenses; and dumping fees.

Send all questions about per diem rates to the NGS Plans and Requirements Staff, N/CG1x10.

1.6.4 Reports

1.6.4.1 Routine Reports

All individuals responsible for NGS field units, observatories, mark maintenance personnel, and State geodetic advisors are required to submit several reports on a routine basis.

1. *Field Party Monthly Report and Journal* (NOAA Form 76-92). This report is to be submitted to the Field Operations Section or the Network Maintenance Section (mark maintenance and advisors) at the end of each month. The Field Party Monthly Report and Journal receives wide circulation at Headquarters and is a primary source of information concerning NGS field activities.

Instructions for completing each item in the Monthly Report and Journal are given on NOAA Form 76-92A. The remarks and recommendations section should be used to call attention to problems, solutions to problems, and new ideas. This section should also be used to provide a tabulation of a participating agency's effort in a cooperative project.

Example:

*(see below) Personnel

Staff days =

Standard paid days =

Staff months =

*Enter participating agency name such as State of Maine.

The remarks section of the form should also be used for comments about conditions affecting progress and to call attention to any noteworthy accomplishments. It is not necessary to retabulate statistics listed elsewhere in the report.

2. *Other Routine Reports*. See section 1.6.5.1 for a listing of all forms and reports to be submitted biweekly, monthly, quarterly, annually, or as needed.

1.6.4.2 Nonroutine Reports

Accident and injury reports, personnel actions, project reports, and reports on changes in inventory are nonroutine reports and should be submitted when necessary.

1. *Accident/Injury Reports*. These reports should be submitted in accordance with the *NOAA Directives Manual* (chapter 6.4). The necessary forms are listed in section 1.6.5.1, "Summary of Forms."

2. *Personnel Actions*. Requests for personnel actions should be submitted to the Field Operations Branch on the form shown in figure 1.6.2-1. See section 1.6.2.2 for a listing of forms needed for initiating and terminating employment.

Date:

To:

From:

Purpose: Request for Travel Orders

Type of order 20 ☐ 24 ☐

Names of Travelers		From	To
Purpose of Travel:			
Beginning About		Ending About	Task
			Org. Code
Mode of Transportation		Special Provisions	
Gov't Vehicle ☐ POV ☐ Bus ☐ Rail ☐ Air ☐ Rental Car ☐ Other		Towing POV by Gov't Truck ☐ Towing of Privately-Owned House Trailer by Gov't Truck ☐ Annual Leave Enroute Requested ☐ Give Dates: Dependent Passenger ☐ NOAA 22-1 Submitted ☐ (on file at N/CG1 x 10)	
Special Expenses			
Mileage Authorized for POV	☐	Bridge and Road Tolls	☐
Miscellaneous Expenses Authorized		Hire of Taxis	☐
In Lieu of Imprest Fund	☐	Excess Baggage	☐
Meeting Registration Fees	☐		

Figure 1.6.3-1—NGS form used to request travel order

3. **Project Reports.** Project reports should be submitted after each project is completed. See sections 2.2.22, 2.3.11, 2.4.5, 2.5.6, 2.6.6, and 2.7.6 for the report requirements for different type surveys.

4. **Other Nonroutine Reports.** Other forms and nonroutine reports are listed in section 1.6.5.1.

1.6.5 Summary of Administrative Forms

NOAA Handbook No. 18 (NDM 59-17), which includes NOAA Forms Catalog, contains the requisitioning procedures for and a listing of all NOAA, Department of Commerce, and Standard Forms available to NGS field parties. This subchapter lists some of the more frequently used administrative forms which should be kept on hand at the party level.

1.6.5.1 Summary of Forms

1.6.5.2 NGS Forms

This Section describes the forms produced within NGS.

1. **Request for Travel Orders.** This form is to be submitted as needed to N/CG161. It is used to request travel orders for either single employee or party travel. (See fig. 1.6.3-1.)

2. **Mileage Report.** This report is to be submitted to N/CG161 by the 10th of each month. It is a tabulation of miles traveled by each vehicle during the previous month. (See fig. 1.6.5-1.)

3. **Report of Estimated Travel.** This report is an estimate of travel by the field party during the current month. It should be filed with N/CG1x10/4 by the 15th of each month.

4. **Request for Personnel Action.** This form is used to assist N/CG161 in preparing SF-52, Request for Personnel Action. (See fig. 1.6.2-1.)

1.6.5.3 NOAA Forms

All NOAA forms should be ordered on NOAA Form 37-4 from the NOAA Logistics Supply Center (NLSC), Kansas City, Missouri.

1. **NOAA 34-8: Time and Attendance Card.** This card should be completed for each employee and forwarded to the Management Service Center (MSC) on the Thursday of the second week of the pay period. The yellow copy should be forwarded to N/CG1x10. NOAA Form 34-8A must be completed to reflect changes in task numbers, and forwarded to MSC.

2. **NOAA 34-19: Cashier Fund Verification.** This form is used as a quarterly audit. Send original to AT/GSMx31 and one copy to N/CG1x10.

3. **NOAA 34-63: Standard Task Number Assignment Request.** This form must be used to change the party's Standard Task Number (STN) each time the party begins a new project which is expected to last 2 months or more. (Time and Attendance cards are printed three pay periods ahead). All NOAA Forms 34-63 should be submitted to N/CG1x10, to be verified and forwarded to payroll.

4. **NOAA 37-4: Stores Requisition.** This form is used for ordering supplies from NLSC. Submit original to NLSC and one copy to N/CG1x10/4. Make sure administrative (forms and publications) and technical (equipment, instruments, and accessories) requests are on two separate requisition forms.

5. **NOAA 37-12: Report for Personal Property.** This form is used for the disposal of Government equipment. In the block "custodian," list the name and telephone number of the person to contact and the actual place where the equipment is stored, i.e., gas station, warehouse location, etc. Also list the condition and mileage (vehicles) of all equipment. All nonoperable equipment except vehicles and trailers should be sent to the NGS Instrumentation and Equipment (I&E) Section in Corbin, Virginia, for disposition. Send NOAA Form 37-12 to N/CG161.

6. **NOAA 42-8: Aircraft Charter Agreement.** This form must be completed in triplicate for all aircraft and helicopter rentals. This form must be signed by both the lessor and lessee. Actual payment for helicopter rental may be made with a Government Transportation Request (SF-1169).

7. **NOAA 42-16: Travel Roll Voucher (Field Party).** This form is for use when field parties are on a fixed per diem rate and in one location during the entire month covered by a voucher. Attach copies of the travel orders and forward to N/CG1x10.

8. **NOAA 55-1: Clearance of Employee Accountability.** This form is to be completed when an employee resigns, retires, or is terminated from appointment. Return driver's license, official credential, and any other pertinent material as listed on the form. Send to N/CG161 the original and one copy with the SF-52 attached.

9. **NOAA 76-92: Field Party Monthly Report and Journal.** This form is to be completed and forwarded to N/CG161 by the 10th of every month.

10. **NOAA 76-104: Monthly Report-Leveling Observing Unit.** This report should be completed monthly for each level unit. It can include more than one project for the same month.

1.6.5.4 Standard Forms

This section describes some of the Standard Forms, their uses, and routing. All Standard Forms can be ordered from GSA on SF-344 unless otherwise indicated.

1. **SF-44: Purchase Order.** This form is intended for over-the-counter purchases and nonpersonnel services. (See section 1.6.1.1.) Copies 1, 2, and 3 should be forwarded to N/CG1x10. Copy 4 should be retained in the party files. Copy 5 should be given to the vendor. This form is available from NLSC.

2. **CD-45: Supply, Equipment, or Service Order.** The use of Form CD-45 is explained in the NOAA Small Purchase Guide (chapter 6). A purchase order will be issued by N/CG1x10 upon request.

3. **SF-172: Supplemental Experience and Qualification Statement.** Employees should submit this form at least annually. It is used to reflect acquired knowledge and work

Table 1.6.5.1—Administrative forms used by NGS Operations Branch

Form No.	Title	When to Submit	Where to Submit
NOAA 22-1	Release from Claim for Injury or Death		Chief of Party
NOAA 34-6	Imprest Fund Purchases	Monthly	N/CG1x10
NOAA 34-8	Time and Attendance	Biweekly	MSC
NOAA 34-8A (green stripe)	Salary and Wage Distribution Report	As needed	N/CG1x10
NOAA 34-19	Cashier Fund Verification	Quarterly	AT/GSM51/N/CG1x10
NOAA 34-63	Standard Task Number Assignment Request		N/CG1x10
NOAA 37-4	Stores Requisition		NLSC/N/CG161
NOAA 37-12	Report of Personal Property		N/CG161
NOAA 42-8	Aircraft Chapter Agreement		Vendor/N/CG1x10
NOAA 42-16	Travel Roll Voucher	Monthly	N/CG1x10
SF-44	Purchase Order		AT/GSM51/N/CG1x10
SF-52	Request for Personnel Action		N/CG161
NOAA 53-45	Performance Plan and Appraisal	Annual	N/CG161
NOAA 53-5	Quality Step Increase		N/CG161
NOAA 55-1	Clearance of Employee Accountability		N/CG161
NOAA 76-92	Monthly Report and Journal	Monthly	N/CG161
NOAA 76-104	Monthly Report-Leveling Observing Unit	Monthly	N/CG161
SF-172	Supplemental Experience and Qualifications Statement		N/CG161
SF-344	Multiline Requisition		GSA/NCG1x10
CD-369	Travel Advance	Monthly	N/CG1x10
CD-370	Travel Voucher	Monthly	N/CG1x10
SF-1103	U.S. Government Bill of Lading	Monthly	Vendor/N/CG1x10
SF-1129	Reimbursement Voucher	Monthly	Treasury/NCG1x10
SF-1169	Government Transportation Request		Vendor/N/CG1x10
For Government Driver's License			
CD-133	Application for Operator's ID Card		N/CG1x10
SF-47	Physical Fitness Inquiry for Motor Vehicle Operators		N/CG1x10
Injury Forms			
(Personal Injury)			
CA 1 & 2	Federal Employee Notice of Major or Occupational Disease		N/CG1x10
CA 16	Request for Examination and/or Treatment		N/CG1x10
CA 20	Doctor's Report of Treatment		N/CG1x10
NOAA 64-1	Supervisor's Report of Accident/Hazard		N/CG1x10
(Motor Vehicle Injury)			
Opt 26	Data Bearing Upon Scope & Employment of Motor Vehicle Operator		N/CG1x10
NOAA 64-1	Supervisor's Report of Accident/Hazard		N/CG1x10
SF-91	Operator Report of Motor Vehicle Accident		N/CG1x10
SF-91A	Investigation Report of Motor Vehicle Accident		N/CG1x10
SF-94	Statement of Witness		N/CG1x10
Forms to Enter a Person on Duty			
SF 61	Appointment Affidavits		N/CG161
SF 61 B	Declaration of Appointee		N/CG161
SF 85	Data for Nonsensitive or Non Critical-Sensitive Position		N/CG161
SF 87	U.S. Civil Service Fingerprint Chart		N/CG161
SF 171	Personal Qualifications Statement		N/CG161
NOAA 52-10	Statement of Relatives Employed by the DOC		N/CG161
NOAA 55-3	Statement Relating to Employee Responsibilities and Conduct		N/CG161
W-4	Employee's Withholding Exemption		N/CG161
	Certificate Request for Personnel Action		N/CG161
Unnumbered Forms			
	Report of Estimated Travel	Monthly	N/CG1x10
	Mileage Report	Monthly	N/CG1x10
	Truck Inventory	Annually	N/CG1x10
	Request for Travel Order	As needed	N/CG1x10
	Truck Reports (Monthly Operations Summary Section III)	Monthly	MB/A07

10. *SF-1169*: Government Transportation Request: This form is used to purchase airline tickets or to rent helicopter time. A copy of the travel order must be sent in with the

buff copy. If traveling on a blanket travel order, be sure to enter the trip authorization number. The airline retains original TR. Attach the buff copy to the travel voucher.

1.7 FIELD RECORDS AND DATA

1.7.1 Safeguards Against Loss

Field records and data are the product of a considerable investment in labor and money and should receive appropriate safeguarding. They should be stored so that if one portion is destroyed, another will preserve the information (such as storing record books separately from abstracts). The most basic records and data must be stored in a fireproof safe or file normally located at the field office. Field parties without a good-quality fireproof container should arrange to purchase one. In deciding which records to store in the fireproof container, remember that the more basic the record, the greater its value. For example, if an abstract is destroyed it can be reproduced from a field record book, but the reverse is not true.

1.7.2 Formats and Specifications

Information on this topic is given in *Input Formats and Specifications of the National Geodetic Survey Data Base*, commonly called the "Blue Book." This publication contains three volumes: Volume I, Horizontal Control Data; Volume II, Vertical Control Data; and Volume III, Gravity Control Data. All NGS field units should maintain copies of this publication.

1.7.3 Forms

The purpose of a form is to provide a convenient sheet on which to record information. As the type or format of the needed information changes, the form should be revised. Unless the most current version of a form is used, its purpose may be partially or wholly defeated. Table 1.7.3 lists the NOAA forms for recording geodetic observations, computations, and other field data. The list does not contain forms used primarily for administrative purposes. They may be found in Chapter 1.6. Forms may be requisitioned on NOAA Form 37-4 from the NOAA Logistics Supply Center, 619 Hardesty Street, Kansas City, Missouri 64124.

1.7.4 Data Transmittal

Data transmittals from the field party to the NGS Headquarters are discussed here. More specific information on transmittal of mark maintenance, horizontal, vertical, and astronomic data may be found respectively in sections 2.1.2, 2.2.22, 2.3.11, and 2.5.7.

Records and data (including the exact designations and number of records in all computer files to be released) from

projects are to be forwarded to NGS Headquarters at the earliest possible date after they are no longer needed in the field. For ongoing work that is not well defined as a "project," records are to be submitted monthly. Examples include astronomic and gravity observations and mark maintenance records. Send all records and data via Registered Mail—Return Receipt Requested to the following address:

Quality Control Branch, N/CG164
National Geodetic Survey, NOAA
Rockville, Maryland 20852

Generally, records should not be sent through the U.S. mail unless a backup exists at the party location or at NGS Headquarters. There should be a portion of the data that can be used to reconstruct information lost in the mail. For example, original records of observations and abstracts should be shipped in separate packages. When deciding how complete a backup to maintain, consider the volume of data being shipped and the amount of work that would be needed to recreate the data.

Mark clearly packages containing data stored on magnetic tape or disks to warn mail handlers of the content. Use specially made aluminum cases. Magnetic tapes and disks must not be exposed to magnetic and electrical fields nor subjected to temperature extremes because this exposure may destroy the data.

To keep track of the data within NGS, each project must have an accurate inventory or index of its contents. The method NGS uses to inventory or index data is the "Letter Transmitting Data," NOAA Form 61-29 (see fig. 1.7.4-1). This transmittal is not only an archival inventory device, but it is the official method by which NGS field parties must transmit their field data to headquarters. The original and one copy of this letter should be sent to N/CG164 separate from the data. One copy of the letter should be included with each package. This letter is then used as a checklist to verify that all the data forwarded were actually received. When all data forwarded have been accounted for, a signed copy of the original is returned to the submitter; this copy is the submitter's official notification that the party has been released from responsibility for the data. The original letter of transmitted data remains with the accessioned data as the official inventory or index for that project data. If data for more than one project is to be packaged and transmitted in the same mailing package, make a separate transmittal form for each project.

Therefore, the transmittal letter should be as accurate and complete as possible. As a minimum, the transmittal letter should state these six items:

Table 1.7.3-1—List of NOAA geodetic forms used by NGS Operations Branch

<i>Primarily used by</i>	<i>Form Number</i>	<i>Form Title</i>
Builders	40-5	Daily Report of Building Foreman on Establishment of Station
Theodolite Observers	75-54	Wye Leveling
	75-82	Station Description
	75-82A	Station Description-Short Form
	76-46	Short-Traversal Observations and Computations
	76-52	Observations of Horizontal Directions
	76-86	Abstract of Directions
	76-156	Observations of Double-Zenith Distances
	76-135	Abstract of Zenith Distances
EDMO Observers	76-132	Instrument Frequency Count
	76-43A	Model 4 Geodimeter Observations
	76-33	Model 8 Geodimeter Observations
	76-19	Hewlett-Packard Distance Meter Observations
	76-170	Ranger III Observations
	*	MA-100 Tellurometer Observations
Horizontal Computers	76-126	Computation of Elevation & Refraction from Reciprocal Observations
	76-147	Computation of Elevation from Nonreciprocal Observations
	76-102	Computation of Triangles
	76-162	Reports on Triangulation Computations
	76-158	Reduction to Center
BM Setters	76-186	Bench Mark Description
	*	Monthly Bench Mark Setting Statistics
Level Observers	77-82	Geodetic Leveling (Backup sheet for auto recording)
	77-81	Geodetic Leveling Compensation Check
	76-104	Monthly Report-Leveling Observing Units
	76-189	Geodetic Leveling Three-Wire Observations
	76-191	Geodetic Leveling Micrometer Observations (Δh)
	76-187	Geodetic Leveling Field Abstract
	*	Valley or River Crossing Observations
Vertical Computers	76-188	Geodetic Leveling Line Identification
	*	Valley or River Crossing Computations
Mark Maintenance	76-91	Report on Condition of Survey Mark and Instructions
	76-60	Report on Relocation of Bench Mark Maintenance
	76-109	Observation of Horizontal Directions, Traverse and EDM Measurement, Leveling
	76-46	Short-Traversal Observations and Computation
Doppler Observers	*	Equipment Log, MX 1502
	*	Equipment Failure Report, MX 1502
	*	Antenna Measurements
	*	Obstruction Survey
	*	Doppler Station Observation Log, MX 1502
	*	Record of Meteorological Observations
Astronomic Observers	76-55	Determination of Level Value
	76-49	Astronomy Abstract of Results
	*	Longitude Record and Coding Form
	*	Latitude Record and Coding Form
Gravity Observers	76-55	Gravity Meter Observations
	*	Gravity Survey Computation Form

* These forms were not printed or stocked by NOAA at the time of this writing. They are created by the user using a conventional form.

NOAA FORM 61-29 (12-71)		U. S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION		REFERENCE NO.	
LETTER TRANSMITTING DATA				DATA AS LISTED BELOW WERE FORWARDED TO YOU BY (Check):	
				☐ ORDINARY MAIL ☐ AIR MAIL ☐ REGISTERED MAIL ☐ EXPRESS ☐ SBL (Olive number) _____	
TO:				DATE FORWARDED	
L				NUMBER OF PACKAGES	
NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.					

FROM: (Signature)				RECEIVED THE ABOVE (Name, Division, Date)	
Return receipted copy to:					
L					

Figure 1.7.4-1—NOAA Form 61-29, Letter Transmitting Data

1. Where the work was done (usually given in the title);
2. The title of the work (including the task number);
3. The Project Director or Party Chief;
4. Date data were forwarded;
5. An item by item inventory of the contents, exact file designations, and number of records; and
6. The submitter's reference number.

The first two items are by far the most important because they will be used to retrieve or find the data within NGS. The sixth item is the party reference number and should be maintained by the party. The reference number should contain four items: namely, the organization (NGS), the unit (G37), the year (1980), and the transmittal letter number. The transmittal letter number is numbered consecutively each year starting with the number 01 (1), e.g., NOSPMC: 1979-10, NOSAMC: 1980-06, or NGSG16: 1979-04.

When writing the transmittal letter, the contents of each package must be separated by a horizontal line so there is

no confusion as to what is in each package (figs. 1.7.4-2, and 1.7.4-4). Also, within a given package where data are made up into books or where printouts are assembled, there should be a page count for the books or the printouts. In this way, the transmittal letter becomes the source for what was accessioned and actually put into the cahiers.

All data pertaining to one project are listed on one original transmittal letter. The project report and progress sketches should be listed even if they are to be mailed at a later date; i.e., everything on that project must be accounted for on the original LTD. This allows the person receiving the data to know exactly how many packages to expect in the total shipment. Each package must have a copy of the original transmittal letter placed inside with the data and the correct package number circled. The outside of each package of a transmittal should be numbered (e.g., 1/7, 2/7, 3/7) so that the person who receives the packages can determine which packages have been received without opening each package. Do not write the contents on the outside of the packages.

NOAA FORM 61-29 (12-71)		U. S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION		REFERENCE NO. NGSGL9: 1979-02 Sheet 1/2	
LETTER TRANSMITTING DATA				DATA AS LISTED BELOW WERE FORWARDED TO YOU BY (Check): ☐ ORDINARY MAIL ☐ AIR MAIL ☒ REGISTERED MAIL ☐ EXPRESS ☐ GBL (Give number) _____	
TO: Quality Control Branch - OA/C174 National Geodetic Survey, NOAA Rockville, Maryland 20852				DATE FORWARDED July 5, 1979	
				NUMBER OF PACKAGES 5 (4 boxes and 1 roll)	
NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.					
Area Triangulation in Vicinity of Swainsboro, GA					
Pkg. 1: 180 Books - NOAA Form 75-82 Station Descriptions 1 Book - NOAA Form 75-82A Station Descriptions Short Form (102 sheets) 2 Books - Project Report (Original and 1 copy)					
Pkg. 2: 20 Books - NOAA Form 76-52 Observations of Horizontal Directions 10 Books - NOAA Form 76-156 Observation of Double-Zenith Distances 1 Book - NOAA Form 76-102 Computation of triangles (50 sheets)					
Pkg. 3: 2 Sheets - Project Sketch. (Roll)					
FROM: (Signature) George E. Leigh, COP G-19				RECEIVED THE ABOVE (Name, Division, Date)	
Return receipted copy to: George E. Leigh - COP G-19 c/o National Geodetic Survey P.O. Box 907 Swainsboro, Georgia					

Figure 1.7.4-2—Example of a properly completed NOAA Form 61-29 (horizontal data)

NOAA FORM 61-29 (12-71)		U. S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	
LETTER TRANSMITTING DATA		REFERENCE NO. NGSC19: 1979-02 Sheet 2/2	
TO:		DATA AS LISTED BELOW WERE FORWARDED TO YOU BY (Check): ☐ ORDINARY MAIL ☐ AIR MAIL ☒ REGISTERED MAIL ☐ EXPRESS ☐ CBL (Give number) _____	
L		DATE FORWARDED July 5, 1979	
L		NUMBER OF PACKAGES 5 (4 boxes and 1 roll)	
NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.			
Area Triangulation Vicinity of Swainsboro, GA			
Pkg. 4: 1 Book - NOAA Form 76-86 Abstract of Directions (234 sheets) 1 Book - NOAA Form 76-46 Short Traverse Observations (15 sheets) 1 Book - NOAA Form 76-135 Abstract of Zenith Distances (221 sheets)			
Pkg. 5: 1 Book - Combined Lists - 150 Computer Sheets - Abstracts - 150 Computer Sheets 1 Book - Base Checks 30 Computer Sheets - Quad Checks 12 Computer Sheets 1 Book - GP Computations 184 Computer Sheets			
FROM: (Signature) George E. Leigh		RECEIVED THE ABOVE (Name, Division, Date)	
Return receipted copy to: L		L	

Figure 1.7.4-2—Example of a properly completed NOAA Form 61-29—Continued

NOAA FORM 61-29 (12-71)		U. S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION		REFERENCE NO. NGSG37:1980-03 Sheet 1/2																	
LETTER TRANSMITTING DATA				DATA AS LISTED BELOW WERE FORWARDED TO YOU BY (Check): ☐ ORDINARY MAIL ☐ AIR MAIL ☒ REGISTERED MAIL ☐ EXPRESS ☐ GBL (Give number) _____																	
TO: Quality Control Branch - OA/C174 National Geodetic Survey, NOAA Rockville, MD 20852				DATE FORWARDED November 24, 1980																	
				NUMBER OF PACKAGES 6 (5 pkgs & 1 roll)																	
NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.																					
L24465-2 (line 210) Ladysmith via Stanberry to Superior, WI																					
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;">Pkg. 1</td> <td style="width: 15%;">21 Maps</td> <td style="width: 40%;">USGS topo maps (Smooth plotted)*</td> <td style="width: 35%;"></td> </tr> <tr> <td></td> <td></td> <td> Superior Sunnyside South Range Poplar Solon Springs (15') 2-Minong (15') Stanberry West </td> <td> Stanberry East Hayward Reserve Bean Lake Stone Lake Haver Couderay </td> </tr> <tr> <td></td> <td></td> <td></td> <td> Radisson Wxeland Weingor Crane Exeland SE Ladysmith </td> </tr> <tr> <td></td> <td>1 Sheet</td> <td>USGS topo map index</td> <td></td> </tr> </table>						Pkg. 1	21 Maps	USGS topo maps (Smooth plotted)*				Superior Sunnyside South Range Poplar Solon Springs (15') 2-Minong (15') Stanberry West	Stanberry East Hayward Reserve Bean Lake Stone Lake Haver Couderay				Radisson Wxeland Weingor Crane Exeland SE Ladysmith		1 Sheet	USGS topo map index	
Pkg. 1	21 Maps	USGS topo maps (Smooth plotted)*																			
		Superior Sunnyside South Range Poplar Solon Springs (15') 2-Minong (15') Stanberry West	Stanberry East Hayward Reserve Bean Lake Stone Lake Haver Couderay																		
			Radisson Wxeland Weingor Crane Exeland SE Ladysmith																		
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Pkg 2	21 Maps	USGS Topo maps (Field plotted)*																			
		Superior Sunnyside South Range Poplar Solon Springs (15') 2-Minong (15') Stanberry West	Stanberry East Hayward Reserve Bean Lake Stone Lake Haver Couderay																		
			Radisson Wxeland Weingor Crane Exeland SE Ladysmith																		
*All topo maps are 7-1/2 minute quads unless otherwise noted.																					
FROM: (Signature)				RECEIVED THE ABOVE (Name, Division, Date)																	
Return receipted copy to:																					
Mr. Lester Williams, COP G-37 c/o National Geodetic Survey P.O. Box 1276 Grand Rapids, MI 34225																					

Figure 1.7.4-3—NOAA Form 61-29, Letter Transmitting Data (vertical data)

NOAA FORM 61-29 (12-71)		U. S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION		REFERENCE NO. NGS37:1980 - 03 Sheet 2/2	
LETTER TRANSMITTING DATA				DATA AS LISTED BELOW WERE FORWARDED TO YOU BY (Check):	
				☐ ORDINARY MAIL ☐ AIR MAIL ☒ REGISTERED MAIL ☐ EXPRESS ☐ GBL (Give number) _____	
TO:				DATE FORWARDED	
L				NUMBER OF PACKAGES	
NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.					
L24465-2 (Line 210) Ladysmith via Stanberry to Superior, WI (continued)					
Pkg. 3	2 Books 1 Sheet 1 Sheet	NOAA Form 77-82 Geodetic Leveling (backup sheet 40/41)(351 sht) File release letter New-Old Computations			
Pkg. 4	1 Book 2 Books	NOAA Form 76-186 BM Descriptions (190 sheets) T.I. XOFF sheets for HG files HGF1 (1854 lines) HGF2 (1850 lines)			
Pkg. 5	3 Sheets 1 Sheet 1 Sheet 1 Pkg	Field printouts of EXABS program Field printout of CKSPSN program Listing of remotely printed jobs of NEWREC, FUNJOB, EXABS, CKSPSN NOAA Form 75-82A Station Descriptions (8 sheets)			
Pkg. 6	1 Book 1 Copy 1 Sheet	Project/Seasons Report Project Instructions with Attachments & Sketches Sketch of Level Line location			
FROM: (Signature)			RECEIVED THE ABOVE (Name, Division, Date)		
Return receipted copy to:			L		

Figure 1.7.4-3—NOAA Form 61-29, Letter Transmitting Data—Continued

NOAA FORM 61-69 (7-81)		U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION		REFERENCE NO. SHEETS _____ OF _____ DATA AS LISTED BELOW WERE FORWARDED TO YOU BY: (Check) ☐ ORDINARY MAIL ☐ AIR MAIL ☐ REGISTERED MAIL ☐ EXPRESS ☐ GBL (Give Number.) _____ DATE FORWARDED _____ NO. OF PACKAGES _____												
LETTER TRANSMITTING DATA (MARK MAINTENANCE)																
TO: QUALITY CONTROL BRANCH, N/CG164 NATIONAL GEODETIC SURVEY NATIONAL OCEAN SURVEY, NOAA ROCKVILLE, MARYLAND 20852																
NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition, the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.																
MARK MAINTENANCE		ITEMIZED DESCRIPTION OF DATA														
TASK NO. _____ REGION _____ STATE _____		Precise Levels, 3-Wire 75-29 Abstract of Directions 76-86 Mark Maintenance Vol 76-109 Abstract of Zenith Dist 76-135 Station Description 75-82 Station Description SF 75-82A Bench Mark Description 76-186														
STATION - BENCH MARK DESIGNATION		SHT	SHT	BK	SHT						D	R	O	R	O	R
TOTALS																
FROM (Signature) _____						RECEIVED THE ABOVE (Name, division, date.) _____										
RETURN RECEIPTED COPY TO _____																

Figure 1.7.4-4—NOAA Form 61-69, Letter Transmitting Data (Mark Maintenance)

1.8 OFFICE SUPPORT

1.8.1 Field-Office Communications

A clear line of communication between the office and field must be maintained. Each field party must keep the Field Operations Section, N/CG161, informed of the party's physical location, post office address, and telephone number(s).

Although field parties must maintain a commercial telephone line, they should use the Federal Telephone System (FTS) whenever calling offices within the Federal Government. Parties should have the current edition of the FTS directory. The directory contains user instructions and the local telephone numbers of the FTS Operators through whom FTS calls must be placed. The NOAA Telephone Directory gives a listing of FTS numbers within NOAA. The user identification number for all NGS field parties and the directories are supplied by the Operations Branch. The identification number is changed periodically.

Units working remotely from the party headquarters should charge official calls to the party's telephone number. Field parties have also been supplied with telephone credit cards for use when no commercial number is maintained. The credit cards shall be used for official calls only.

1.8.2 Technical Support

1.8.2.1 Action and Information Memorandums

This manual replaces the Action and Information Memorandum system. That system was originally established to disseminate policy and procedural changes throughout the NGS Operations Branch. Such memos are no longer being issued.

1.8.2.2 Planning and Project Instructions

1. **Planning.** The following procedure is used to facilitate the planning, scheduling, and issuing of project instructions and the monitoring of field party projects.

a. Semi-annually, N/CG1x10 will organize a meeting of all interested units of NGS to prepare a 12-month operations plan and a summary of projects scheduled for the next fiscal year. This meeting will be chaired by the Deputy Chief, NGS. The plan will then be submitted to the Chief for approval and then distributed within NGS.

b. N/CG1x10, N/CG12, N/CG13, N/CG14, and N/CG16 will hold a monthly meeting to review the current plan of operations for compliance and to initiate necessary modifications. All modifications will be documented by N/CG1x10 and forwarded to the Chief, through the

Deputy Chief, for approval and then distribution within NGS.

c. Project Instructions are generated in the Operations Division (N/CG16) using the technical specifications set forth by the respective branches involved (horizontal, vertical, etc). The sequence of events necessary to prepare and issue project instructions will be as follows:

(1) Approximately 16 weeks before the scheduled start of a project, N/CG16 will request N/CG12, N/CG13, or N/CG14 to prepare the technical portion of the instructions (including sketches and liaison contacts).

(2) Approximately 12 weeks before the start of a project, the appropriate branch will submit the technical specifications to N/CG16. N/CG16 will prepare draft project instructions and circulate the draft for comment.

(3) Approximately 9 weeks before the start of the project, N/CG16 will prepare the final project instructions. Concurrently, the appropriate branch will assemble the necessary support data and forward it directly to the field unit with a copy of the transmittal letter to N/CG16.

All projects that need more than 1 staff-day of effort require project instructions. All short lead time projects will be given special handling.

2. **Project Instructions.** Project instructions are supplied for all NGS projects that require more than 1 staff-day of effort. These instructions give complete guidelines to be followed on each project. The project instructions for all NGS field parties (astronomy, base line, gravity, horizontal, reconnaissance, satellite, and vertical) follow a basic format. Paragraphs are added or deleted as required by the specific project.

TO: (Name)
Project Director or Party Chief, Party G-
Present Address

FROM: (Name)
Chief
National Geodetic Survey

SUBJECT: INSTRUCTIONS: List project titles and
task numbers of the survey. The Subject
is given as SUPPLEMENTAL INSTRUCTIONS for all supplements to previously
issued instructions.

GENERAL: Give starting date, location, and other general information about the project.

PURPOSE: Give a concise statement of the purpose of the project.

LOCATION: Give location of level lines for vertical control projects.

CONNECTIONS: List connections to be made on vertical control projects.

SPECIFICATIONS: List order and class of survey to be accomplished and reference the specifications and publications to be followed. Provide specific items and methods of work which must be used. This should include such items as junctions to be made, specific stations to be established or recovered, locations of base line measurements and astronomic azimuth observations, and any deviation from accepted standard procedures.

LIAISON: List the names, addresses, and telephone numbers of persons to be contacted in any cooperative projects. This paragraph will also list the technical advisor or field coordinator, if any, for the project.

The remainder of the project instructions will have the following standard wording:

DATA: Supporting project data will be forwarded to you by _____. All records in connection with this project shall be titled "_____."

REPORTS: Furnish Field Party Monthly Report and Journal in accordance with National Geodetic Survey regulations and instructions listed in section 1.6.4.1. Other required reports are also listed in Section 1.6.4.

ADDRESS: Keep National Geodetic Survey Headquarters informed of the party's post office address, physical address, and telephone number(s) at all times.

PUBLICITY: Notify National Geodetic Survey Headquarters of party moves and contacts with newspapers and radio and TV stations in accordance with chapter 1.4.

EXPENSES: Expenses on this project will be charged to Task _____.

TRAVEL: Travel and per diem are authorized in accordance with the NOAA Travel Handbook. Travel Orders shall be requested through N/CG161.

EMERGENCY ORDERS: General Emergency Order No. 1, Geodesy 1 is no longer in effect. Consult section 1.3.1.

ACKNOWLEDGMENT: Please acknowledge receipt of these instructions in the Monthly Report and Journal.

3. Supplemental Project Instructions. N/CG16 issues supplemental project instructions to implement changes to previously issued project instructions. The supplemental instructions clearly state what portions of the previous instructions have been changed.

1.8.2.3 Data Supplied to the Field Parties

Field parties will be supplied with data from previous surveys that were conducted in the project area. Support will be as follows:

1. Reconnaissance Parties. The Field Records Analysis Section, N/CG121, supports the reconnaissance parties. Data supplied will normally include the items in the following list. The reconnaissance party should request from N/CG121 the data needed for special projects (e.g., the reconnaissance for the National Crustal Motion Network sites or the three-dimensional survey sites).

- (1) Station data sheets
- (2) Data from previous surveys
- (3) Topographic maps
- (4) Charts
- (5) Geodetic Control diagrams

2. Horizontal Control Parties. The Field Records Analysis Section, N/CG121, supports the horizontal control field parties. Data supplied will include the following:

- (1) Coordinates
 - a. Horizontal and vertical data sheets
 - b. USGS published coordinates
 - c. Unadjusted coordinates
- (2) Sketches
 - a. Project progress sketches
 - b. Reconnaissance sketches
 - c. 1° x 2° geodetic diagrams
 - d. State triangulation diagrams
 - e. USGS topographic quad sheets previously used by

the Reconnaissance Party

- f. Aeronautical charts
- (3) Observations
 - a. Lists of directions
 - b. Lists of distances
 - c. Lists of astronomic azimuths
- (4) Descriptions
 - a. Horizontal station descriptions
 - b. Bench mark descriptions
 - c. Reconnaissance descriptions
- (5) Miscellaneous
 - a. Letters of permission from property owners
 - b. Photographs of the intersection stations

3. Vertical Control Parties. The Vertical Network Branch, N/CG13, supports the vertical control field parties. Data supplied will normally include three copies of the following:

- (1) NGS State Index Map of Control Leveling
- (2) NGS geodetic control diagrams
- (3) NGS vertical control data (bench mark elevations and descriptions)
- (4) NGS archive listings
- (5) Unpublished (reset or recent) descriptions
- (6) Horizontal control data
- (7) Summary sheets from past NGS surveys
- (8) NOS tide and water-level station reports
- (9) Descriptions of points requested by outside agencies or individuals
- (10) USGS State Index to Topographic Maps
- (11) USGS 7½' or 15' topographic maps

4. Astronomy Field Parties. The Astronomy and Space Geodesy Section, N/CG142, supports the astronomy field parties. Data supplied will normally include the following:

- (1) Station descriptions
- (2) Observing lists
- (3) Latitude and longitude lists

5. Doppler Satellite Parties. The Astronomy and Space Geodesy Section, N/CG142, supports these field parties. Data supplied will normally include the following:

- (1) Station descriptions
- (2) Station occupation reports
- (3) Station observation logs

6. **Gravity Field Parties.** The Gravity Section, N/CG141, supports these field parties. Data supplied will normally include the following:

- (1) Station descriptions
- (2) Line sketches
- (3) Base station descriptions and values
- (4) Topographic maps (when necessary)

1.8.3 Equipment Maintenance

All instruments and equipment used by NGS personnel shall be properly maintained. Proper maintenance will ensure that accuracy and safety standards are met. Each field unit is responsible for the proper service of the instruments and equipment in its possession.

1.8.3.1 Survey Instruments

All electronic distance measuring instruments (EDMI), theodolites, level instruments, first-order level rods, and vertical collimators shall be serviced at regular intervals. A routine maintenance and calibration schedule has been set up by the NGS Instrumentation and Equipment (I&E) Section in Corbin, Virginia. All survey instruments will be serviced as follows:

EDMI.....	Every 12 months
Theodolites.....	Every 18 months
Level instruments.....	Every 18 months
Level rods.....	Every 12 months
Vertical collimators.....	Every 18 months

Occasionally, the time limit may be extended as much as 2 months when project requirements dictate. When an instrument is overdue for servicing, the I&E Section will send a notice requesting it for servicing purposes. In the event the instrument has been transferred from its original user to another field party, the original user will forward the notice to the other party.

In situations where an instrument was used in adverse weather conditions, where an instrument has had rough handling (i.e., dropped, jarred, submerged, etc.), or where data reflect a change in calibration, the instrument should be sent immediately to the I & E Section for servicing.

Each instrument that is serviced will have a certification label as follows:

<i>NGS, I&E Section</i>	<i>NGS, I&E Section</i>
Constant: _____	Offset Constant: _____
Calibrated: _____	Serviced: _____
Due: _____	Due: _____
By: _____	By: _____

EDMI

Level Rod, First-Order

<i>NGS, I&E Section</i>	<i>NGS, I&E Section</i>
Stadia: _____	Bubble: _____
Serviced: _____	Serviced: _____
Due: _____	Due: _____
By: _____	By: _____

Level

Theodolite

I&E Section

Serviced: _____
Due: _____
By: _____

Vertical Collimator

This information is also sent to the appropriate branches.

1.8.3.2 Vehicles

All trucks and trailers must be properly serviced. Maintenance on trucks should be performed in accordance with the schedule on Form CD-46, Motor Vehicle Inspection Record. (It is not necessary to submit this form.) Improperly maintained vehicles are not only inefficient and waste fuel, they can endanger the public and operators as well.

Trailers should be thoroughly checked before each party moves. This check should include turn signals, running lights, brakes, hitches, break-away switches, and tires.

1.9 TWO-WAY RADIOS

Two-way radios are used for communication between the various units on field parties. This chapter outlines the use, calling procedure, restriction, and maintenance of two-way radios.

1.9.1 Authorization

1.9.1.1 Handie-Talkie

National Geodetic Survey field parties use handie-talkies, radio transceivers, or radios which operate on a VHF frequency of 34.98 megahertz. Call signs are assigned to each field party by the Operations Branch. The call signs originate from the Department of Commerce Office of Radio Frequency Management (MB/RFM) and are allocated upon request to NGS Operations Branch by the Radio Frequency Management Staff (AT/IMSx2).

The NGS Operations Branch has assigned blocks of call signs to the parties as follows:

Party	Call Sign
G-01	KF 3712—KF 3713
G-02	KF 3714—KF 3715
G-10	KF 3716—KF 3725
G-16	KF 3726—KF 3745
G-18	KE 8200—KE 8219
G-35	KE 8220—KE 8222
G-36	KF 3768—KF 3769
G-37	KE 8223—KE 8224
G-38	KE 8225—KE 8226
G-48	KF 3746—KF 3747
G-52	KF 3748
Mark Maintenance	KF 3771—KF 3800
I & E Branch	KF 3749—KF 3765

Project Directors and Party Chiefs are responsible for assigning call signs to individuals on the parties. Requests for additional call signs should be made to the Operations Branch.

1.9.1.2 CB Radios

Some parties and mark maintenance personnel also operate citizen band (CB) radios. These radios may be operated by employees of the Federal Government only for emergencies and for interfacing with non-Government licensees to coordinate essential and mutual activities. Operation of CB radios is subject to compliance with Federal Communications Commission (FCC) rules and regulations. The use of CB radios by NGS personnel is restricted to the States of Massachusetts, Pennsylvania, North Carolina, Mississippi, Kentucky, Indiana, South Dakota, Montana, Texas, Washington, Oregon, California, New York, and Colorado.

1.9.2 Limitations and Restrictions

Radios have made communicating between various units quite easy. Because radios may not work under all conditions, observers and lightkeepers should be proficient at Morse Code. Terrain, atmospheric conditions, and distance have a great influence on the effectiveness of radio transmissions.

Personnel are cautioned not to use two-way radios near construction sites or any other areas where explosives may be used or stored. The use of two-way radios may also be restricted or prohibited on or near military installations. Check with the base security office before using the radios.

1.9.3 Radio Operations and Maintenance

The following suggestions are given for the proper operation and maintenance of radios.

1. **CAUTION:** Do not key transmitter unless antenna, dummy, or equivalent is connected to the antenna receptacle. An equivalent load would be 50 ohms or more.

2. Never store radio for a period of 2 weeks or more without removing the batteries. Batteries should be checked and replaced frequently.

3. Never allow water to get on the top of the radio. There is no protection from water into the speaker, which is located at top center of the radio.

4. Never transport the radio in a truck with the antenna attached, because this allows for the chance of undue pressure to be put on the loading coil at the base of the antenna, which is easily broken or damaged. Use the truck-mounted antenna if available.

5. Do not attempt to tune the loading coil. The loading coil consists of a series of resonant tunable inductors. The combination of whip and loading coil produces a $\frac{1}{4}$ -wavelength antenna tunable within a given band of 25-54 MHz range. This coil cannot be accurately tuned without proper instruments. A $\frac{1}{4}$ -wavelength whip antenna for a frequency of 34.98 MHz should be 2.142 meters long.

6. Do not subject the hand microphone to sharp blows or expose it to water. It is a capacitance operated transducer which contains a delicate fiber diaphragm that is easily damaged.

7. Curling of the antenna will not damage the radio, but will reduce its efficiency when transmitting.

8. Additional range may be obtained when the radio is placed on the hood or top of a truck. This furnishes a good ground plane for the antenna.

9. Shorting of the antenna to ground will reduce its ability to load the output of the transmitter resulting in possible damage.

10. The microphone works better when held firmly in the palm of the hand as it is built to react to body capacitance, which becomes a part of the circuitry of the radio. To transmit, hold the mouthpiece 1 to 2 inches from the lips, with the slots facing you, and speak slowly and clearly across the mouthpiece in a normal to loud voice.

11. To adjust squelch control, first, turn control fully counter-clockwise. Then, with no signal being received, turn the control clockwise until the noise just cuts off (squelches).

12. Two-way radios should be checked daily for proper operation before they leave the party headquarters. This precaution may save a schedule. Replace the batteries or exchange the radio prior to leaving for a schedule. It is too late to do this after an observing unit or lightkeeper is on station.

1.9.4 Calling Procedures

All calls should be kept brief and free of profanities. Section 1464 of the U.S. Criminal Code makes it a criminal offense for any person to transmit communications containing obscene, indecent, or profane words, language, or meaning. Whoever utters any obscene, indecent, or profane language by means of radio communication may be fined not more than \$10,000 or imprisoned not more than 2 years, or both.

The proper calling procedure is as follows:

Listen for a break in transmission when others are talking before calling.

STATION CALLED (name and call sign, if known)—

THIS IS (Station Calling: name and call sign)—OVER

(use of "OVER" is optional)

Example: Nonemergency Call

STATION DODGE KF 5678—THIS IS STATION
CLARKE KF 1234—OVER

The preliminary call should not exceed 30 seconds. If not answered, the station should wait 2 minutes before repeating the call.

PART 2

Specific Field Operations



Horizontal Control Surveys



Vertical Control Surveys



Astronomic Surveys



Gravity Surveys



Crustal Movement Investigations



Calibration Base Line Program



Mark Maintenance

2.1 MONUMENTATION AND MARK MAINTENANCE

Positions and monuments are the two distinct yet inseparable products of geodetic surveying. The importance of permanent, locatable, stable monuments is unquestionable. There are a number of principles that apply to all monuments, regardless of the type of survey for which they are established.

This chapter contains general information applicable to monumentation, including installation and description writing, for all types of surveys. Guidance pertinent only to particular types of marks is contained in sections 2.2.4, 2.3.4, and 2.7.2, monumentation for horizontal, vertical, and calibration base line surveys, respectively. Also, *NOAA Manual NOS NGS 1, Geodetic Bench Marks*, gives procedures for setting bench marks. Mark maintenance, the natural extension of mark setting, is also covered in this chapter.

2.1.1 Mark Setting

2.1.1.1 Site Selection

1. *Survey Requirements.* A number of project requirements related to topography and location of roadways affect the selection of sites for survey monuments. Triangulation stations must often be set on high points of land and within a certain configuration. Bench marks must usually be set along roadways and within certain spacing requirements. Calibration base line marks must be set in line with one another on level terrain. Within these limitations, other factors should also be considered.

In the past, the policy was not to set marks along controlled access highways. Now, under certain conditions, marks may be established along such highways with the consent of the supervising highway engineer. When possible, the marks should be reachable from an access or frontage road, instead of from the controlled access highway. Also, they must be placed so that the extremity of any structure erected over them has a minimum clearance of 30 feet from the edge of the highway pavement. These conditions were extracted from *Highway Design and Operational Practices Related to Highway Safety*, published by the American Association of State Highway Officials. The supervising highway engineer should be consulted for advice on the particular requirements to be met.

If the purpose of a survey is to furnish control points in the vicinity of the centerline of a proposed highway, the marks should be located as close to the proposed right-of-way line as is practical. Close liaison with the supervising highway engineer is essential in this case.

2. *Permanency.* The only physical evidence left after a survey has been completed is the marks; therefore, permanency is of utmost importance. Site selection is the most influential factor in assuring permanency. The additional time and effort involved in locating marks where they are least likely to be disturbed will not only save money but will also lessen the mark maintenance load.

Although the sites for many survey monuments are chosen for their accessibility by the mark truck, this procedure is not the primary criterion for selecting a site. The probability of future construction and vulnerability to maintenance equipment is more important. Entire lines of bench marks have been destroyed shortly after they were established because time was not taken to consult the local highway engineers to determine future construction in the area. Advance preparation is imperative for setting permanent marks.

3. *Monument Accessibility to Local Surveyors.* The value of a geodetic control monument is greatly enhanced if it is accessible to local surveyors. This is especially true of bench marks. By the nature of the survey, horizontal control stations must often be located in remote or inaccessible places, but supplemental stations should be located at sites convenient to the local surveyor.

2.1.1.2 Courtesy to Property Owners

Projecting a cooperative and courteous attitude when dealing with property owners is not only required of all Federal employees but is necessary from an operational point of view. Since mark setters work in advance of the observing units, good will established early will have its obvious advantages as the project progresses.

Also, in order to support the preservation of NGS monuments, copies of the descriptions and data sheets shall be provided to property owners on whose land the monuments are located. To achieve this, each Party Director and Party Chief will prepare a memo to the Chief, National Geodetic Information Center (NGIC) at the completion of each project, listing the marks and the corresponding names and addresses of the property owners to which copies of the property descriptions are to be mailed. Mark maintenance and geodetic advisor personnel will provide the same information on each new monument established or recovered, but will forward the listing to the Chief, Network Maintenance Section, who will in turn forward the list to NGIC for action.

2.1.1.3 Mixing Concrete

1. **General.** Desirable properties of concrete are that it be workable, strong, and durable. Workability refers to the ease with which concrete can be effectively placed, consolidated, and finished, while remaining free from segregation. Workability depends on the proportions of the ingredients and the shape of the individual particles of aggregate. Strength refers to the ability to withstand external forces without rupturing. For survey monuments, high strength is not the most important property, although strong concrete usually indicates that it is durable. Durability is the ability to withstand deterioration over a long time and is primarily influenced by the watertightness of the cured concrete.

2. **Destructive Forces.** Several factors can lead to the weakening or deterioration of concrete. The freezing of water in cured cement exerts great pressure against the inner walls of the pores, tending to break down the concrete. In fresh concrete, the expansion of freezing water breaks the bonds developing between solid particles, making the concrete weak and porous. Leaching and chemical attack also have detrimental effects on concrete. Leaching occurs over a long period when water slowly percolates through concrete and dissolves some of its constituents. Chemical attack is particularly common in alkali soils. Dense, impervious concrete is resistant to these destructive forces.

3. **Ingredients.** The quality of the ingredients and their proportions help determine how dense and impervious the cured concrete will be. The ingredients include aggregate, cement, and water. The aggregate should be clean (free from silt and clay, harmful chemicals, and organic matter) and well-graded, i.e., it contains proportionate amounts of many particle sizes. In specifying mix proportions, the aggregate is usually divided into two parts—sand (particle size less than $\frac{2}{3}$ cm) and gravel (particle size greater than $\frac{2}{3}$ cm). Both parts should be well-graded. Aggregates that are porous, split easily, or are otherwise weak or permeable result in poor concrete. Examples of poor aggregates include shale, claystone, sandstone, and micaceous rocks.

Portland cement is designated by one of five types. Type I is for general use where no special properties are needed. Type III is a high-early-strength type for use when concrete will be curing during cold weather. Type V is used where the concrete will be subject to an alkali environment. Types II and IV are not suited for setting marks. Local concrete companies should be contacted to determine the best concrete type to use in the work area.

The water used in a concrete mix should be relatively free of impurities such as acids, alkalis, salts, oil, organic matter, and silt. These can decrease the strength and durability of cured concrete. As a rule, do not use water that you would not drink. Salt water may be used if unavoidable.

4. **Mixing, Placing, and Curing.** Suitable proportions (by bulk volume) of cement to sand to gravel are 1:2:3. If the gravel is made up of fragmented or angular particles,

use a little less gravel and proportionately more sand. Add only enough water to make the mix workable. About half the water added to the mix is used in the chemical reaction (hydration) that causes the paste to harden into binder. The rest is necessary only to make the mix workable, and is somewhat detrimental because it leaves pores in the binder. If too little water is used, however, the mix will not compact properly and spaces will be left in the mass. A good indication of the right amount of water is that the mix neither runs nor falls off the shovel but sluggishly slides off and flattens upon hitting the ground.

Fresh concrete must be well mixed before it is placed, otherwise the minute particles of cement will not be sufficiently wetted and the aggregate will not be completely coated with paste. Before placement, the hole should be damp so moisture will not be drawn from the fresh concrete into the surrounding soil. In no case should it be so wet as to be muddy. Segregation of the various sizes of aggregate should not be much of a problem when pouring concrete survey monuments, but be aware that segregation can occur and is undesirable when it does. While filling the hole, continuously tamp the mix into a compact mass so it becomes less pervious and consequently more durable. Some bleeding (water gain at the surface) is to be expected when finishing the mark. Excessive bleeding indicates too much water in the mix or poor gradation of the aggregate. Concrete should normally be covered for at least 7 days after it is placed. This prevents rain from making the mix too wet and from ruining the finished surface. It also prevents the surface from drying too rapidly, leaving too little water for complete hydration.

5. **Cold Weather Precautions.** The freezing of fresh concrete has a damaging effect because the expansion of water as it freezes separates the solid particles in the mix. This reduces the strength of the bond and makes the concrete more porous and correspondingly less durable.

Three protective measures should be taken in cold weather, either singly or in combination. First, use warm ingredients. During the first 24 hours after a mix has been placed, it develops little heat of its own to prevent freezing. After 24 hours some heat is developed as a product of the chemical reactions occurring in the mix. The use of warm ingredients is especially beneficial during the first 24 hours. Note however, that mixing water above 165°F could cause a flash set. Some mark trucks used in cold weather have their exhaust pipes routed through the water tanks to keep the water warm. The design will depend on the particular truck. Essentially it would consist of a solid pipe through the longest dimension of the tank with connections to the exhaust system using flexible pipe. Avoid sharp, right-angle bends. To keep the aggregate and cement warm, store them indoors.

Second, use Type III (high-early-strength) cement or special additives that speed curing. Calcium chloride is good for this in amounts not exceeding 2 pounds per 94-pound sack of cement. The calcium chloride should be dissolved in the mixing water instead of mixing it with the other ingredients. Other additives include Thoroguard

and Trimix. If a large number of concrete marks are being installed by mass production using a "ready-mix" contractor, fast-curing additives should not be added until the concrete is delivered on site.

Third, insulate the finished mark for a week after the concrete is poured. One method is to cover the mark with boards resting on the form or otherwise supported. This is covered with paper or plastic, then by a layer of straw, styro-foam, or similar insulating material about 15 centimeters thick, and finally by a layer of soil 15 to 30 centimeters thick. Pile snow loosely on top if it is available.

The concrete monument must extend well below the frost line. See *NOAA Manual NOS NGS 1, Geodetic Bench Marks*. Field personnel should contact local concrete contractors to determine their cold weather methods. Any new techniques or additives should be reported to NGS Operations Branch.

2.1.1.4 Ferrous Metal in Marks

NGS no longer requires that ferrous metal be placed in concrete marks. If a Project Director or Party Chief believes that the ferrous metal will aid in the future recovery of a mark (as in the case of recessed marks), an iron or steel rod should be driven into the ground beside the concrete monument. It should be possible to remove the rod when the station is occupied by magnetic sensitive instruments.

1. Iron or steel may be placed beside concrete marks to provide a field which can be detected with magnetic locators. Use elongated pieces where the mark will accommodate them with the long axis vertical. A ½-meter piece of # 3 (¾") steel reinforcing bar in the least expensive grade is preferable. These bars normally are sold in 20- or 30-foot lengths and must be cut to size. If they are unavailable, use any elongated piece of ferrous metal, such as pipe, fence post, or angle, which is fairly straight and ½ meter long. A magnet or compass can be used to make sure the metal is ferrous.

2. When a mark is recovered in which ferrous metal is absent, but would be appropriate, an iron or steel rod should be driven flush or slightly below the surface beside the concrete monument. The recovery description should mention this.

3. Magnets must not be used for this purpose because they disturb gravity meters.

2.1.1.5 Projection of Marks

Normally, in order to facilitate recovery, concrete marks should project 10 to 15 centimeters above ground. However, at the request of the property owner, if the marks are in danger of being jarred by maintenance equipment or farm machinery, or when the risk of vandalism is high, they should be set flush or below the surface.

2.1.1.6 Witness Signs

Witness signs are extremely helpful to persons searching for survey monuments. Not only do they save time by bringing a person directly to the mark, but they are useful

in providing a good reference measurement to a monument that becomes covered and would otherwise be lost. Except in the following instances, always use witness signs.

1. When the property owner (whether private, corporate, or government) would object.

2. When a post cannot be driven and no other suitable means to support the sign is available. Note: Do not nail witness signs to utility poles, trees, buildings, etc.

3. When the mark should not be easily visible because of a high risk of vandalism.

2.1.1.7 Description of Control Point

Descriptions should provide a comprehensive word picture of the exact location of a control point. The information must be comprehensive, clear, and concise. Wordiness will only confuse the searcher. The text of descriptions should be arranged consistently so readers become accustomed to the way they are written, making recovery easier. Refer to *Input Formats and Specifications of the National Geodetic Survey Data Base* (the Blue Book) for proper computer formats and codes.

1. **Recording Mileages and Distances.** These measurements should be recorded on the proper form at the time of reading and never listed on a scrap of paper which may get lost or misplaced. Such sloppiness causes extra trips and gross errors.

2. **Order of Directions.** Give directions in the order that a person searching for the mark would need them, i.e., generally the longer distances first. Reference measurements from the most conspicuous objects should be given before those from inconspicuous objects, regardless of the lengths of those measurements.

3. **Units.** In general, quantities in descriptions shall be recorded in metric units. This applies particularly to linear measurements. Where possible and practical, English equivalents shall be enclosed in parentheses following the metric values. However, standard commercial or nominal dimensions may be used to describe reference objects.

Measurements indicating mark size and dimensions should be recorded in metric units only. Nominal dimensions and standard commercial sizes are exceptions to this general rule. Here are some examples:

- a 2 x 4-inch timber, not a 5.1 x 10.2 cm timber (standard size)
- a timber about 15 x 25 cm, not about 8 x 10 inches (approximate size)
- a 1-inch pipe, not a 2.54-cm pipe (standard size)
- a pipe 10 cm in diameter, not 3.9 inches in diameter (measured size)

Descriptions submitted to Headquarters via NOAA Forms 75-82, 75-82A, or 76-186 should include the English equivalents wherever the forms allow. Where partially coded text permits an option for metric or English units, use metric units with the English equivalents in parentheses.

For descriptions transmitted to Headquarters via computer terminals using "prompt" programs, there are various opportunities to include English equivalents. Among

these are: the narrative sections, the prompts that allow a certain latitude in their responses, and the prompts that require English equivalents. Persons who prepare NOAA Forms 75-82, 75-82A, or 76-186 should record English equivalents on the form, where necessary, to allow their entry on the computer terminal as required above. For horizontal station descriptions (NOAA Form 75-82 or 75-82A), this includes the *40*, *50*, *51*, *52*, *60*, *64*, *65*, *66*, *70*, *74*, *75*, *80*, *84*, *85*, *86*, and *90* records. For bench mark descriptions (NOAA Form 76-186), this includes the *18* and *30* records.

Most units of measure should be abbreviated, but some should not because it would make the meaning unclear. Follow the conventions listed below. Place a period after the abbreviation only when it falls at the end of a sentence.

Unit	Convention
millimeter	MM
centimeter	CM
meter	METER
kilometer	KM
inch	INCH
foot	FT
mile	MI

Distances and lengths should normally not be given in such units as decimeters (DM), dekameters (DAM), hectometers (HM), yards (YD), chains (CH), rods (RD) or links (LK). If common sense indicates that these units should be used in certain instances, use the abbreviations as indicated in parentheses.

Numbers should normally be recorded as figures, not words. When two separate numbers occur in sequence in a sentence, record the first number as a word. For example, write "five 6-inch pipes." When a number is used as a part of a modifier, as in the preceding example, separate the number and its unit with a hyphen.

4. Significant Digits. The number of significant digits in a figure is an indication of how accurately its value was measured. Numbers should be recorded accordingly. Highway distances should generally be measured to the nearest tenth or five-hundredths of a mile (e.g., 0.6 MI) and recorded to the nearest tenth of a kilometer (e.g., 1.0 KM). Reference distances from monuments to prominent objects should usually be measured and recorded to the nearest tenth or hundredth of a meter, depending on the distinction of the point measured to. Distances to and between reference marks must be measured to the nearest millimeter and the nearest hundredth of a foot (e.g., 34.528 METERS, 113.28 FT). Both values should be recorded in the *30* code field (NOAA Form 75-82 and 75-82A).

When converting metric units to English equivalencies, the accepted practice is to record one less decimal place for the English equivalent. If the measurement is roughly made, it should be preceded by the words "approximately" or "about."

5. Hyphenation. In order to improve readability of descriptive material, when a number is followed by a fraction, such as 5½, insert a hyphen between the integer and the fraction, e.g., 5-½.

6. Mention of Ferrous Material. Some concrete marks contain ferrous metal which is detectable by magnetic locators. This should be mentioned in the descriptions.

7. Recovery Descriptions. Recovery descriptions are required whenever a search is made for any previously described geodetic control monument. In some instances, two descriptions are required for one monument to assure that the information is properly entered in the NGS data base. Two recovery descriptions are required when an elevation has been (or will be) established for a horizontal control monument or when a horizontal position has been (or will be) established for a vertical control monument.

The method of conveying the recovery description(s) to Headquarters will vary with the type of field party submitting the description and the type of monument described. *Horizontal and vertical control field parties shall recover all geodetic control monuments located within their respective project areas.* This systematic recovery program should be implemented as follows:

a. The limits of a horizontal control project area are defined as the observations which connect the outermost station on the project sketch. All horizontal and vertical control marks within the set of 7-½ minute quadrangles which cover the project area should be recovered.

b. The limits of a vertical control project area are defined as the set of 7-½ minute quadrangles which cover the leveling routes of the project. All horizontal and vertical control marks within these quadrangles must be recovered.

c. All other NGS field parties are required to recover only the monuments necessary to meet project requirements.

d. Recovery descriptions for vertical control monuments not leveled to, including those destroyed or not recovered, must be coded on NOAA Form 76-186, assembled by quad separately from the automated descriptions, inventoried on a data transmittal sheet, and submitted with project data. These descriptions will be automated by the Vertical Data Section, N/CG172.

e. Recovery descriptions for horizontal control monuments not positioned should be coded on NOAA Form 75-82 or 75-82A, inventoried on a data transmittal sheet and submitted with project data. These descriptions will be automated by the Horizontal Data Section, N/CG171.

f. Horizontal and vertical control parties should transmit over their computer terminals all recovery descriptions for vertical control monuments used to meet project requirements. All other parties should submit the recovery descriptions on NOAA Form 76-186 with the project data.

g. In addition, all parties should use the guidelines listed in section 2.3.4.4 when they report, plot, and scale bench marks leveled to.

2.1.1.8 Ordering Supplies

The NOAA Logistics Supply Center (NLSC) in Kansas City, Missouri, stocks many of the supplies needed to

set marks. Use NOAA Forms 37-4 and 37-4A, Stores Requisition and Continuation Sheet, to order them. Send the forms to:

NOAA Logistics Supply Center, AT/GSM42
National Oceanic and Atmospheric Administration
619 Hardesty Street
Kansas City, Missouri 64124

Send an extra (6th) copy to the Plans and Requirements Staff, N/CG1x10.

Table 2.1.1-1 gives the National stock numbers for each item stocked. Other items available from NLSC are listed in the NOAA Stock Catalog.

Table 2.1.1-1—National stock numbers for frequently used surveying equipment

(Descriptions are given as stated on NLSC inventory listings. Information in parenthesis further clarifies the items.)

Description	Unit of Issue	Stock Number
Mark Horizontal Rod	Each	6675-00-069-3196
Mark Horizontal Stem	Each	6675-00-069-3205
Mark Azimuth Rod	Each	6675-00-069-0000-X
Mark Azimuth Stem	Each	6675-00-069-0001-X
Mark Reference Rod	Each	6675-00-069-3195
Mark Reference Stem	Each	6675-00-069-3204
Mark Vertical Rod	Each	6675-00-069-3197
Mark Vertical Stem	Each	6675-00-069-3206
Mark Survey (base line w/cross)	Each	6675-00-069-0002-X
Mark Survey (base line w/o Cross)	Each	6675-00-069-0003-X
Mark Blank	Each	6675-00-069-3209
Rod, Intermediate (stainless steel)	Each (std. length)	5945-00-999-0008-X
Studs, for SS Rod	Each	5945-00-999-0010-X
Cap, Stainless St (datum cap)	Each	5945-00-999-0013-X
Pipe, PVC 1" Bell	Each (10-ft length)	5945-00-999-0002-X
Coupling PVC (1")	Each	5945-00-999-0004-X
Fitting, PVC (1" to ¾")	Each	5945-00-999-0005-X
Female Adapter	Each	5945-00-999-0000-X
Cement, For PVC	Quart	5945-00-999-0006-X
Petrolatum Filler	16-gal drum	5945-00-999-0011-X
Grease	16-gal drum	9150-00-530-7369
Ring	Each	5945-00-999-0001-X
Pipe PVC, 5"	Each (10-ft length)	5945-00-999-0003-X
Aluminum Logo Cap	Each	5945-00-999-0012-X
Sign Witness Post	Each	9905-00-689-8327
Sign Post	Each	CFN-9905-00-689-8327

2.1.1.9 Use of NGS Disks

National Geodetic Survey disks are to be used by NGS field units and by outside organizations or private individuals performing maintenance or contract work for NGS. They are not to be used by organizations outside NOS for marking their own control points.

2.1.2 Mark Maintenance

2.1.2.1 Purpose, Scope, and Organization

1. **General.** This section is a guideline for mark maintenance field practices. It establishes objectives for the maintenance

program and explains the proper steps for completing each phase of a project. It does not try to instruct personnel in the procedures necessary for measuring distances and directions but does reinforce some subjects already detailed in *Special Publication 247*. It has been so written that qualified engineers can use it and achieve satisfactory results in performing mark maintenance.

2. **Regions.** The mark maintenance program divides the 48 contiguous states into 14 regions. Hawaii has no mark maintenance program and Alaska has a field office that coordinates work done by the Highway Department.

3. **Requirements.** Field work consists of precise vertical and horizontal observations and measurements made in order to maintain the geodetic accuracy of marks established by high precision surveying techniques. All NGS maintenance personnel are highly skilled surveyors capable of independent and responsible analysis of maintenance problems.

4. **Responsibilities.** Field work is coordinated by the Network Maintenance Section, N/CG162. Periodically, the Instrumentation and Equipment Section, N/CG163, repairs, maintains, and calibrates the instruments and equipment used by the mark maintenance engineers (chapter 1.8).

5. **Data Transmittals.** Mark maintenance data should be sent monthly to the Quality Control Section, N/CG164. See section 1.7.4 and figure 1.7.4-1. In addition, the following procedures apply to submitting mark maintenance data:

a. All data should be transmitted on the modified version of NOAA Form 61-29 shown in figure 1.7.4-3.

b. A single Letter Transmitting Data may contain data from several States, but each State must be listed on separate sheets because each State's work is accessioned separately.

c. Within each State the data must be further separated by type (either horizontal or vertical). Both horizontal and vertical data can be submitted as part of the same transmittal but must be listed on separate sheets because horizontal and vertical data are accessioned separately by State.

2.1.2.2 Horizontal, Vertical, and Astronomic Azimuth Observations and Expected Accuracy

The geometry necessary to move a mark or to establish a new azimuth mark is discussed in sections 2.1.2.9 and 2.1.2.10. This section will provide guidance on the number and quality of direction observations necessary to move a mark or to re-establish an azimuth. It will also cover the accuracy expected in work of this type.

1. **Direction Observations.** The number of direction observations required is governed by either the geometry of the existing main scheme network, the order and class of the replaced station, the nearness of other monumented horizontal control, and the distance the mark is to be moved. Unless otherwise noted, the procedures outlined are designed to relate the new station to the old station within 1 part in 50,000. In no case should the procedures employed fail to meet the requirements for third-order, class II surveys as specified in *Classification, Standards of Accuracy, and*

General Specifications of Geodetic Control Surveys. Since checks on mark maintenance work are often by nonstandard methods, it is imperative that the specifications for observations be followed closely.

The following standards apply for setups where the primary lines are shorter than 400 meters. If only the azimuth mark and reference marks are observed in a set of directions, three positions of the circle are required. If additional azimuth points, such as intersection stations, old or new horizontal stations, new azimuth marks, etc., are observed in the same set, four positions of the circle are required. If a mark is moved more than 400 meters, the direction observations and triangle closures will conform to specifications for the order of the mark being moved. When moving marks more than 400 meters, NGS Headquarters should be contacted for recommendations.

Rejection limits between positions of the circle for horizontal directions remain the same as specified in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. Rejections will be made immediately in the field and reobservations will be taken to make certain the proper number of observations are made.

When old reference marks are reobserved, check the old angle by the following criteria:

$$[(300/S_1)^2 + (300/S_2)^2]^{1/2} = \text{minutes of difference between new and old angle (rounded up to next minute),}$$

where

S_1 = Distance to RM 1 in meters

S_2 = Distance to RM 2 in meters

Example:

Distance to RM 1 = 15.6 meters

Distance to RM 2 = 21.7 meters

$$[(30/15.6)^2 + (30/21.7)^2]^{1/2} = 3' \text{ allowed between old and new observations to the RM's.}$$

2. Observation of Astronomic Azimuth. When it is necessary to observe an astronomic azimuth for orientation, eight positions of the circle will be observed using at least a 1-second instrument. The mark station will be the most distant visible horizontal point from the observing station. Preference will be given to "in the ground" marks. If there are two stations nearly equidistant from the observing station, both stations will be included in the observations with the star. The rejection limit for positions of the circle is 5 seconds from the mean. After rejections, a minimum of six positions must remain or the azimuth should be completely reobserved. If possible, the azimuth should be computed before destroying the occupied or mark station.

A correction for the inclination of the standing axis (instrument not level) must be made. The higher the latitude, the more critical this becomes. The inclination correction at 48° latitude is about twice as much as it is at 30° latitude for equal amounts of inclination (mislevel). Therefore, bubble readings must also be taken after each pointing on Polaris. If the vertical angle to the mark sta-

tion is greater than ± 2 degrees, bubble readings must also be taken after each pointing on it. Sufficient time must be allowed between each pointing and bubble reading, to ensure that the bubble has completely stabilized. When the level vial is progressively numbered from the vertical circle end to the other end, compute the corrections as follows:

Correction = $d/4 [(W)-(E)] \tan h$, where

d = Bubble value in seconds of arc per level vial graduation.

W = Arithmetic difference of the direct and reverse readings of the west end of the bubble.

E = Arithmetical difference of the direct and reverse readings of the east end of the bubble.

h = Vertical angle of Polaris or station (positive angle if Polaris or station is above the horizontal, negative angle if below horizontal).

Example:

$$d = 7.''567$$

$$W = 19.5$$

$$E = 18.9$$

$$h = 35^\circ 41' 56''$$

Bubble readings

W	E
05.6	24.8
25.1	05.9
W = 19.5	E = 18.9
(W) - (E) = +0.6	

$$(7.''567/4) (0.6) (0.718543) = 0.''82$$

Even when bubble readings are taken for the inclination correction, the instrument should be kept close to level in case there is any error in the bubble value or in the uniformity of the graduations of the level vial. Bubble readings should be estimated to the nearest 0.1 graduation.

Pointings on Polaris can be made simultaneously with the 1-minute radio signal or by using a reliable timepiece and computing a drift rate for it. When using a timepiece, three sets of radio vs. timepiece comparisons should be made for each set of observations (eight positions in this case), one each at the beginning, middle, and end. At least three, and preferably five, 1-minute signals should be noted. The timepiece should be read and recorded to at least the nearest 0.5 second and preferably to the nearest 0.25 second for the comparison. During the observations, it should be read and recorded to the nearest 0.5 second for pointings on Polaris.

3. Vertical Observations. Differences in elevation must be determined between stations where distances are measured. If vertical angles are observed, they should be observed reciprocally when the vertical angle exceeds 1° or if both marks will be occupied for other reasons. Zenith distance observations will be made during daylight hours and corrected for the heights of instruments and lights (t-o). The sum of the corrected reciprocal zenith distances should equal $180^\circ \pm 1'$. For long lines, curvature of the Earth must be considered in the closure. The number of seconds of curvature and refraction for reciprocal observations is approximately equal to the distance in meters between the stations multiplied by 0.0277. Elevations computed from different points should agree within 10 cm per km. Zenith distances will consist of a minimum of three observations

agreeing within a 10-second spread. In order to achieve checks on lines less than 30 meters, it is necessary to measure the height of instrument and height of target to the nearest millimeter. Over short lines requiring one or two setups, it may be easier and more accurate to observe differences by differential leveling than by zenith distance observations.

If elevation differences are observed by differential leveling, they will be observed to a minimum of third-order specifications. It is preferred that the leveling between stations be recorded separately from leveling between benches over or under stations. Unusual signal placement, such as target set underneath the station, or over the underground mark should be well documented. The sole use of abbreviations or arithmetic signs to indicate unusual conditions is insufficient. When pulling a surface mark to determine if it was disturbed, or to lower it or the underground mark, record the difference in elevation between the surface and underground mark. If lowering the surface and underground marks, also record the elevation differences between the old and new marks.

2.1.2.3 Distance Measurements and Expected Accuracy

1. **Sources of Error.** Distances measured using Electronic Distance Measuring Instruments (EDMI) are subject to errors arising from instrumental components, calibration, meteorological conditions, elevation discrepancies, and the collimation of the instruments or reflectors. Distances measured using tapes are affected by the same conditions; however, the magnitude of error arising from calibration and the condition of the tape are much smaller, and in the case of condition of the tape, generally visually detectable, e.g., a bent tape. On the other hand, incorrect temperature corrections applied to a tape affect the measurement more than incorrect temperature corrections applied to EDM measurements. The EDM used for mark maintenance should have a manufacturer's stated accuracy of no less than ± 5 mm. Standardized tapes used in mark maintenance are expected to yield accuracies of $1 \text{ mm} \sqrt{n}$, where n is the number of tape lengths.

2. **Slope Correction.** Differences in the elevation of the ends of measured lines must be determined. A discussion of the techniques to be employed are discussed in subsections of section 2.1.2.2.

3. **Accuracy.** When EDM's are employed to measure a line, the procedures outlined for second-order, class I traverse will be employed. These procedures, found in *Specifications To Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*, are modified slightly for mark maintenance as follows:

Instruments: ELECTRO-OPTICAL, MICROWAVE, and INFRARED.

Complete Measurement: ELECTRO-OPTICAL: Three observations, one concentric, and two offset ± 0.4 meter. (A shorter offset bar may be used.)

MICROWAVE: A full set of fine and coarse readings as recommended by the manufacturer. For instruments that measure from both ends, the observations at one end should be completed prior to beginning observations at the other end. Observations are to be made in opposite directions when the remote unit serves as a slave only.

INFRARED: Indirect readout-three observations, one concentric and two offset ± 0.15 meter to ± 0.4 meter.

Direct readout-10 readings for each measurement, rejecting any individual measurement that exceeds 3 times the manufacturer's claimed accuracy from the mean.

One concentric measurement and two offset ± 0.15 meter to 0.4 meter.

Spread between observations: ELECTRO-OPTICAL: Seldom to exceed 17 mm, never to exceed 25 mm.

MICROWAVE: Difference between observations made at both ends of the line not to exceed 0.1 meter after applying meteorological corrections.

INFRARED: Seldom to exceed 10 mm and never to exceed 15 mm.

4. **Meteorological Measurements.** The wet (for microwave instruments) and dry bulb temperatures and the barometric pressure should be observed at both ends of a line whenever the difference in elevation exceeds 30 meters, whenever one end of the line is in the sun and the other is in the shade, or whenever the length of the line exceeds 1 km. Otherwise, these quantities may be observed at the instrument only.

Temperatures should be measured at instrument height. Meteorological equipment should always be shaded from the direct rays of the sun.

5. **Instrument Errors.** Certain instruments have a zero constant that is unstable due to temperature changes, electronic deterioration, or physical abuse. The Instrumentation and Equipment Section developed a calibration cap for the HP 3800. By correct application of the cap before each measurement, error due to a shifting zero constant is nullified. The use of the cap is not time consuming. It is required for all measurements using HP 3800's.

All other instruments must be carefully calibrated and the zero constants faithfully recorded along with reflector constants, offsets, and any irregularities.

6. **Taped Distances.** Precise taped traverses should be made with standardized 30-meter steel tapes or standardized 50-meter invar tapes. These traverses should be taped both forward and backward and agree within 3 mm for distances less than one tape length. Forward and backward measured distances greater than one tape length should agree within $20 \text{ mm} \times \sqrt{k}$, where k is the distance in kilometers. All measurements should be made with the tapes under standard tension. Temperature, inclination, and catenary corrections must be recorded and should be computed in the field. The difference in elevation between tape supports must be determined by differential leveling.

2.1.2.4 Horizontal Recovery and Description Procedures

1. **Existing Data.** When a mark is to be visited, all published information on the station, both vertical and horizontal, should be collected and reviewed. Data that can be acquired from NGS are horizontal quads and lithos, USGS 7-1/2 minute quadrangles, 1° x 2° geodetic control diagrams, NGS vertical quads and listings, and local data supplied by State and county agencies. Special note should be made of landmarks/intersection stations (see note) and other nearby survey marks that may be visible from the ground at the station being recovered. These intersection stations and survey marks are useful for verifying the position of the recovered station.

Note: Historically, NGS has used the term "intersection station." The terms "landmark" and "intersection station" are used synonymously in this manual. "Landmark" is defined in the *Input Formats and Specifications for the NGS Data Base* as an "unmonumented recoverable horizontal control point (usually an intersection station) such as a flagpole or church spire." *Special Publication 247* defines intersection stations as "prominent objects such as church spires, water tanks, standpipes, towers, beacons, tall chimneys, and prominent mountain peaks."

2. **To Reach.** While driving to a station, note any changes to the "to reach" portion of previous descriptions in a new recovery description. Notes should be made in NOAA Form 75-82 (9-78 version) or 75-82A.

3. **Reference Measurements.** Check all measurements used as references, such as "30 ft south of centerline of road, 22 ft east of telephone pole" and, where changes are needed, note them for inclusion in a recovery description. An attempt should be made to locate any mark involved with the original station, i.e., reference marks, azimuth marks, bench marks, etc.

4. **Public Contacts.** Contact property owners before moving or replacing marks on private property. If requested to lower or remove marks, comply with the wishes of the property owner. If a mark may be endangered by construction, contact the office in charge of the new construction for the area and then coordinate the movement of the mark.

5. **Condition of Marks.** Check all marks for damage, noting any irregularity and/or destruction. Tape the distances between the station and old reference marks and also the distance between reference marks. Occupy the station and measure the directions to all marks concerned in the recovery. Details of objects and marks concerned are explained in sections 2.1.2.5 through 2.1.2.10. Record all observations in NOAA Form 76-109.

6. **Replacing Marks.** If the old station and underground mark were destroyed, but can be reset from previous data, set a temporary point from tape distances and turn angles to all old references, azimuth marks, and objects observed in previous occupations. If the angle between reference marks checks within prescribed limits (section 2.1.2.2) and/or the angle between two well-defined distant azimuth marks checks a previously observed angle within 10°, reset the mark. If the directions check within prescribed limits

(section 2.1.2.2) between reference marks and/or within 10 seconds between two well-defined distant azimuth objects, reset the marks. If the underground mark is still intact, make all check measurements before and after resetting the surface mark. Record all measurements in NOAA Form 76-109. Record all descriptive text in NOAA Form 75-82 (9-78 or newer version).

A positioned intersection station or other survey mark published on the North American Datum of 1927 should not be ignored because it was not previously observed from the recovered station. Field personnel have the capability of inverting between two stations using portable programmable calculators. From the computed azimuths, angles between sighted objects should be determined as a check on observations. (See fig. 2.1.2.1.) When this approach is taken, the allowable angle check is 30 seconds. In the event both the observed and computed angles are used, the observed angle specification takes precedence over the computed angle specifications.

7. **Recovery Descriptions.** When all observations have been completed for the recovered mark, a recovery will be written on NOAA Form 75-82 (9-78 or newer version) or 75-82A using the format written and explained in chapter 3 of the *Input Formats and Specifications for the NGS Data Base*. Entries must be clear and legibly written in ink. If other stations or intersection stations are used in connection with work at a horizontal station, they will be visited and recoveries written for each.

8. **Descriptions.** When a replacement station is set with accompanying reference and azimuth marks, and all measurements are made as outlined in the following sections, a station description must be filled out using NOAA Form 75-82 (9-78 or newer version) or 75-82A following the format of chapter 3 of the *Input Formats and Specifications for the NGS Data Base*. The description must be clearly and legibly written in ink.

2.1.2.5 Horizontal Control Marks

The setting of marks when old stations have been destroyed is explained in *Special Publication 247* (pp. 88-94). The following will emphasize some aspects of setting marks.

1. **Reference Marks.** New reference marks should be set by the following rules whenever the immediate terrain permits. The angle between two reference marks should not be less than 30° nor larger than 150°. An angle closer to 90° provides a very strong side-angle-side (SAS) check and less chance of error if the station mark must be reset from reference mark measurements. Setting two reference marks in line is not permissible.

Where terrain permits, reference marks should be set within one 30-meter tape length and more than 5 meters from the station. However, an additional reference mark may be set between 100 and 400 meters from the station *only when an azimuth mark cannot be set and no positioned landmarks or intersections are visible from the ground*. It should not be noted in the description that this mark is considered an azimuth mark. *Caution:* Centering, leveling, and

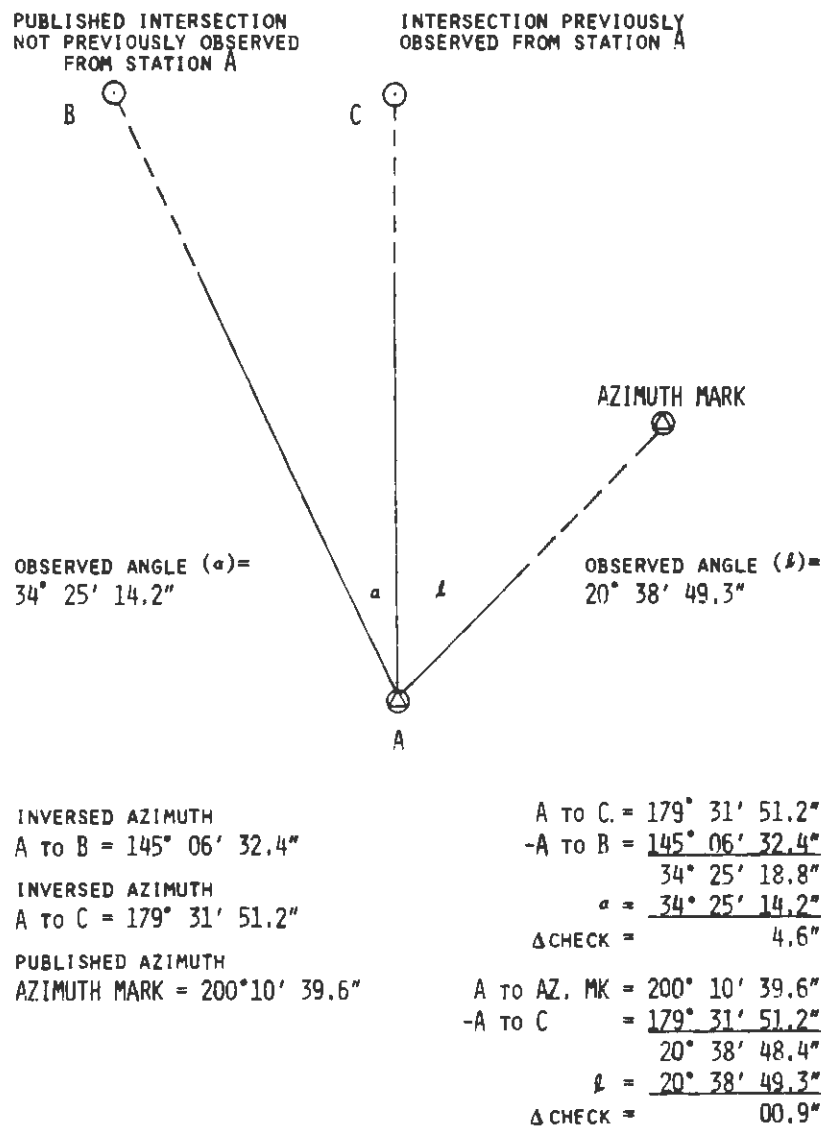


Figure 2.1.2-1.—Angle check using distant points and computing inversed azimuths

pointing the instrument and the target over the marks are very critical on short sight distances.

2. **Azimuth Marks.** Azimuth marks will be set at least 400 meters but no more than 3,200 meters from the station, or they will not be set.

3. **Damaged Marks.** New marks should replace reference and azimuth marks that are badly disturbed or uprooted.

Drill holes left after a disk is lost may be reused for a new restamped reference or azimuth mark if new measurements are made. The stamping for the reference mark should bear the next consecutive number. The azimuth mark should be stamped as shown in section 2.1.2.6, paragraph 2, case VII.

2.1.2.6 Naming Marks

Technical Memorandum *C&GSTM-4*, Specifications for Horizontal Control Marks, and *Special Publication 247* (pp. 86-89) give rules and examples for naming and marking

stations. Section 2.2.4.3 lists the maximum length allowed for station names.

This section lists changes to *C&GSTM-4* for cases VII and VIII, and changes to *Special Publication 247* for the use of the word "reset."

1. **Reset.** The word "reset" shall not be used for horizontal disk stampings.

2. **Case VII-Station Not Moved.** The station mark is not remarked or moved, but the azimuth mark is reset in the same position. In this case the azimuth mark shall be stamped with the name and year of the original station above the arrow and the year of the new mark establishment below the arrow.

Example: A new azimuth mark is reset in the same position for station ARZO 1948.

ARZO 1948
 →
 1968

3. Case VIII-Azimuth Mark Moved. A new azimuth mark is established for the station. The new azimuth should be stamped with the name of the station, including the original year established, NO 2 (or the next unused consecutive number) and the year in which the new mark is established. This procedure will be used regardless of whether the original azimuth exists or not.

Example: Station BAKER 1955 has an azimuth which was established in 1955. In 1968, a second azimuth was established at the station.

BAKER 1955

NO 2

1968

4. Marks of Other Organizations. Marks other than NGS or USC&GS horizontal marks, reference marks, azimuth marks, or bench marks will not be restamped or changed in any way unless a replacement is specifically requested by the agency that sets the mark.

a. When another agency's mark is used as a horizontal station, it will not be restamped with the date of occupation. The date of NGS occupation will appear on the description as the NGS date for the station mark. Any actual stamping appearing on the disk or mark will be described in the body of the description.

b. Marks of other agencies will always be recognized by the name designated by the agency setting the mark. This designation will be fully described in the body of the description.

c. Other agency marks used for a reference or an azimuth mark will be listed in the box score by the agency designation of the mark. Only NGS reference or azimuth marks will be listed by station name, date, and RM number or AZ MK. Thus, USGS TT 675 1927 will be listed in the box score as TT 675 USGS. If it is used as an azimuth mark it will be described in the body of the description as "Azimuth mark is a standard USGS disk stamped TT 675 1927, set in concrete. . ."

2.1.2.7 Redundant Observations

Redundant observations or measurements are those that exceed the minimum needed to establish a horizontal position. Some redundancy is necessary for check purposes; however, excessive redundancy should be avoided. This section explains excessive redundancy, excessive measurements, and useless observations.

1. Excessive redundancy. After a check has been made on the reliability of an azimuth or position, additional checks are not useless but are redundant. Observations to four or more published stations or landmarks are excessively redundant, since the primary purpose is to provide a check on the azimuth or position.

2. Excessive Observations and Measurements. The use of modern instruments has created a tendency to measure all distances and directions at every mark at a station site to all other marks at a site. The direction measurements from the reference marks and azimuth marks and some of

the distance measurements are excessive except in cases where no other checks are available. Examples of cases where the reference and azimuth marks should be occupied are discussed in sections 2.1.2.9 and 2.1.2.10.

3. General Rule. In general, take no observations that are useless. Redundant observations are not wrong, but are undesirable because they cause excessive recordkeeping and computations. Keep redundancy to a minimum.

2.1.2.8 Occupying a Station for Check

1. Undisturbed Stations. When a station is recovered, check the condition and stability of the station. If all marks are found undisturbed, it is not necessary to do more than make the following check measurements. However, see subsection 2 of Section 2.1.2.9 concerning old azimuth marks.

2. Distance Measurements. Assuming that all marks are firmly in the ground and the recovery is straightforward, make distance measurements to the reference marks using a 30-meter steel tape. Attempt to make the measurements horizontally. If this is not possible because of excessive slope or obstructions, measure the slope distance, and compute the horizontal distance. This may be accomplished by using the difference in elevation, preferably determined by leveling or by using a nonreciprocal vertical angle. The measurement need not be reduced for catenary or temperature. When reference marks are more than one tape length away and an EDM is available, it may be used to measure the check distances as long as care is taken as outlined in section 2.1.2.3. All observations will be recorded on NOAA Form 76-109.

3. Distances Between RM's. Whenever possible, measure between reference marks. Use a SAS computation to check reference mark directions and distances when the distance between reference marks was measured.

4. Observation of Directions. For the initial pointing, select the best available point as the initial direction using the following priority list:

- A published horizontal control station more than 400 meters away.
- A published intersection station more than 400 meters away.
- An azimuth mark.
- A nonpositioned previously observed intersection station. If used, describe fully.
- If nothing else is visible, use the most distant reference mark.

All directions will be recorded on NOAA Form 76-109 along with any problems. See section 2.1.2.2 for specifications for horizontal directions. See figure 2.1.2-2 for a sketch of a recovery and check procedure.

5. Checking "Box Score" Values. Compare old box score values against the new observations and, if discrepancies occur, recheck the new observations. Directions to reference marks should check within the limits specified in section 2.1.2.2. Distances to reference marks should check within 1 cm. If the previous measurements indicate a slope distance (unless mark to mark), no check is possible. The previ-

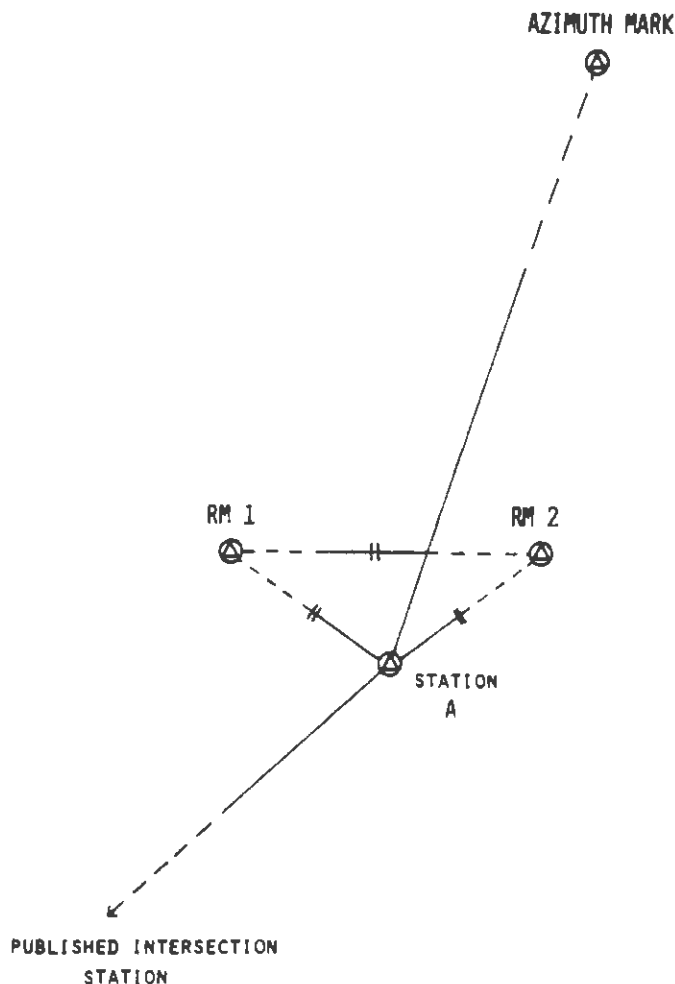


Figure 2.1.2-2.—Sketch of observations taken when occupying a station for a check

ous measurements should be known prior to the new measurements, so that a check on the new can be made immediately without breaking down the tape benches. Azimuths to intersection stations and azimuth marks should check within 10 seconds. Note any discrepancies on NOAA Form 75-82 (9-78 version) or 75-82A. If no discrepancies exist, specify in the body of the descriptive text that the angles and distances between the station, reference marks, and azimuth marks were verified with the latest published box score values.

2.1.2.9 Occupying a Station To Set Reference Marks and/or Azimuth Marks

1. *Undisturbed RM's.* When an undisturbed reference mark is to be moved, check the distance and direction as in section 2.1.2.8 before removing mark. New reference marks will be set as described in section 2.1.2.5 and stamped as described in section 2.1.2.6. If no other work is to be done, observations will be made and checked as described in section 2.1.2.8.

2. *Disturbed or destroyed RM's.* When a station is recovered and reference marks and/or azimuth marks are found disturbed or destroyed, new marks will be set unless the

situation does not allow for replacements. In some cases there may be no suitable place to set a new mark. This will be noted along with the reason, such as "area under cultivation." Record notes on NOAA Form 75-82 or 75-82A.

3. *Undisturbed Azimuth Marks.* If the old azimuth mark is recovered undisturbed and is still visible from the station, several possible situations may exist.

a. If the old azimuth mark is not to be moved but was never positioned, a distance will be measured to the azimuth mark if an EDM is available. Reciprocal zenith distance observations will be made to obtain differences in elevation. Reduce the measurements to horizontal distances using the computed differences in elevation.

b. When a new azimuth mark is established to replace an old azimuth mark, the following should be done. Measure from the station to the new azimuth mark using an EDM. Observe horizontal directions from the station to both azimuth marks and to other horizontal control stations or intersection stations in order to transfer the azimuth from the old to the new azimuth mark. Observe reciprocal zenith distances from the station and the new azimuth mark. Reduce the EDM measurement from a slope distance to a horizontal distance.

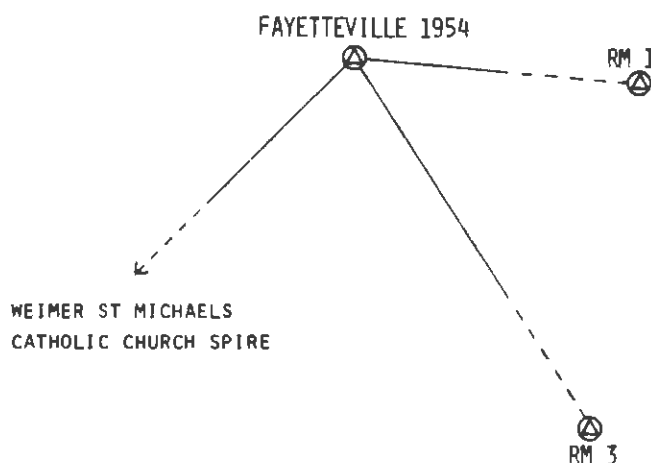
c. When the old azimuth mark cannot be checked through published intersection stations or other horizontal stations, the reliability of the mark must be taken on faith. If the old reference marks check within the tolerable limit with the azimuth mark (section 2.1.2.2), some assurance exists that the mark is stable. If a check with the RM's does not match previous observations but the RM's check between themselves, the reliability of the azimuth mark is questionable. Check the mark carefully for signs of disturbance. If an unpublished point was observed in a previous box score and is still visible, observe it for an additional check. If an attempted check does not match previous work, observe an astronomic azimuth to resolve the problem. Astronomic azimuth observations are discussed in section 2.1.2.2.

d. If the reference marks are gone, no other observations can be made to check the old azimuth mark, and no sign of disturbance is apparent, accept the mark as stable. Simply set new reference marks and make observations to orient them to the azimuth mark. It is not necessary to observe an astronomic azimuth or make any observations that require excessive time and work unless some evidence exists of possible movement or error in previous work.

e. When a published station more than 400 meters distant is visible, a check must be made on the angle between the old azimuth mark and the distant station. The azimuth mark is considered reliable if the angle as determined by published directions is within 10 seconds of the angle as determined by observed directions. If the difference exceeds 10 seconds, compute the same angle using azimuths determined from the published data (see figs. 2.1.2-3 through 2.1.2-6), and make similar checks using directions and azimuths to other published stations more than 400 meters distant if possible. If not possible, make similar checks to the reference marks. By deduction, one may sometimes

STATION REOCCUPIED IN 1978

OBSERVED ANGLE FROM SPIRE TO RM 3	289 51' 30.0"	
FROM 1974 BOX SCORE	<u>289 51' 42.5"</u>	
	12.6"	NO CHECK
PULISHED AZIMUTH RM 3	310 02' 43.9"	
INVERSED AZIMUTH TO SPIRE	<u>20 10' 59.8"</u>	
	289 51' 44.1"	
OBSERVED ANGLE	<u>289 51' 30.0"</u>	
	14.1"	NO CHECK
OBSERVED ANGLE RM 1 TO RM 3	67 34' 30.9"	
FROM BOX SCORE	<u>67 34' 02.6"</u>	
	28.3"	GOOD CHECK



NOTE: CONSIDERING THE RESULTS AS GIVEN ABOVE AND WITH NO OTHER CHECKS AVAILABLE, OBSERVE AN ASTRONOMIC AZIMUTH TO RM 3 UNLESS DEFINITE PROOF EXISTS OF CHANGE TO THE SPIRE.

Figure 2.1.2-3.—Example of where check angles fail and an astronomic azimuth is necessary

determine whether the occupied station, the azimuth mark, or the distant station is suspect.

When it is probable that the distant published point is unchanged, or both the azimuth mark and the published point agree within RM limits given in section 2.1.2.2, observe an astronomic azimuth to the azimuth mark. If the published point is confirmed to be in error and the azimuth mark and reference marks are in agreement, accept the azimuth mark as stable.

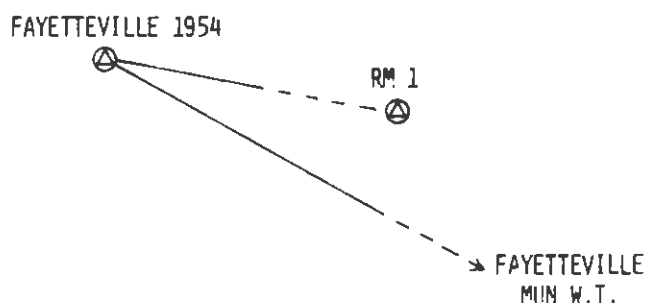
4. **Disturbed or Destroyed Azimuth Marks.** When the old azimuth mark has been destroyed or disturbed, all traces of it are to be removed. If convenient, a new mark will be set nearby. If the area of the old azimuth mark is no longer suitable, select a new location where the new azimuth mark is unlikely to be disturbed. If two published intersection stations can be observed and the observed angle and the

difference in their computed azimuths check to within 10 seconds, make the initial pointing on one of the intersection stations and turn directions to the reference marks, the new azimuth mark, and the second intersection station. Take an EDM measurement to the new azimuth mark and observe the reciprocal zenith distances.

a. If only one published intersection station is visible, check that observed angles and the old observations to the reference marks agree within specified limits (section 2.1.2.2). This may require carrying the computed azimuth through the old azimuth to the reference marks. (See fig. 2.1.2-4.) If a check cannot be made because the old reference marks do not fit, or are destroyed or disturbed, an astronomic azimuth observation must be taken to the new azimuth mark. Also, measure to the azimuth mark with an EDM and observe the reciprocal zenith distances.

OCCUPATION IN 1978, AZIMUTH MARK (RM 3) FOUND DESTROYED

PUBLISHED AZIMUTH TO RM 3	310 02' 43.9"
INVERSED AZIMUTH TO FAYETTEVILLE MUN W.T.	290 00' 43.8"
(SEE FIGURE 2.1.2 - 6)	20 02' 00.1"
FROM 1974 BOX SCORE RM 3 TO RM 1	292 25' 57.4"
	312 27' 57.5"
OBSERVED ANGLE FROM INTERSECTION TO RM 1	312 28' 26.0"
	28.5" GOOD CHECK



NOTE: THE ABOVE WOULD BE SUFFICIENT CHECK ON THE INTERSECTION IF NO OTHER INTERSECTION OR HORIZONTAL MARK WERE VISIBLE.

Figure 2.1.2-4.—Example of where check angle is acceptable

b. When the old azimuth mark is destroyed, but a monumented published station over 400 meters away is visible, the published station may be used to establish an azimuth to the new azimuth mark after the following is done. Visit the station to be used for the initial pointing and follow the recovery procedures as outlined in section 2.1.2.4. Make certain there is no sign of disturbance of the mark. If necessary and possible, reset the mark as described in section 2.1.2.4. Return to the original station and turn angles to establish the azimuth to the new azimuth mark as specified in section 2.1.2.2. If possible, use a monumented intersection station for a check. At the same time, measure an EDM distance between the stations, as described in section 2.1.2.3, and inverse between the published stations. Reduce the EDM measurement to sea level distance. If the difference between the inversed distance against the measured distance exceeds 1 part in 300,000 plus or minus the standard error for the instrument, check the equipment for plumbing. If all appears correct, note the discrepancy on NOAA Form 76-109. It is possible for two published station positions adjusted in separate projects to exceed the standards of accuracy, so do not assume the EDM is

in error. However, check the equipment on a calibration base line at the earliest opportunity.

2.1.2.10 Occupying a Station To Set a Replacement

The replacement of a station that has been or will be destroyed involves much that has been described previously. Some of this section will be repetitive. For procedures covering recovery and resetting of old stations and setting new azimuth or reference marks, refer to sections 2.1.2.4 through 2.1.2.9.

1. *All Marks Recovered in Good Condition.* Assume that a station to be replaced has been recovered in good condition and both reference marks and the azimuth mark are also recovered in good condition. Locate a suitable place to set the replacement station, preferably within one 30-meter tape length of the old station. It may be possible to use the old azimuth mark and at least one old reference mark at the new station. (See fig. 2.1.2-7.) Otherwise set new marks as described in Section 2.1.2.5 and stamp new marks as described in section 2.1.2.6. (See fig. 2.1.2-8.)

a. When the old azimuth mark can be used for the new station, occupy the old station and turn directions to the

OCTOBER 1966
U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
COAST AND GEODETIC SURVEY
Revised JULY 1974

HORIZONTAL CONTROL DATA

by the
Coast and Geodetic Survey
NORTH AMERICAN 1927 DATUM

QUAD 290964 STATION 1007
TEXAS
LATITUDE 29°30' TO 30°00'
LONGITUDE 96°30' TO 97°00'
DIAGRAM NH 14-9 SEGUIN

DEPARTMENT OF COMMERCE
U.S. COAST AND GEODETIC SURVEY
Form 533
Rev. Aug 1965

DESCRIPTION OF TRIANGULATION STATION

NAME OF STATION: FAYETTEVILLE STATE: TEXAS COUNTY: Fayette

CHIEF OF PARTY: H.S.C. YEAR: 1954 Described by: R.W.H.

NOTE	HEIGHT OF TELESCOPE ABOVE STATION MARK	HEIGHT OF LIGHT ABOVE STATION MARK	DISTANCES AND DIRECTIONS TO AZIMUTH MARK, REFERENCE MARKS AND PROMINENT OBJECTS WHICH CAN BE SEEN FROM THE GROUND AT THE STATION
1a	20 METERS	23 METERS	
7a	Surface station mark		
	Underground station mark		
	OBJECT	BEARING	DISTANCE
			FEET METERS
	MOORE 1943		
11a	Reference mark 2	NW	73.78 22.490 0 00 00
11a	Reference mark 1	NE	97.90 29.840 08 49 17
16a	Azimuth mark	SE	Approx. 0.35 mile 189 56 24.2

Station is located about 1.25 miles west-northwest of Fayetteville on the right of way of State Highway 159.

To reach the station from the post office in Fayetteville, go south 0.1 mile to State Highway 159, turn right, go 0.9 mile to the azimuth mark on the right. Continue 0.35 mile to the station on the left.

The station mark, a standard disk stamped FAYETTEVILLE 1954, is set in a concrete monument flush with ground level. It is 44 feet southwest of the center line of State Highway 159, 27 feet west of a lone oak tree and 3 feet west of a witness post.

Reference mark 1, a standard disk stamped, FAYETTEVILLE NO 1 1954, is set in a concrete monument that projects 6 inches. It is

51 feet northeast of the center line of State Highway 159 and 1 foot southwest of a large fence post.

Reference mark 2, a standard disk stamped FAYETTEVILLE NO 2 1954, is set in a concrete monument that projects 6 inches. It is 48 feet southwest of the center line of State Highway 159 and 2 feet southeast of a telephone pole.

The azimuth mark, a standard disk stamped FAYETTEVILLE 1954, is set in a concrete monument that projects 3 inches. It is 51 feet northeast of the center line of State Highway 159, 40 feet west of a house, 2 feet northwest of a witness post and 2 feet west of a fence corner.

RECOVERY NOTE, TRIANGULATION STATION Quad: 290964 R
STATION: 1007

NAME OF STATION: FAYETTEVILLE
ESTABLISHED BY: H.S.C. YEAR: 1954 STATE: TEXAS BENCH MARK ALSO []
RECOVERED BY: C.L. NOVAK YEAR: 1974 COUNTY: Fayette
AIRLINE DISTANCE AND DIRECTION FROM NEAREST TOWN: 1-1/4 miles west of Fayetteville
HEIGHT OF TELESCOPE ABOVE STATION MARK: 5 FEET. HEIGHT OF LIGHT ABOVE STATION MARK: FEET.

DISTANCES AND DIRECTIONS TO AZIMUTH MARK, REFERENCE MARKS AND PROMINENT OBJECTS WHICH CAN BE SEEN FROM THE GROUND AT THE STATION				
OBJECT	BEARING	DISTANCE		DIRECTION
		FEET	METERS	
Weimar, St. Michaels Catholic Church Spire 1943	S	(16 miles)	00 00 00.0	
Weimar, Muni Water Tank 1943	S	(16 miles)	00 23 01.9	
Ammanville, Catholic Church Spire 1943	SW	(16 miles)	28 56 50.0	
La Grange, Cable TV Mast	WSW	(12 miles)	57 12 47.2	
La Grange, Microwave Mast	WSW	(12 miles)	57 45 56.6	
Reference Mark No. 2	NW	73.78 22.490	109 02 34	
Reference Mark No. 1	NE	97.95 29.855	222 17 40	
Reference Mark No. 3 (Az Mk)	E	(0.35 mile)	289 51 42.6	
Azimuth Mark 1954 (Destroyed)	E	(0.35 mile)	290 03 16.5	
Weimar, Microwave Tower	S	(16 miles)	356 48 57.9	

The station mark, and reference marks No. 1 and No. 2 were recovered in good condition. The azimuth mark was found destroyed, it was tilted toward the west. A new azimuth mark (reference mark No. 3) was set. The original azimuth mark was observed for a rough check and then removed. A new description follows:

ADJUSTED HORIZONTAL CONTROL DATA

NAME OF STATION: FAYETTEVILLE YEAR: 1954
STATE: TEXAS LOCALITY: Brenham Area
Second -ORDER Triangulation SOURCE: G-10657 FIELD SKETCH: TEXAS 148

GRID DATA	COORDINATES (Feet)	PLANE AZIMUTH & FOR S&B ANGLE	MARK
STATE: TEXAS	x 3,153,109.33	308°22'21"	AZIMUTH MARK
ZONE: C	y 107,925.29	+ 1 52 29	
CODE: 4203		308 10 15	AZIMUTH MARK RM 3
STATE: TEXAS	x 2,730,678.05	309 07 02	AZIMUTH MARK
ZONE: S C	y 762,828.86	+ 1 07 48	
CODE: 4204		308 54 56	AZIMUTH MARK RM 3

GEODETIC DATA	POSITION		SECONDS IN METERS	ELEVATION
	LATITUDE	LONGITUDE		METERS FEET
	29°54'41"524	96°41'36.691		

TO STATION	GEODETIC AZIMUTH (From south)	DISTANCE	
		LOGARITHM (Meters)	METERS
AZIMUTH MARK		THIRD ORDER	
AZIMUTH MARK RM 3		310°14'50.70	
		310 02 43.9	

Figure 2.1.2-5.—Data necessary to compute check angles in figures 2.1.2-3 and 2.1.2-4

OCTOBER 1966
U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
COAST AND GEODETIC SURVEY

HORIZONTAL CONTROL DATA

by the
Coast and Geodetic Survey
NORTH AMERICAN 1927 DATUM

QUAD 290964 STATIONS 1041, 1042
TEXAS
LATITUDE 29°30' TO 30°00'
LONGITUDE 96°30' TO 97°00'
DIAGRAM NH 14-9 SQUIN

ADJUSTED HORIZONTAL CONTROL DATA

NAME OF STATION WEIMAR MUNICIPAL WATER TANK YEAR 1943
STATE TEXAS LOCALITY Giddings to Tivoli and Wallis to Stockdale
Third ORDER Triangulation SOURCE G-6123 FIELD SKETCH TEXAS 95

GRID DATA	COORDINATES (Feet)	PLANE AZIMUTH STATION ANGLE	MARK
STATE: TEXAS ZONE: S C CODE: 4204	X 2,703,659.43 Y 686,264.89	+ 1 05 09	
STATE: ZONE: CODE:			

GEODETIC DATA	POSITION	SECONDS IN METERS	ELEVATION
	LATITUDE 29°42'08"836 LONGITUDE 96°47'00"140	NORTH WEST	METERS FEET

TO STATION	GEODETIC AZIMUTH (From mark)	LOCALITY (Meters)	DISTANCE METERS
Computed from stations SCHULENBURG, HERMANN, KALUZA, GLIDDEN, JANAK, WEIMAR			

WEIMAR, CITY WATER TANK (Colorado County, Tex., P.L.S., 1943)--
This intersection station is the municipal tank of Weimar which is
located in the westerly part of town on S side of U.S. 90. Tank
is supported on 4 steel legs and the entire structure, which is
painted aluminum, is about 115 feet high. The name "WEIMAR" is
painted on the westerly side. Point observed on was ball on apex
of conical roof.

Form 502
(11-6-66)

U.S. DEPARTMENT OF COMMERCE - COAST AND GEODETIC SURVEY
RECOVERY NOTE TRIANGULATION STATION

R

Name on Station: Weimar City Water Tank
Revised by: P. L. S. Year: 1943 State: Texas
Revised by: K. M. Bates Year: 1963 County: Colorado

Detailed description as to the status of the original description, including marks found, changes made, and other pertinent facts.

Station was recovered in good condition as described.
Directions for proceeding to station are correct.

K. M. Bates

* Name of kind of mark should be inserted here. The station was actually visited by the party should also be noted at the end of the recovery note.
Remarks—Data of this form must be sent to every station recovered. Coast GE 500-1a

ADJUSTED HORIZONTAL CONTROL DATA

NAME OF STATION WEIMAR ST MICHAELS CATHOLIC CHURCH SPIRE YEAR 1943
STATE TEXAS LOCALITY Giddings to Tivoli and Wallis to Stockdale
Third ORDER Triangulation SOURCE G-6123 FIELD SKETCH TEXAS 95

GRID DATA	COORDINATES (Feet)	PLANE AZIMUTH STATION ANGLE	MARK
STATE: TEXAS ZONE: S C CODE: 4204	X 2,704,776.98 Y 687,831.94	+ 1 05 16	
STATE: ZONE: CODE:			

GEODETIC DATA	POSITION	SECONDS IN METERS	ELEVATION
	LATITUDE 29°42'24"138 LONGITUDE 96°46'47"132	NORTH WEST	METERS FEET

TO STATION	GEODETIC AZIMUTH (From mark)	LOCALITY (Meters)	DISTANCE METERS
Computed from stations SCHULENBURG, KALUZA, GLIDDEN, JANAK, WEIMAR			

WEIMAR, CHURCH SPIRE (Colorado County, Tex., P.L.S., 1943)--This
intersection station is the spire of St. Michael's Catholic Church
which is located on the northerly side of town. Church is a light-
colored brick building with a slate-covered spire about 100 feet
high on W end. Point observed upon was the cross on spire.

Figure 2.1.2-6.—Data necessary to compute check angles in figures 2.1.2-3 and 2.1.2-4

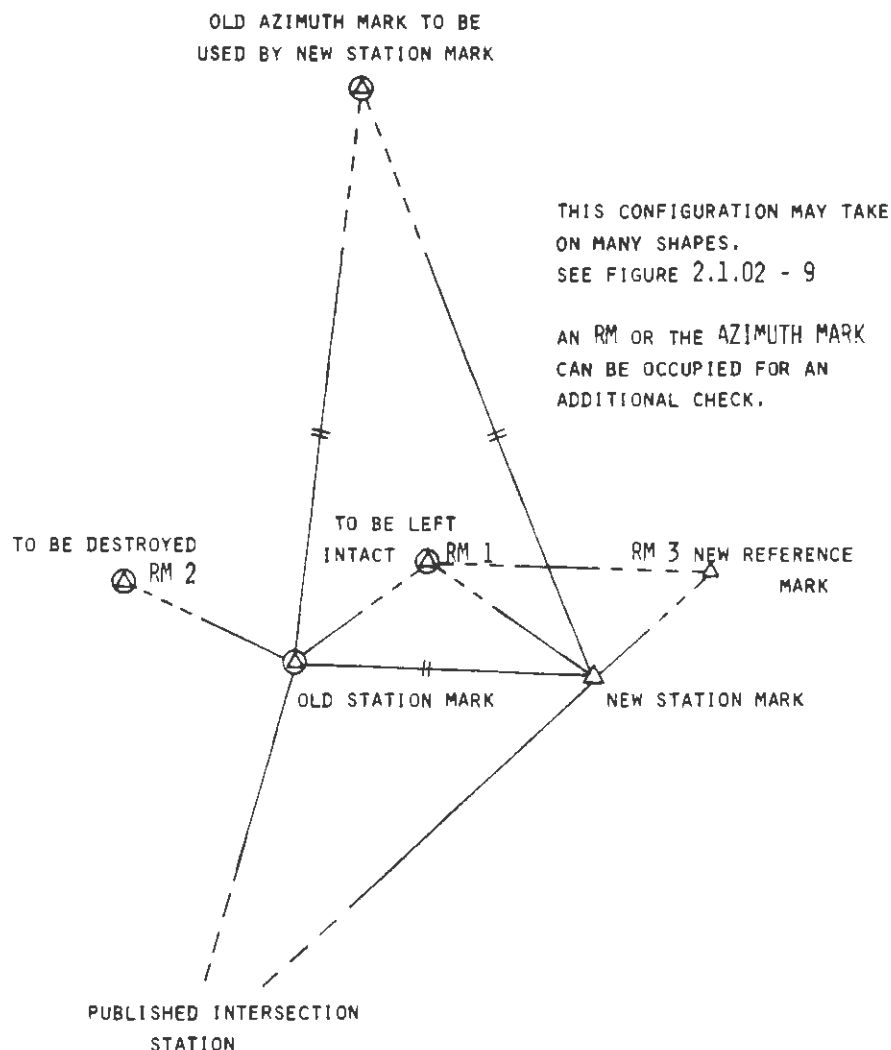


Figure 2.1.2-7.—Sketch of the establishment of a new station using the existing azimuth mark and some existing reference marks

old azimuth mark, reference marks, and to the new station (fig. 2.1.2-7). Make the initial pointing on a published intersection station if visible or preferably another horizontal station at least 400 meters away. Compare observed angles against old observations or angles derived from computed inverses. Resolve any discrepancies before continuing. Tape between stations using two standardized 30-meter steel tapes and follow instructions in *Special Publication 247* (pp. 235-236), and section 2.1.2.3. If terrain or circumstances will not permit the replacement station to be set within 30 meters of the old station, the distance between stations should be measured with an EDM using procedures outlined in section 2.1.2.3. Occupy the replacement station and measure the angles between the intersection stations or other distant horizontal control station (if visible), the old station, the old azimuth mark, and the reference marks. Measure an EDM distance to the old azimuth mark from the old and new stations. If a well defined intersection station was observed from the replacement station, no further observations are needed. If no distant

horizontal published point is visible, occupy the azimuth mark and observe angles to the old and new station. (See fig. 2.1.2-9.) When all observations are complete and distances have been reduced and checked, compute a geographic position for the replacement station. Even when the old azimuth mark was previously positioned, compute a geographic position for check purposes. When the azimuth mark is occupied and a triangle closure is obtained, it must close within the tolerance, in seconds, of 180 (600 divided by shortest side rounded to the nearest meter). Observe the reciprocal zenith distances.

b. When the old azimuth mark is to be destroyed, although it is considered or proven stable, establish a new azimuth mark. If the new azimuth mark can be seen from the old station, occupy the old station and turn directions to the old azimuth mark (if visible), the new azimuth mark, the new station, and any check points or references. Occupy the new station. If an established intersection or horizontal station more than 400 meters away can be seen, make the initial pointing on it and turn directions to the old sta-

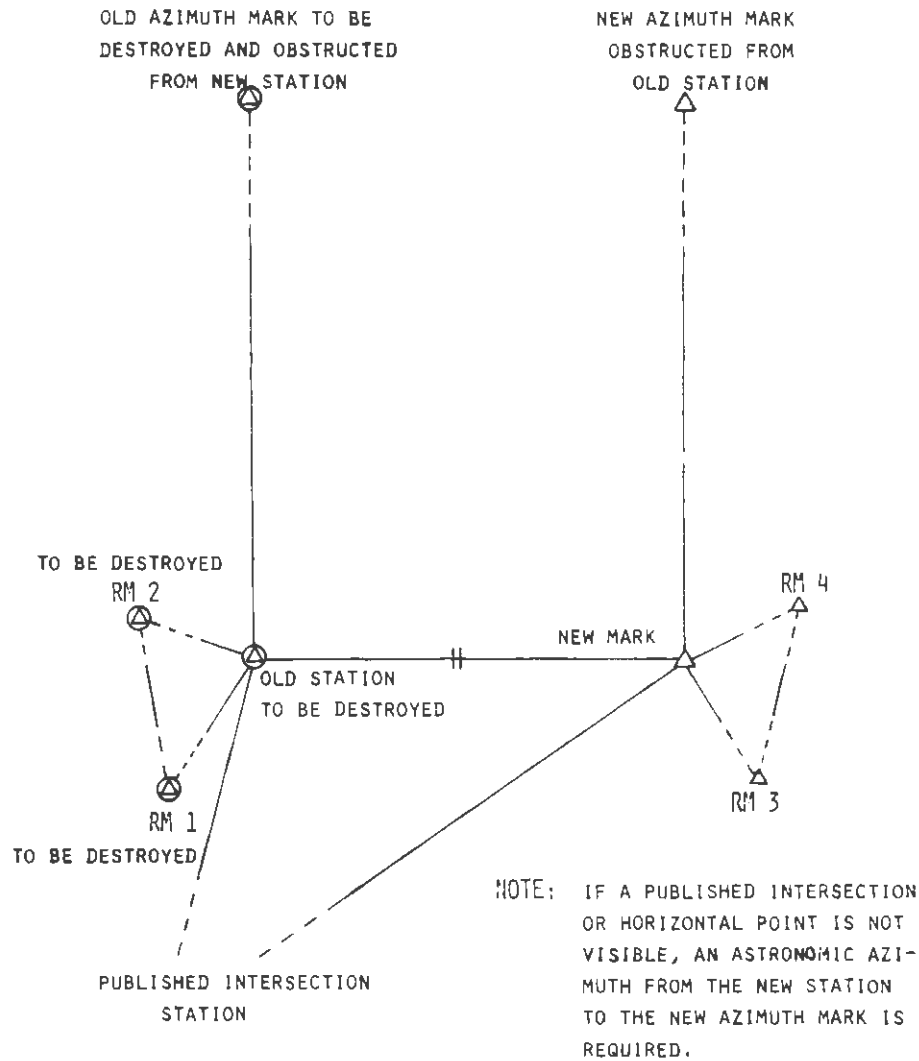


Figure 2.1.2-8.—Sketch of the establishment of a new station using a new azimuth mark and all new reference marks

tion, old azimuth mark, reference marks, and new azimuth mark. Otherwise, use one of the azimuth marks. If a distant horizontal station of second-order or better is not visible, occupy the new azimuth mark and turn directions between the old station and the replacement station. (See fig. 2.1.2-10.) Measure distances from the old station and the replacement station to the new azimuth mark. Compute preliminary geographic positions for the replacement station and the new azimuth mark.

c. If a new azimuth mark cannot be set in a place visible from the old station and the replacement station cannot see the old azimuth mark, do the following. If a published horizontal station over 400 meters away or a published intersection station can be seen from both old and new stations, check the observed angle at the old station between the published point and the azimuth mark using either the box score or computed inverses. If the observations check, turn directions to the old azimuth mark, old RM's, and new station using the intersection station or horizontal station for the initial pointing. Compute a preliminary geographic

position for the replacement station. Occupy the replacement station and turn directions between the intersection station or distant horizontal station and the old station, reference marks, and new azimuth mark. If a second intersection station can be seen, observe it for an additional check. (See fig. 2.1.2-11.) If no distant positioned point can be observed from the replacement station, observe an astronomic azimuth to the new azimuth mark. If the old azimuth mark will not be destroyed, measure an EDM distance to it from the old station and, using the reduced distance measurement, compute a preliminary geographic position for the old azimuth mark. Likewise, measure an EDM distance to the new azimuth mark from the replacement station and compute a preliminary geographic position. Reciprocal zenith distance observations are necessary to reduce all EDM measurements.

2. *Old Azimuth Mark Destroyed or Not Recovered.* If the old azimuth mark is destroyed or not recovered, locate a safe place for a new azimuth mark. Attempt to set the replacement azimuth mark so that it is visible from both

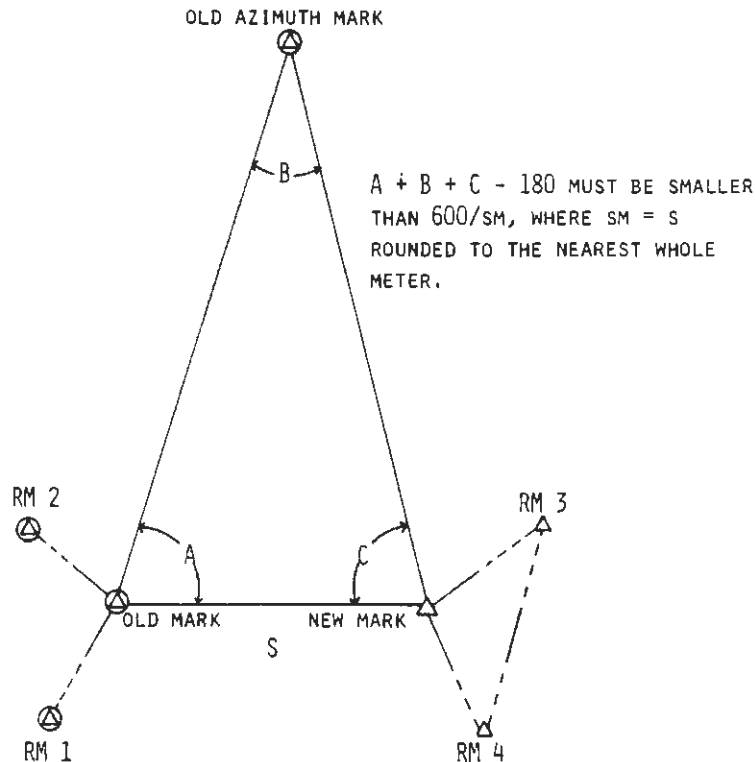


Figure 2.1.2-9.—Sketch of the establishment of a new station and new reference marks with the existing azimuth mark when no distant published point is visible

the old station and the new station. Occupying the old station, make the initial pointing on a visible distant published intersection or horizontal station, and turn directions to the new azimuth mark, the replacement station, old reference marks, and any check points such as temporary hubs placed as a check for distances. (See fig. 2.1.2-12.) If no visible published point is available for azimuth, an astronomic azimuth observation will be needed from the old station to the new azimuth mark. Occupy the replacement station and make the initial pointing on a visible published point or on the azimuth mark if no distant point can be seen. Turn directions to include the azimuth mark, reference marks, old station, and any check points. If no check points are visible from the replacement station, occupy the azimuth mark and turn the directions from the old station to the replacement station. Remember, the triangle must close within $180^\circ \pm (600 \text{ divided by the distance between old and new marks rounded to the nearest whole meter})$. Measure EDM distances to the new azimuth mark from the old station and the replacement station and observe the reciprocal zenith distances.

3. Azimuth Mark Never Established. In cases of dense urban development, heavily wooded terrain, or other conditions that denied the setting of an azimuth mark, it may be necessary to establish a replacement station using reference marks or reference objects. An azimuth in these cases is highly critical and every possible means must be made to set the replacement station as close to the old station as

possible, definitely within one 30-meter tape length of the old mark.

a. If two or more reference marks or check points still exist, make careful observations and measurements as noted in sections 2.1.2.2 and 2.1.2.3. If a check is not obtained, try to determine if one or more marks have been disturbed. When one mark is seemingly stable but another is in doubt, state the reason for such doubt in the body of the NOAA Form 75-82 or 75-82A. For example, "Reference Mark 2 was found slightly tilted and distance did not check within 2 cm of the 1936 measurement." When at least one of the reference mark measurements is accepted, consider setting the replacement station on line with the good reference mark. (See figs. 2.1.2-13 and 2.1.2-14.) In this way, the original initial pointing for the reference marks can be used to establish an azimuth for the replacement station. Occupy the old station and turn directions between all reference marks and the replacement station. Occupy the replacement station and observe all reference marks and the old station. Measure distances between the new and old stations with a calibrated 30-meter tape, following methods described in section 2.1.2.3. Use standard procedures to measure to and between reference marks, and using SAS computations, check all distance measurements. Compute a preliminary geographic position for the replacement station.

b. When the replacement station cannot be set on line with a reference mark, it should be set in such a way as to create a strong geometric figure. Distances should be kept

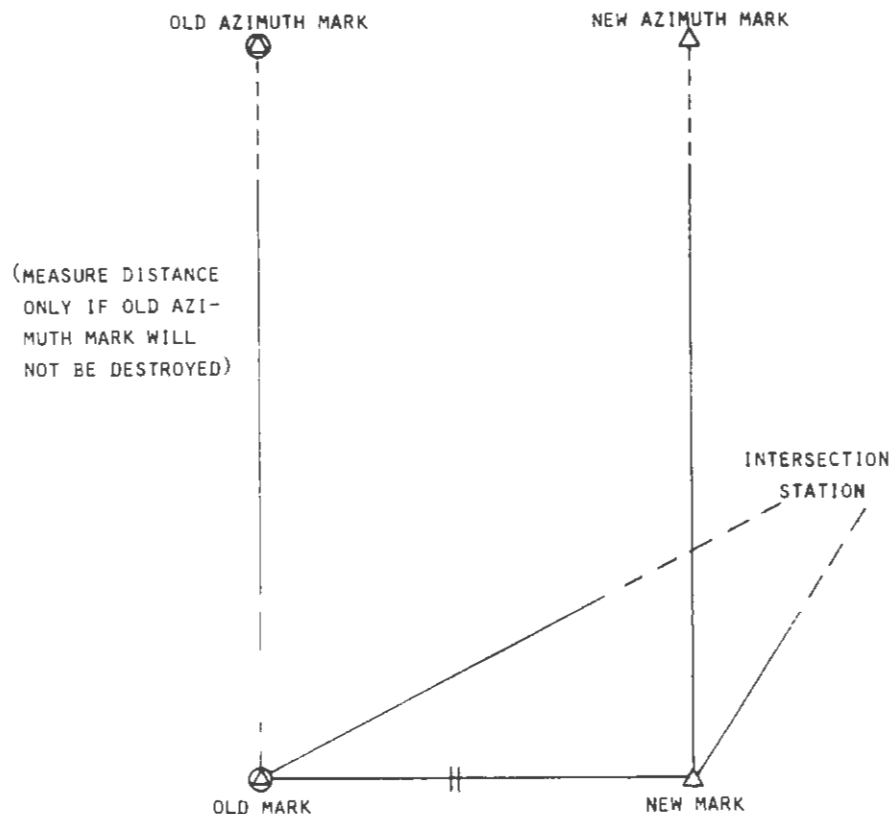


Figure 2.1.2-11.—Sketch of the establishment of a new station with a new azimuth mark if a distant published point is visible

erence mark and the replacement station. (See fig. 2.1.2-17.) Measure distances and reciprocal zenith distances to the azimuth mark from the replacement station. Compute a preliminary geographic position for the replacement station and compute inverses to intersection stations and horizontal points for check purposes.

5. **Positioning Bench Marks.** Position all visible bench marks within 3.2 km of the station. For marks close to the station, specifications as outlined for a replacement station will be observed. For marks at some distance, specifications will be the same as for setting an azimuth mark. Carefully

observe reciprocal zenith distances, or preferably differential levels over short lines, to transfer the bench mark elevation to the horizontal mark.

2.1.2.11 Preliminary Horizontal Control Data Sheets

Mark maintenance personnel should submit a completed "Preliminary Horizontal Control Data" sheet (fig. 2.1.2-18) with the survey data for each reset or newly established station. These data sheets will ensure that preliminary geodetic positions, geodetic azimuths, state plane coordinates, and plane azimuths will be available to the user as soon as possible.

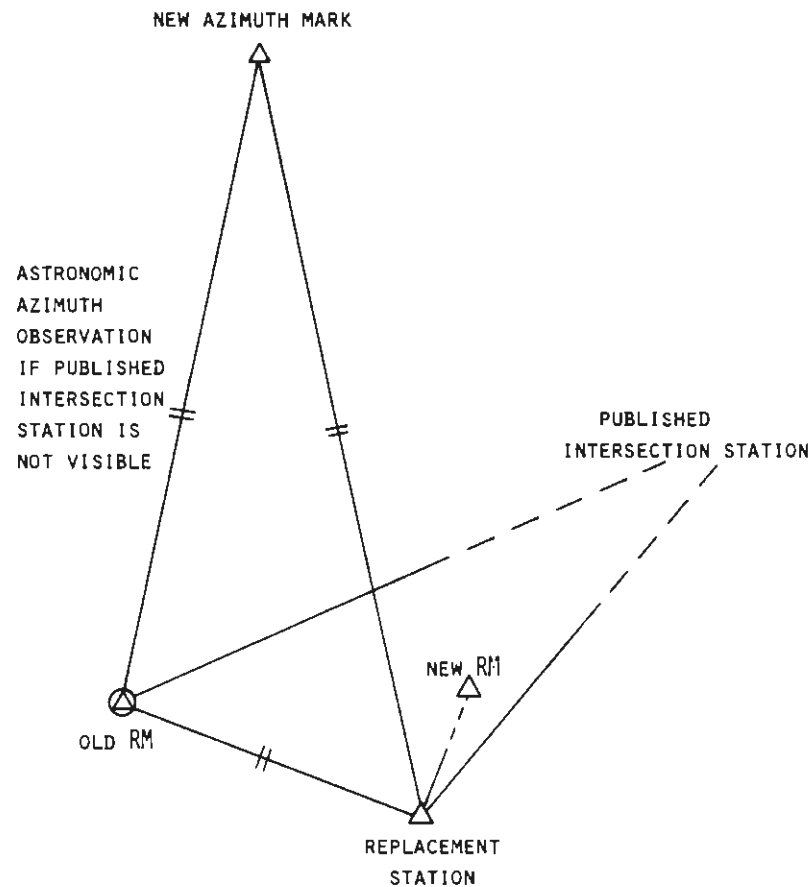


Figure 2.1.2-12.—Sketch of the establishment of a new station with a destroyed or lost azimuth mark

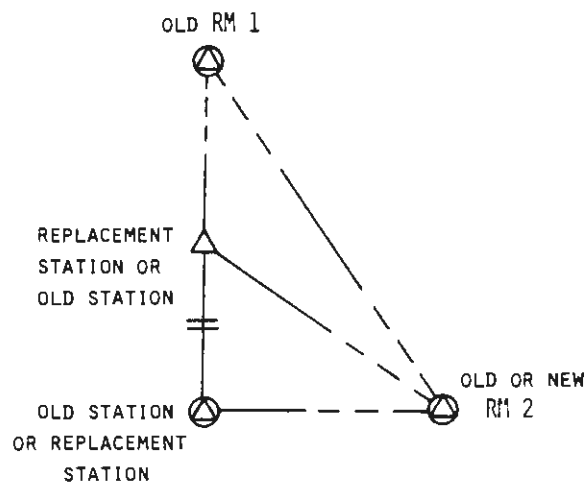


Figure 2.1.2-13.—Sketch of the establishment of a new station on line with an existing reference mark when an azimuth mark was never established

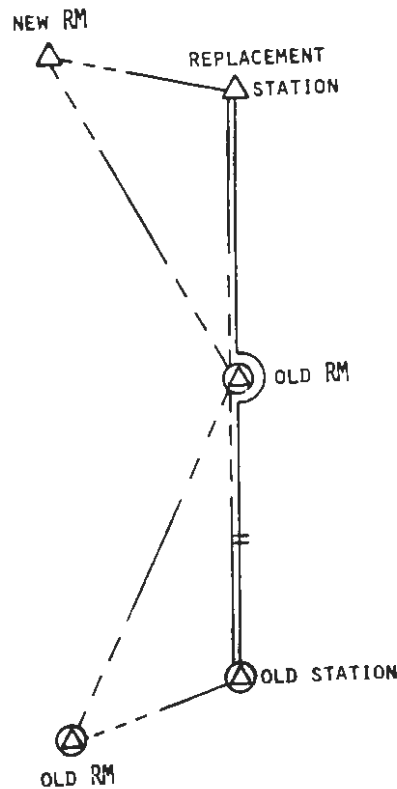


Figure 2.1.2-14.—Sketch of the establishment of a new station on line with an existing reference mark when an azimuth mark was never established

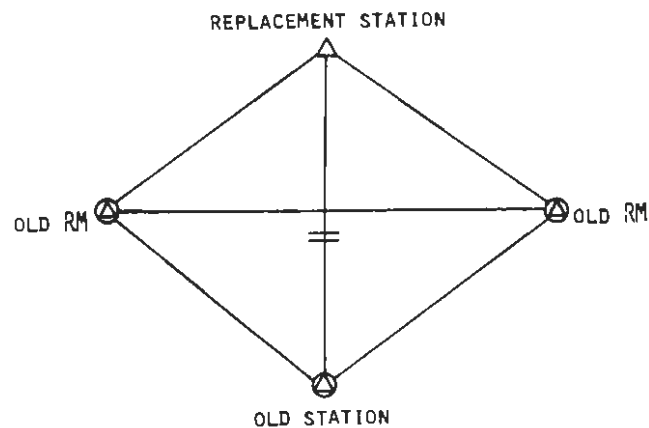


Figure 2.1.2-15.—Sketch of the establishment of a new station impossible to put on line with an existing reference mark when an azimuth mark was never established

HORIZONTAL CONTROL DATA

by the
Coast and Geodetic Survey
NORTH AMERICAN 1927 DATUM

QUAD 370781 STATION 1001
VA
LATITUDE 37° 30' TO 38° 00'
LONGITUDE 78° 00' TO 78° 30'
DIAGRAM NJ 17-9 ROANOKE

ASHBY (Cumberland County, Va., G.W.L., 1941)--Station is on high ground on the property of Mr. William T. Sanderson, about 8 miles NNE of Cumberland Courthouse at a small settlement known as Ashby. It is in the chicken yard fence line 40 feet W of State Route 45 and 30 feet N of the center line of the driveway entering Mr. Sanderson's yard. The disk is stamped "ASHBY 1941" and is set flush with surface of the ground.

Surface, underground, reference, and azimuth marks are standard bronze disks set in concrete, as described in notes 1a, 7a, and 11a.

Reference mark No.1 is NE of the station, 2 feet W of the fence line and 20 feet E of State Route 45. The disk is stamped "ASHBY 1941 No.1" and projects 6 inches above the surface of the ground.

Reference mark No.2 is SE of the station, 16 feet E of State Route 45 and 13 feet S of the concrete post in the SW fence corner. The disk is stamped "ASHBY 1941 No.2" and projects 6 inches above the ground.

The azimuth mark is 0.6 mile S of the station at the home of Charles G. Sanderson, 55 feet NNW of the NW corner of the house and 4 feet S of the S garden fence. The disk is stamped "ASHBY 1941" and projects 6 inches above the ground. To reach the azimuth mark, go S on State Route 45 for 0.6 mile to a dirt road on the left, turn left and go 0.25 mile to the Sanderson home and the azimuth mark as described.

To reach the station from the courthouse in Cumberland Courthouse, go E on U.S. Route 60 for 2.45 miles to the junction of U.S. Route 60 and State Route 45 here turn left (N) on State Route 45 and go 5.8 miles to the Sanderson house on the left and station as described.

A 64-foot tower will see an 87-foot light at station SNODDY.

A 64-foot tower will see a 74-foot light at station BOTTOM.

A 64-foot tower will see a 100-foot light at station BUSH

PARK.

OBJECT	DISTANCE		DIRECTION
	meters	feet	
SNODDY			0°00'00"0
R.M.No.1	25.270	82.90	131 23 39
R.M.No.2	26.346	86.43	223 32 47
Azimuth mark			241 02 21.3
Height of light above station mark - 26 meters.			
Height of telescope above station mark - 23 meters.			

ADJUSTED HORIZONTAL CONTROL DATA

NAME OF STATION ASHBY

STATE VIRGINIA

YEAR 1941

FIRST

-ORDER

LOCALITY DANVILLE TO BEAVERDAM

SOURCE G-4961

FIELD SKETCH VA 115

GEODETIC LATITUDE	37° 35' 32.28200	ELEVATION	METERS
GEODETIC LONGITUDE	78° 10' 26.22900		FEET

STATE COORDINATES (FEET)				
STATE & ZONE	CODE	X	Y	GEOD. ANGLE °
VA. S.	4502	2,094,470.52	458,533.89	+ 0° 11' 52"

* PLANE AZIMUTH HAS BEEN COMPUTED BY THE GEOD. FORMULA NEGLECTING THE SECOND TERM

TO STATION OR OBJECT	GEODETIC AZIMUTH (From North)	PLANE AZIMUTH (From North)	CODE
AZIMUTH MARK	350° 01' 56.3	349° 50' 04"	4502

EXPLANATION:

DIRECTION TO AZIMUTH MARK 241° 02' 21.3
DIRECTION TO RM2 223° 32' 47"
ANGLE 17° 29' 34"

AZIMUTH TO AZIMUTH MARK 350° 01' 56.3
ANGLE - 17° 29' 34"
AZIMUTH TO RM2 332° 32' 22"

USING THE COMPUTED AZIMUTH TO RM2 AND THE 1941 DISTANCE TO THE RM, A PRELIMINARY GEOGRAPHIC POSITION CAN BE COMPUTED FOR REPLACEMENT OF THE OLD STATION IF SUITABLE CHECKS ARE AVAILABLE.

Figure 2.1.2-16.—Computation of azimuth to RM 2 and instructions on how to compute preliminary position for RM 2

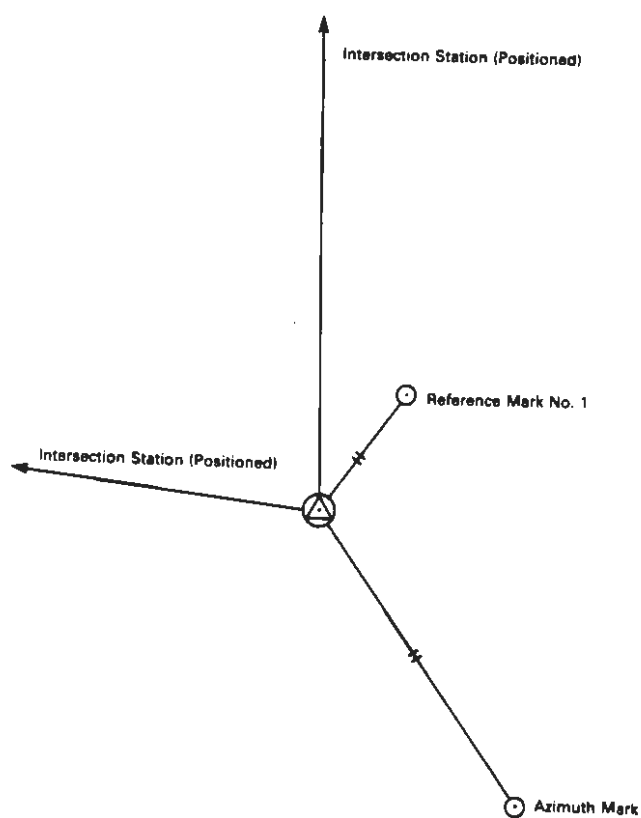


Figure 2.1.2-17.—Sketch of the establishment of a new station from a single existing stable reference mark

▼ ~~ADDITIONAL~~ HORIZONTAL CONTROL DATA
PRELIMINARY

371222-1006

NAME OF STATION: BENCH MARK H 111

STATE: CALIFORNIA

YEAR: 1932

THIRD — ORDER

LOCALITY:

SOURCE: G-16473

FIELD SKETCH:

GEODETIC LATITUDE:	37 24 41.65057	ELEVATION:	5.62	METERS
GEODETIC LONGITUDE:	122 03 07.71742		18.4	FEET

STATE COORDINATES (Feet)				
STATE & ZONE	CODE	X	Y	θ (OR $\Delta \alpha$) ANGLE
CA 3	0403	1,549,212.05	335,641.43	- 0 57 01
CA 4	0404	1,113,598.67	770,675.63	- 1 49 15

TO STATION OR OBJECT	GEODETIC AZIMUTH (From south)	PLANE AZIMUTH (From south)	CODE
AZIMUTH MARK	159 48 15.3	160 45 16	0403
AZIMUTH MARK	159 48 15.3	161 37 30	0404
Original position in error by 281.8 ft. Mark Maintenance will reobserve for final position in the near future.			
D.R.Doyle 1/18/82			

Figure 2.1.2-18.—A completed "Preliminary Horizontal Control Data" sheet

2.2 HORIZONTAL CONTROL

2.2.1 Classification, Standards of Accuracy, and General Specifications

2.2.1.1 General

The specifications set forth in the most recent editions (listed in chapter 1.1) of the publications *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* and *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* are to be strictly followed unless otherwise directed by the project instructions. (See section 1.8.2.2.) Any problems in meeting these guidelines should be discussed with the technical advisor or project coordinator listed in the project instructions.

2.2.1.2 Modified Specifications

Project instructions will identify when modified specifications for geodetic control surveys are to be used. Typically, those instances will involve first- or second-order class I surveys with lines shorter than 5 km. Standards of accuracy (i.e., 1:100,000 or better for first-order surveys and 1:50,000 or better for second-order, class I surveys) will be maintained by following the modified specifications.

NOTE: The changes in the angles and distances suggested in this section do not mean the observed quantities are to be actually changed. These changes are made simply to test whether the specifications have been satisfied.

2.2.1.3 Horizontal Directions

1. Abstracts of directions differing by as much as 2."0 may be meaned. If the triangle closures *and* side (pole) checks are improved or remain within the limits given in sections 2.2.1.2 and 2.2.1.3, directions differing by as much as 3."0 may also be meaned.

2. Theodolite plate settings will conform to section 2.2.7.3.

3. Astronomic azimuths will be observed on two nights, preferably using different observers and different instruments. At least two of the same main-scheme stations will be observed with the star. The astronomic azimuth will be computed independently for each line. Either of these observed lines may be used to prove the tolerances. The standard error should not exceed 0."45 for first- and second-order, class I surveys.

2.2.1.4 Triangle Closures

The average triangle closure for a project is the algebraic sum of the triangle closures divided by the total number of triangles. This average should approach zero. In comput-

ing this average, only main-scheme triangles that have a spherical excess greater than 0."01 are to be included.

1. First-Order Control.

a. The standard error of a single triangle closure for all triangles in a project should not exceed $\pm 1."$ 4. No triangle closure should exceed $\pm 4."$ 5. When closing triangles in the field, closures of $\pm 2."$ 0 will be acceptable and no reobservations will be taken during that occupation except when it is obvious one or more identifiable directions are in error.

b. In those cases where the average triangle closure for a figure (quadrilateral or polygon) is 2."0 or greater, and one or more directions are shown by the closures and side checks to be in error by 2."0 or more, a reoccupation is justified. However, if the closure and side tests are inconclusive as to the direction(s) in error, the lengths of two sides of the figure not in the same triangle are to be measured on one night. One of the sides may correspond to a side required by the project instructions to be measured. If two sides of the figure were designated for measurement in the project instructions, then another side, preferably not in the same triangle, should be measured on one night. See section 2.2.1.5, Length Checks.

NOTE: Distance measurements may be made during the day or night and the term "on one night" simply infers that a single complete measurement is required. This applies to all accuracy classes in first- and second-order surveys with modified specifications.

2. Second-Order, Class I Control

a. The standard error of a single triangle closure for all triangles in a project should not exceed $\pm 1."$ 7. No triangle closure should exceed $\pm 5."$ 0.

b. The first-order control criteria, for triangle closures and reoccupations, apply here. However, the measurement of a single side in one night in the strongest chain passing through the figure will suffice. In those cases where a side is specified to be measured in the project instructions, another side in the same figure, but not in the same triangle, is also to be measured on one night. (See section 2.2.1.5, Length Checks)

3. Side (Pole) Checks

a. Make a distinct effort to hold to the side check specifications (0."3 average correction to a direction for first-order and 0."4 average correction to a direction for second-order, class I triangulation). An increase of 0."1 to 0."15 to the average correction to a direction specification is allowed in those cases where small angles (10° and less) are involved.

An acceptable test to evaluate an excessive side check is to change the smallest or one of the smaller angles in the side check by as much as $1.''0$ in the direction of the triangle closure and recalculate the side discrepancy. If the resulting side check is within the specifications, no reobservations are required. It is also acceptable to apply another $1.''0$ change to one other of the smaller angles included, provided this change, in combination with the first change will bring the side check within specified tolerances. This changed direction is only to be used to confirm that observations meet the specifications. The changes are not to be transmitted as data.

b. In area networks, all side checks should be prepared either in a clockwise or counterclockwise order. Where all angles are greater than $30''$ and the sum of two or more of the side check closures exceeds $\pm 5.''0$, consider measuring one or more of the common sides involved in the side checks, unless it is shown that an identifiable angle or angles are in error by a sufficient amount to cause the side discrepancy. In this case, it may be best to reobserve the angles. This specification applies to the main-scheme framework only. It does not apply to any supplemental points, including central point figures within a quadrilateral with observed diagonals.

For those cases where the smallest angles are on the order of $20''$, the side check closures should not exceed $\pm 10.''0$. Where angles of less than $20''$ are entered into the basic framework, at least one (the shortest) and probably two (the two shortest) sides should be measured. When sides are measured in such situations, the side check restrictions are modified such that the average correction to a direction may be twice the specified tolerance. For example, in first-order triangulation, the side check specification of $0.''3$ per direction may be increased to $0.''6$ under the conditions related.

2.2.1.5. Length Checks

1. **First-Order Base Lines.** Measured base lines will usually be spaced at intervals of four to eight triangles depending on the strength of figure. On the average, the spacing will be six triangles.

a. The check between base lines over the fewest number of triangles or the strongest route should be 1:100,000 or better. When this specification is not met, the smallest angle in the route may be changed by as much as $2.''0$ in the direction necessary to improve the length closure. A factor from table 2.2-1 should be applied to the lengths to obtain revised closures, as explained in section 2.2.1.6.

b. If the revised closure obtained by employing the factor still does not meet the specifications, each measured distance may be changed by as much as 3.0 cm in the direction necessary to improve the check. No remeasurements can be made until approval to proceed is given by the Project Director. In addition, the decision made will be documented in the project report. This requirement also applies to any reobservation of directions considered necessary to improve the length closure, unless the observations are dictated by other considerations.

2. **Second-Order Base Lines.** Base lines will be measured on one night and will usually be spaced at intervals of six to ten triangles, depending on the strength of figure. On the average, spacing will be eight triangles.

a. The check between base lines over the fewest number of triangles or the strongest route should be 1:50,000 or better. When this requirement is not met, the angular changes and factors from table 2.2-1 are to be applied as described above.

b. If the revised closure obtained by employing the factor still does not meet the specifications, each measured distance may be changed as much as 3.0 cm in the direction required to improve the check. No remeasurements will be made until approval is given by the Project Director to proceed. In addition, the decision made will be documented in the project report.

2.2.1.6 Sample Length Checks

Table 2.2.1-1 contains factors equivalent to a $1.''0$ change in an angle in a length computation. The factors are applied to the computed length in a length check to determine if a $1.''0$ change to the smallest angle in the length computation will make the length check meet the modified specifications for first- and second-order surveys.

Table 2.2.1-1.—Factors equivalent to a 1-second change in an angle

Angle	Length Factor	Angle	Length Factor
10°	0.0000275	36°	0.0000067
11	0.0000249	37	0.0000064
12	0.0000228	38	0.0000062
13	0.0000210	39	0.0000060
14	0.0000194	40	0.0000058
15	0.0000181	41	0.0000056
16	0.0000169	42	0.0000054
17	0.0000158	43	0.0000052
18	0.0000149	44	0.0000050
19	0.0000141	45	0.0000048
20	0.0000133	46	0.0000047
21	0.0000126	47	0.0000045
22	0.0000120	48	0.0000044
23	0.0000114	49	0.0000042
24	0.0000109	50	0.0000041
25	0.0000104	51	0.0000039
26	0.0000100	52	0.0000038
27	0.0000095	53	0.0000037
28	0.0000091	54	0.0000035
29	0.0000088	55	0.0000034
30	0.0000084	56	0.0000033
31	0.0000081	57	0.0000032
32	0.0000078	58	0.0000030
33	0.0000075	59	0.0000029
34	0.0000072	60	0.0000028
35	0.0000069		

When the computed length is shorter than the measured length, add 1.0000000 to the factor corresponding to the smallest angle in the computation and multiply this sum by the computed length. When the computed length is longer than the measured length, subtract the factor from 1.0000000 and multiply the difference by the computed length.

Since the arbitrary change to the smallest angle of the length computation cannot exceed 2.0, the factor from table 2.2-1-1 may be multiplied by the arbitrary change. The product may then be added to or subtracted from 1.0000000 as described in the previous paragraph.

Example I: Given that the smallest angle involved in a length computation is 35.4°, the measured side is 6904.198 meters, and the same side as determined through the triangulation from another measured side equals 6904.102 meters, determine whether or not the computed length meets modified specifications for first-order.

(1) Determine the relative proportional part difference of the computed length.

$$\frac{\text{Measured}-\text{Computed}}{\text{Measured}} = \frac{6904.198 - 6904.102}{6904.198}$$

$$= \frac{+0.096}{6904.198} = \frac{1}{71,900}$$

(2) Because the computed length is shorter than the measured length, add 1.0000000 to the factor in table 2.2-1 to determine the value equivalent to a 1.0 change in the smallest angle. For 35.4°, the value is 1.0000068.

(3) Multiply the computed length by the value and recompute the relative proportional part difference.

$$1.0000068 \times 6904.102 \text{ m} = 6904.149 \text{ m}$$

$$\frac{6904.198 - 6904.149}{6904.198} = \frac{1}{140,900}$$

A 1.0 change in the smallest angle will satisfy the length check.

Example II: The same as Example I except that the computed distance is 6904.335 meters.

(1) Determine the relative proportional part difference of the computed length.

$$\frac{6904.198 - 6904.335}{6904.198} = \frac{1}{50,400}$$

(2) Because the computed length is longer than the measured length, subtract the factor in table 2.2-1 from 1.0000000 to determine the value equivalent to a 1.0 change in the smallest angle.

$$1.0000000 - 0.0000068 = 0.9999932$$

(3) Multiply the computed length by this value and recompute the relative accuracy.

$$0.9999932 \times 6904.335 = 6904.288$$

$$\frac{6904.198 - 6904.288}{6904.198} = \frac{1}{76,700}$$

(4) A 1.0 change in the smallest angle does not meet specifications. Try a 1.5 second change in the angle.

(5) The value equivalent to a 1.5 change is determined by multiplying 1.5 times the factor from table 2.2-1 and subtracting the product from 1.0000000.

$$1.5 \text{ Value} = 1.0000000 - (1.5 \times 0.0000068)$$

$$= 1.0000000 - 0.0000102$$

$$= 0.9999898$$

(6) Multiply the computed length by the value determined in (5) and recompute the relative proportional part difference.

$$6904.335 \times 0.9999898 = 6904.265$$

$$\frac{6904.198 - 6904.265}{6904.198} = \frac{1}{103,000}$$

A 1.5 change to the smallest angle in the length computation will satisfy the length check.

Example III: The same as Example I except that the computed distance is 6904.410 meters.

(1) Determine the relative proportional part difference of the computed length.

$$\frac{6904.198 - 6904.410}{\pm 6904.1986} = \frac{-0.212}{904.198} = \frac{1}{32,500}$$

(2) Try a 2.0 change in the smallest angle. Because the computed length is longer than the measured length, multiply the factor in table 2.1-1 by 2.0 and subtract the product from 1.0000000.

$$2.0 \text{ value} = 1.0000000 - (2 \times 0.0000068)$$

$$= 1.0000000 - 0.0000136$$

$$= 0.9999864$$

(3) Multiply the computed length by this value and recompute the relative proportional part difference.

$$0.9999864 \times 6904.410 = 6904.316$$

$$\frac{6904.198 - 6904.316}{6904.198} = \frac{-0.118}{6904.198} = \frac{1}{58,500}$$

(4) A 2.0 change in the smallest angle in the length computation does not satisfy the length check. In addition to the 2.0 change in the angle, try a 2.5 cm change to the measured lengths.

$$\frac{(6904.198 + 0.025) - 6904.316}{(6904.198 + 0.025)} = \frac{-0.093}{6904.223} = \frac{1}{74,200}$$

(5) This still does not satisfy the length check. The computed length was determined through the triangulation from a geodimeter length equal to 1432.066 meters. Since the computed length is too long, subtract 2.5 cm from the originating geodimeter length, compute a factor, and redetermine the computed length.

$$\frac{1432.066 - 0.025}{1432.066} = 0.9999983$$

$$0.9999983 \times 6904.316 = 6904.304 \text{ m}$$

Then:

$$\frac{(6904.198 + 0.025) - 6904.304}{6904.198 + 0.025} = \frac{1}{85,300}$$

(6) Since this still does not satisfy the length check, consult the Project Director.

When these tests fail, the lengths involved should be tested with other measured lengths, if possible. The Project Director must decide which lines must be remeasured, since he or she has knowledge of weather conditions, observing situations (i.e., poor set-ups), etc.

2.2.2 Party Structure

This section updates material presented in *Special Publication 247, Manual of Geodetic Triangulation* (pp. 21-25). Historically, horizontal parties have had 30 to 40 employees. Party size has been streamlined because of changes in funding, a shift in requirements from arc triangulation to area work, and new developments in equipment.

At present, horizontal parties are limited to about 12 persons. A typical party would be the following:

Number	Position	Position classification
1	Project Director	Surveying Technician
1	Asst. Project Director	Surveying Technician
1	Asst. Computer	Surveying Technician
1	Field Coordinator	Surveying Technician
1	Chief Builder	Surveying Technician
2	Observer/EDM Operator	Surveying Technician
2	Builder/Recorder	Surveying Technician
3	Builder/Lightkeeper	Survey Aid/Technician

Detailed descriptions of all party positions are on file with the Field Operations Section (N/CG161).

2.2.3 Reconnaissance

Detailed instructions for reconnaissance procedures are contained in *Special Publication 225, Manual of Reconnaissance for Triangulation*. Some applicable material is also contained in *Special Publication 247* (pp. 1-7). The most recent specifications and requirements for strength of figure and station spacing are listed in publications entitled *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* and *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. Instructions for preparing reconnaissance sketches are contained in section 2.2.2.4 of this manual. Information about the location of stations, station names, and descriptions is contained in section 2.2.4.

2.2.3.1 Reconnaissance Party Structure

At present, NGS has one reconnaissance party consisting of one or two persons. This party operates about 1 year

in advance of the horizontal parties. The party is responsible for selecting station sites, specifying tower heights, selecting elevation ties, obtaining permission from property owners, and proposing survey schemes.

2.2.3.2 Sources of Data

Station data sheets, topographic maps, charts, and Geodetic Control Data sheets are ordered by the Field Records Analysis Section (N/CG121). Extra topographic maps of the project area can be secured locally or from the U.S. Geological Survey. Extra aeronautical charts are available from NOS. These charts give the location of air navigation facilities and hazards which should be incorporated into the scheme. Detailed highway and road maps are available from State and County Governments.

U.S. Geological Survey
Branch of Distribution
1200 South Eads Street
Arlington, Virginia 22202
(east of the Mississippi River)

U.S. Geological Survey
Branch of Distribution
Box 25286, Federal Center
Denver, Colorado 80225
(west of the Mississippi River)

National Ocean Service
Distribution Branch N/CG33
Riverdale, Maryland 20840
(all aeronautical charts)

U.S. Geological Survey
Mid-Continent Mapping Center
Information Center
1400 Independence Road
Rolla, Missouri 65401

U.S. Geological Survey
National Cartographic
Information Center
345 Middlefield Road
Menlo Park, California 94025

2.2.3.3 Station Recovery and Reconnaissance Descriptions

All existing horizontal control published by NGS within the project area shall be recovered. Recovery descriptions will be submitted on NOAA Form 75-82 or 75-82A. These description forms should be completed with the exception of the "box score." The completed forms shall then be photocopied. On the copy, add all information about the height and type of signal, special arrangements made with the property owner, restrictions, etc.

The original description form and the copy must be submitted with the reconnaissance data. The originals will be used to update the NGS data base, while the copies will be routed to the field party who will check and complete them as the observations are made.

Prepare reconnaissance descriptions for new stations as outlined in *Special Publication 225*.

2.2.3.4 Intersection Stations

The reconnaissance party shall make an effort to recover all objects previously used as intersection stations. Any new or prominent object which will be useful as an intersection station should be marked on the reconnaissance sketch as set forth in *Special Publication 247* (p. 6). A reconnaissance description should also be written. All fixed aids to navigation and all air navigation facilities (e.g., VOR's) shall be included. Figure 2.2.3-1 simplifies the reconnaissance descriptions for proposed intersection stations. Good quality

PROPOSED INTERSECTION STATION

NO. _____

QUAD: _____ STATE: _____ COUNTY: _____

NAME: _____

INTERSECT: Top center _____; Ball top center _____; Light of top center _____;
 Light top not center _____; Apex of vent _____; Apex of roof _____;
 Base of cross _____; Ball at base of cross _____; Pole antenna _____;
 Other _____

OWNERSHIP: _____

DESCRIPTION: Cylindrical body _____; Conical shaped top _____;
 Dome shaped top _____; Umbrella shaped top _____; Hemispherical bottom _____;
 Concave bottom _____; Singular column spheroid _____; Guyed mast _____;
 Skeleton steel tower _____; Spire _____; Dome _____; Stack _____;
 Other _____

Number of legs _____; Type: Tubular _____; Truss-work _____; I-beam _____;
 Color _____; Height _____

LOGO: _____

THIS STATION IS LOCATED: _____

_____ ft. (_____) of _____

_____ ft. (_____) of _____

_____ ft. (_____) of _____

Figure 2.2.3-1.—Format for simplifying reconnaissance description for proposed intersection station

photographs should be submitted with the reconnaissance descriptions.

2.2.3.5 Bench Marks

All existing vertical control published by NGS within the project area shall generally be recovered. Consult the Field Operations Section, N/CG16, if operational considerations make this impracticable. Submit recovery descriptions on NOAA Form 76-186.

2.2.3.6 Submission of Data

Upon completion of the project, the reconnaissance party shall submit data to the Quality Control Section, N/CG164. These data will include all recovery descriptions, reconnaissance descriptions, and reconnaissance sketches. The Field Records Analysis Section (N/CG121) will review the data and proposed scheme. It will designate the location of astronomic azimuths, if different from those proposed by the reconnaissance party, and check and, if necessary, supplement the proposed base lines.

2.2.4 Horizontal Control Stations

This section contains information pertaining to the location, monumentation, naming, and description of horizontal control stations.

2.2.4.1 Location of Stations

The reconnaissance party is responsible for selecting station sites and proposing survey schemes. Horizontal control stations should be spaced at the average interval for the particular order, class, and type of survey as specified in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (p. 4). Whenever possible, horizontal control stations should be established at communities with a population greater than 2000, on or near the campus of all recognized technical colleges and universities, at all active airports, at Federal installations if requested, along major waterways, and along principal highways.

Exceptions to these specifications are:

1. When project instructions specify otherwise.
2. When station location is dictated, due to geometric considerations, by the location of previously established control.
3. When topography makes the specified spacing impractical.

Supplemental control stations should be located so they can be accessed easily by both the triangulation party and subsequent users. If possible, the stations should be located in areas where they would be least likely destroyed by construction. (See section 2.1.1.1.)

Two reference marks should be set at the station site. They should be more than 5 meters but less than 30 meters (one tape length) from the station. These reference marks should be set between 30° and 150° apart. The ideal intersection angle would be 90°. This will aid in station

recovery and in resetting the station mark. To achieve a good intersection angle, a reference mark may be set across a road.

Azimuth marks should be visible from the ground at the stations. They should be located no less than 400 meters and, if practical, no more than 3,200 meters from the stations. No more than ½ staff-day should be spent in clearing the line-of-sight. Azimuth marks should be set along roads or at other locations with good visibility and easy access.

2.2.4.2 Specifications for Monuments

Specifications for setting and stamping horizontal control stations are contained in *C&GSTM-4*, "Specifications for Horizontal Control Marks," and in *Special Publication 247* (pp. 84-95). Section 2.1 of this Operations Manual contains updated specifications and information on monumentation. Section 2.1.1.3 discusses mixing concrete, section 2.1.1.4—ferrous metal in marks, section 2.1.1.5—mark projection, section 2.1.1.6—witness signs, section 2.1.1.7—descriptions, and section 2.1.1.8—supply procurement.

2.2.4.3 Station Names

Naming stations and stamping marks are discussed in *Special Publication 247* (pp. 84-86), *Special Publication 225* (pp. 88-90) and in *C&GSTM-4* (pp. 1-8). Section 2.1.2.6 lists additional guidelines for stamping moved or reset marks.

For NGS data processing purposes, the length of an occupied station name (including blanks) is limited to 24 spaces. Reference and azimuth marks, which have *not* been occupied for position, and intersection stations are limited to 30 spaces. If the station was previously established, the station name spelling shall be as listed in the data base. The year a station was established shall be included as part of the station name under the following conditions:

- a. The station was established prior to January 1977.
- b. The year is part of the name listed in the data base.
- c. To avoid confusion with another mark of the same name in the same county or 7½ minute quad.

2.2.4.4 Descriptions and Recovery Descriptions

1. General.

New formats which have been designed for horizontal station descriptions and recovery descriptions supersede much of the information contained in *Special Publication 247* (pp. 97-125). The new formats are given in chapter 3 of *Input Formats and Specifications of the National Geodetic Survey Data Base*, volume I, Horizontal Control Data. Sections 2.1.1.2, 2.1.1.4, and 2.1.1.7 of this manual contain general information that should be included in the descriptions. All parties submitting descriptions of horizontal stations shall use the NGS input formats.

NOAA Form 75-82 (station descriptions), a booklet, or NOAA Form 75-82A, a tablet, shall be used to record the descriptive and recovery data. These forms shall be filled

out in the field at the station site instead of writing descriptions in the "Observation of Horizontal Directions" volume. The completed forms are original field records and should be submitted with project data for archiving.

NOAA Form 75-82 follows the format of program "HZTDES." It has partially coded text that allows observers to fill in the blanks. Much of the station identification data relating to the reporting or establishing agencies, mark and disk types, setting classification, condition, and transportation are coded. These codes are given in NOAA Form 75-82 and in *Input Formats and Specifications of the National Geodetic Survey Data Base* (ch. 3, annex I). The "notes" listed in *Special Publication 247* are no longer used.

Space is provided for a statement of general location, a "To Reach" statement (a concise description of the route to the station), measurements to reference objects and other marks at the station site, and a sketch. Partially coded text is provided for a detailed description of the station, azimuth mark, reference marks, and other marks at the station site. *Input Formats and Specifications of the National Geodetic Survey Data Base* (ch. 3, annex I) contains examples of the text for each paragraph of the description.

The contents of a recovery description depend on whether conditions at the station site or along the route traveled to reach it have changed and on the completeness and accuracy of the previous descriptions. A clear statement should be made of any discrepancies between the published descriptions and what exists at the station site. Any change made to the station by the party should be mentioned.

The descriptions and recovery descriptions should provide a word picture of all pertinent information relative to the station. It should explain in detail any changes that have occurred since that last recovery description, stating the reasons if known. The following are a few examples of omissions that have occurred:

a. A number 2 station was established with no mention being made of the original station or whether a search had been made for its underground mark. Also, no explanation was given for establishing the number 2 station.

b. A number 2 station was set into the same drill hole as the original station, but no mention was made of this fact, or of the original station.

c. Some recovery descriptions have indicated discrepancies in directions and distances to reference marks with no mention made of the value of the differences. When these differences were noted, no attempt was made to explain them or state that the new values had been confirmed.

d. Descriptions and recovery descriptions were written that did not contain the names, addresses, and phone numbers of the lease holder (if any) and owners of the property on which stations are located.

e. Some monuments contain magnets or ferrous metal. This was not indicated on the *12*/*13* M codes in the Station Identification Record fields of the description.

2. Automated Descriptions.

Field units with computer terminals shall enter station descriptions and recovery descriptions into the computer

system, in addition to submitting NOAA Form 75-82 or 75-82A. These units must use the latest programs for compiling the descriptions. (All other units submit NOAA Form 75-82 and 75-82A to the Field Records Analysis Section of NGS for incorporation into the data base.) The descriptions shall be carefully proofread and edited. The final computer listings are generated from files and used for the publication of project station descriptions.

NOAA Forms 75-82 and 75-82A replace NOAA Forms 76-39, 76-81, 76-96, and 76-165.

When an occupied parent station has positioned azimuth marks, one "Station Description" booklet (NOAA Form 75-82) will be used for both the station and its azimuth marks. The following data for each positioned azimuth mark should be filled out on a separate "Station Description-Short Form" (NOAA Form 75-82A) and attached with tape to the "Station Description" booklet on the parent station's pages for *90* codes:

- The header station description codes *10* through *30* where applicable,
- A location paragraph (i.e., airline distances and directions to nearby towns), and
- A route "to reach" those azimuth marks where "to reach" is different or cannot be extracted from the parent station description.

The automated description for the parent station will include complete writeups for its reference marks and for its azimuth marks that are not positioned. If the azimuth marks are positioned, the "to reach" and the local measurements for the azimuth marks can be omitted from the parent station description, since these data will be included on the automated description for the azimuth marks.

A complete, separate and automated description for each azimuth mark will include the following:

- The header station description codes *10* thru *30*,
- A location paragraph,
- A route to-reach paragraph,
- A mark writeup paragraph describing the mark and local measurements made with respect to permanent objects in the immediate area, and
- Name of person describing the azimuth mark.

2.2.5 Instruments and Equipment

Although much of the information in *Special Publication 247* is still relevant, modern instruments and technology will be discussed here.

2.2.5.1 Theodolites

1. **General.** NGS no longer uses the Parkhurst theodolite described in *Special Publication 247*. At present, NGS field parties use the Wild T3 with a 1-minute micrometer drum for measuring directions. This section describes both the 1-minute and the 2-minute micrometer drums for the Wild T3 and two acceptable second-order theodolites.

2. **Wild T3 Theodolites.** The 1-minute model T3 is identical to the instrument described in *Special Publication 247*

(pp. 28-30). On this model, the "seconds" readings from the direct and reverse pointings must be summed to determine the seconds and odd minutes. The 2-minute model reads directly to the odd minute. Figure 2.2.5-1 shows Wild T3 circle readings for a 1-minute and 2-minute micrometer.

3. *One-Second Theodolites.* Other theodolites used by NGS units are the Wild T2 and the Kern DKM2. These instruments should be read only to the nearest second. Figure 2.2.5-2 shows examples of 1-second theodolite circle readings.

4. *Maintenance and Field Adjustments.* All theodolites used in the field will be returned to the Instrumentation and Equipment Section every 18 months for maintenance. Therefore, only minor adjustments are required in the field. The effect of many maladjustments are compensated for by proper observing procedures. It is better to leave an instrument slightly out of adjustment than to continually adjust it in a vain attempt to make it perfect. The following are some routine tests and adjustments which should be made in the field.

a. *Focusing.* The instrument must be correctly focused before observations are begun. Parallax and incorrect focus are not compensated for by the observing procedure. Instructions for focusing the telescope and reading microscope are contained in section 2.2.7.6, subsection 2.

b. *Plate Level.* By following the setup procedure outlined in section 2.2.7.1, subsection 2, observations will be unaffected by a level vial out of adjustment. Level vials more than 2 divisions out should be adjusted as follows:

(1) The instrument should be set up on a stable stand and shaded from the sun and wind.

(2) Rotate the instrument so the plate level is parallel to any two foot screws. Center the bubble accurately by turning these screws equally in opposite directions. The bubble will move in the same direction that the left thumb moves while turning the screws.

(3) Rotate the instrument 90° and center the bubble using only the third screw.

(4) Rotate the instrument back to the first position and recenter the bubble if necessary.

(5) Rotate the instrument 180°. If off-center, bring the bubble halfway back to center using the capstan screws recessed in the right standard. Completely center the bubble with the footscrews.

(6) Rotate the instrument 90° and center the bubble using the third footscrew.

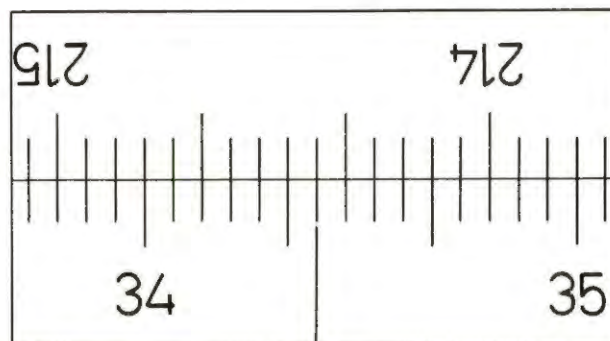
(7) Rotate the instrument through 360°. The bubble should remain within one division of center throughout. If not, steps (5) and (6) must be repeated.

c. *Reticle Verticality.* A skewed reticle is compensated for by using the intersection of the reticle for sighting. The reticle used in modern theodolites consist of lines etched on a glass diaphragm. The horizontal lines are etched precisely perpendicular to the vertical lines in the manufacturing process. Do not adjust a skewed reticle unless collimation must be adjusted.



(a)

circle reading	123°	34'	
first drum reading			13.8"
second drum reading			13.9"
(u represents units)	123°	34'	27.7"



(b)

circle reading	214°	24'	
first drum reading		1'	46.9"
second drum reading		1'	46.9"
	214°	25'	46.9"

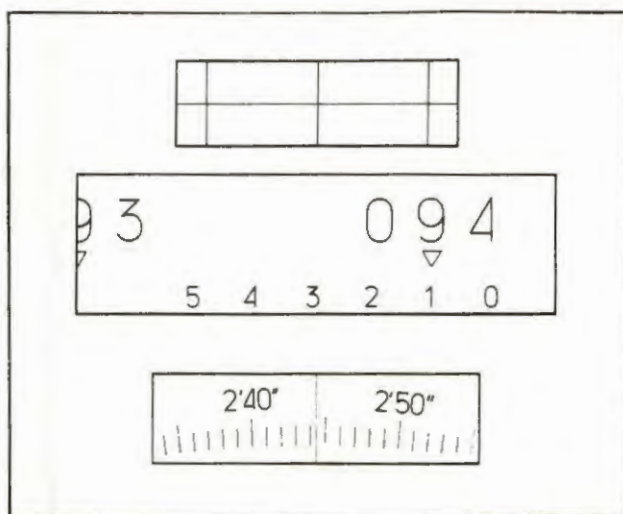
Figure 2.2.5-1.—Examples of Wild T3 circle readings. (a) 1-minute micrometer; (b) 2-minute micrometer. Depending on setting of selector knob, horizontal and vertical circles appear separately in micrometer telescope.

To test for verticality of the vertical hair, carefully level the theodolite and point on a well-defined object such as a



(a)

Horizontal circle reading 265° 47' 23."4



(b)

Vertical circle reading 94° 12' 44"



(c)

Vertical circle reading 85° 35' 14"

Figure 2.2.5-2.—Examples of 1-second theodolite circle readings: (a) Wild T2 (older model), (b) Wild T2 (newer model), (c) Kern DKM-2. Depending on the setting of the selection knob on the Wild T2's, the vertical and horizontal circles appear separately. In the Kern DKM-2 both circles appear simultaneously.—Continued

plumb bob string supporting a plumb bob suspended in a can of water. With the alidade clamped, move the telescope up and down. If the object remains on the vertical cross hair, there is no vertical error. If the object moves off the cross hair, rotate the diaphragm by turning the two oblique correcting screws in opposite directions until the cross hair is vertical. Retest and readjust if required.

d. *Horizontal Collimation.* This error is completely eliminated by the observing procedures outlined in section 2.2.7.3, subsection 2.

(1) To determine the collimation error, point the telescope on a distant well-defined object and read the horizontal circle. Repeat this procedure with the telescope inverted. The difference between the direct and reverse readings, minus 180°, is twice the collimation error of the instrument.

(2) Set the micrometer to the mean of the direct and reverse readings. Using the slow motion screw, move the alidade until the horizontal circle graduations are in coincidence.

(3) Loosen the diaphragm retaining screw(s) on one side and move the diaphragm by tightening the screw(s) on the other side so that the center of the reticle is on the sighted object. Do not loosen the screw(s) more than 1/8 turn before tightening the other(s).

(4) Tighten the retaining screws and recheck the collimation error. If it is under 10 seconds, the instrument is in satisfactory adjustment.

(5) Recheck for verticality of the reticle.

e. *Vertical Collimation.* This error is eliminated using the observing procedures outlined in section 2.2.7.2, subsections 1 and 2. The line of sight must be horizontal when

Figure 2.2.5-2.—Examples of 1-second theodolite circle readings: (a) Wild T2 (older model), (b) Wild T2 (newer model), (c) Kern DKM-2. Depending on the setting of the selection knob on the Wild T2's, the vertical and horizontal circles appear separately. In the Kern DKM-2 both circles appear simultaneously.

the vertical circle reads $90^{\circ} 00'$ exactly. This test and adjustment must be done after the horizontal collimation.

(1) With the instrument in circle left (CL) position, align the horizontal crosshair carefully on a well-defined point at least 100 meters away.

(2) Bring the ends of the vertical collimation level bubble into coincidence using the vertical collimation slow motion screw.

(3) Read and record the vertical circle reading, checking the level bubble to make sure it is still in coincidence.

(4) Plunge the telescope (circle right-CR) and repeat the procedure.

(5) The sum of the two readings should equal 180° . Any variation is equal to twice the error. Any variation less than 20 seconds need not be adjusted.

(6) Divide the variation by 4 and apply it with the proper sign (+ or -) to the last vertical circle reading. Using the micrometer drive knob, set this corrected value on the micrometer.

(7) Bring the circle back into coincidence using the vertical collimation slow motion screw. This will leave the collimation level out of coincidence.

(8) Bring the collimation level into coincidence with the adjusting screw located under the vertical circle level.

(9) Repeat the test as a check on the adjustment.

2.2.5.2 Towers and Masts

1. **General.** NGS uses a variety of towers and masts to elevate the observer and signal above trees and other obstructions. These towers and masts permit triangulation stations to be spaced evenly and allows longer lines to be observed where the terrain is flat and wooded.

Observing tents are required on towers and other observing platforms as a sunshade for early evening work and as a windbreak. The tents will help reduce errors caused by wind and uneven heating of the instrument.

This section discusses the Bilby steel tower, the Pek tower, the truck-mounted observing tower (TMOT), the signal masts, and the trailer-mounted tower. Section 1.3.3.3 discusses tower safety.

2. **Bilby Steel Tower.** The Bilby tower was first introduced in 1927. It provided horizontal control parties with a portable, easily assembled, and inexpensive method to elevate the observer and signal. *Publication 62-3*, Bilby Steel Tower for Triangulation, contains specifications, historic information, and instructions for assembling and dismantling this type of tower. Party personnel should read and understand the safety precautions and the information on sandbagging towers included in *Publication 62-3*.

3. **Pek Tower.** The Pek tower was designed by Ralph Pekinpaugh while working on a mobile field party. It provides a portable observing platform 3 and 6 meters in height.

4. **Truck-Mounted Observing Tower (TMOT).** The Instrumentation and Equipment Branch has developed a TMOT. It provides a 15-meter high observing platform which can be erected in $1\frac{1}{2}$ hours by two persons. Use of the TMOT is restricted by the accessibility and terrain at

the station sites. Assembly and operating instructions are supplied with the TMOT.

5. **Masts.** Some of the NGS parties are equipped with signal masts. These masts are used for showing lights and reflectors and for measuring air temperature from stations which are not occupied.

The mast consists of five telescopic tubes each 6 meters in length. The mast is easily erected by two or three persons and can be extended to a height of 30 meters. It can be erected in about an hour (including rigging and centering) and can be lowered and made ready to be transported in 30 minutes. The mast is held in position with three sets of guy wires. The wires are attached to the top of the first, third, and top sections.

After the mast is initially set up next to the station, and before it is extended, a remotely controlled positioning arm is attached to the top of the mast. The light and/or mirror is attached to this arm. The arm can be extended, retracted, and rotated to collimate the mirror and/or light over the mark. The mirror or light can also be turned horizontally to correctly point it towards the observer. Show lights with motorized tilting lenses are used. The arm also has an antenna mount for better reception on the two-way radios.

6. **Trailer-Mounted Tower (TMT).** The TMT provides an elevated platform for a mirror, show light, or remote reading temperature sensor. It can be erected by one person in a few hours.

The tower consists of six triangular sections ranging from 15 to 66 cm on a side and 6 meters long. The sections are telescoped in and out by means of cables and pulleys. The tower can be extended to a maximum height of 32 meters.

The trailer consists of two long, stiff main frame members, tandem axles, a house trailer-type 20,000-lb ball coupling, and spaces over the axles to mount auxiliary components. A powered, steerable wheel set just after the coupling enables the trailer to be positioned accurately with a minimum of jockeying.

Power for all load-moving components is provided by a hydraulic pump driven by an 8-horsepower gasoline engine. The engine has a starter-generator which also maintains the charge on a 12-volt lead-acid battery. This battery provides power to operate the positioning arm (see paragraph 5, Masts, above) and show light.

The tower is tilted upright and telescoped by using the hydraulic system. The hand-operated outriggers and forward hitch jack are used to level the tower prior to elevation. Bulls-eye levels on the frame aid in this leveling. Detailed operating instructions are supplied with the TMT.

A $\frac{3}{4}$ -ton truck is sufficient to tow the trailer. The trailer wheels are set quite far back to obtain the proper hitch load.

The site selected must be fairly level. The ground at the hitch cannot be more than 0.4 meter above the ground at the wheels. A smooth grade of 20% across the width of the trailer can be accommodated.

The tolerable wind decreases with tower height. The tower should be guyed when used at heights above 15 meters.

2.2.5.3 Stands, Tripods, and Taping Benches

1. **General.** In precise surveys, stands and tripods must be well-made and solid. Driven stakes or some quick setting cement for tripod leg supports may be required. Catwalks or duckboards may also be necessary to ensure satisfactory results. Regular instrument tripods should rarely be used for observing platforms in first-order or second-order, class I surveys.

2. **Stands.** A sketch for the construction of the 1.2-meter wooden stand is shown in figure 2.2.5-3. This type of stand, when properly constructed and set up, provides a very stable observing platform.

The NGS Instrumentation and Equipment Section has developed a metal 1.2-meter instrument stand. It can be set up or dismantled in a few minutes. Assembly instructions are supplied with the stand.

Wooden stands 5 to 9 meters in height may be used when Pek towers are not available.

3. **Tripods.** A 1.2-meter stand must be used for all first-order and second-order, class I stations where a ground setup is required. A tripod should not be used except in the following cases:

(a) When a ground setup is used for measuring directions to azimuth and reference marks.

(b) When occupying a supplemental station which is tied to only one main scheme station. A tripod may be used as an observing platform for measuring the zenith distances.

All tripods should be checked frequently and all worn parts repaired or replaced.

4. **Taping Benches.** Adjustable height taping benches have been designed and fabricated by the Instrumentation and Equipment Section. The benches can easily be assembled and disassembled. The legs are driven into the ground and the bench is guyed in place to provide further stability. The guys are chains fastened to the bench and flat metal stakes driven into the ground. The chains can be tightened using the turnbuckles provided.

2.2.5.4 Electronic Distance Measuring Instruments

1. **General.** The National Geodetic Survey uses several different brands of electronic distance measuring instruments (EDMI). Basically there are three types of EDM: red laser light, infrared light, and microwave. Each EDM has its own operating procedures and limitations. The operating instructions are supplied with each instrument. Specifications and limitations are discussed in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

The minimum distance that should be measured by any EDM depends on four major factors: (1) accuracy required, (2) standard error of a single observation as stated by manufacturer, (3) number of complete multiple measurements, and (4) observing procedures.

Assuming that precise observing procedures are followed and centering errors are negligible (which may or may not be the case because great care is required to achieve centering accuracies of 1 mm or less), the following formula provides a guide for measuring minimum distance:

$$\text{Minimum distance} \approx \sigma/x$$

where σ is the standard error of a single observation expressed in millimeters, x is a factor varying with accuracy class. The different factors (x) are: first-order, 0.005; second-order, class I, 0.010; second-order class II, 0.025; third-order, class I 0.050, and third-order, class II, 0.100.

When complete multiple measurements are observed, the acceptable minimum distance can be determined by dividing the value derived in the formula by $\sqrt{N}$, where N is the number of complete measurements. For example, for second-order, class II accuracy, where $\sigma = 5$ mm, the minimum distance = $5/0.025$ m = 200 m. If two complete measurements are made ($N=2$), the minimum distance shall not be less than $200/1.4 \approx 140$ m. Many manufacturers specify a minimum distance measurement, and in no instance should this minimum be violated.

2. **Red Laser Light.** These instruments use visible light to measure medium to long distances. They should be used for all first- and second-order, class I horizontal control network lines. Instruments of this type used by NGS include the following:

a. Models 4 and 8 Geodimeters, manufactured by AGA Corp.

$$[\sigma^2 = (30 \text{ mm})^2 + (1 \text{ mm/km } D \text{ km})^2], \text{ where } D \text{ is distance.}$$

b. Rangemaster and Ranger Series manufactured by Laser Systems and Electronics, Inc.

$$[\sigma^2 = (30 \text{ mm})^2 + (1 \text{ mm/km } D \text{ km})^2]$$

c. "Big Red," made in-house by the Instrumentation and Equipment Section.

$$[\sigma^2 = (30 \text{ mm})^2 + (1 \text{ mm/km } D \text{ km})^2]$$

3. **Infrared.** Infrared instruments use invisible light. They are short and medium range instruments used for distances from about 50 meters to about 10 km depending on type. They are used for measurements to azimuth marks and near-by bench marks. Instruments of this type include the following:

a. MA100, manufactured by Tellurometer.

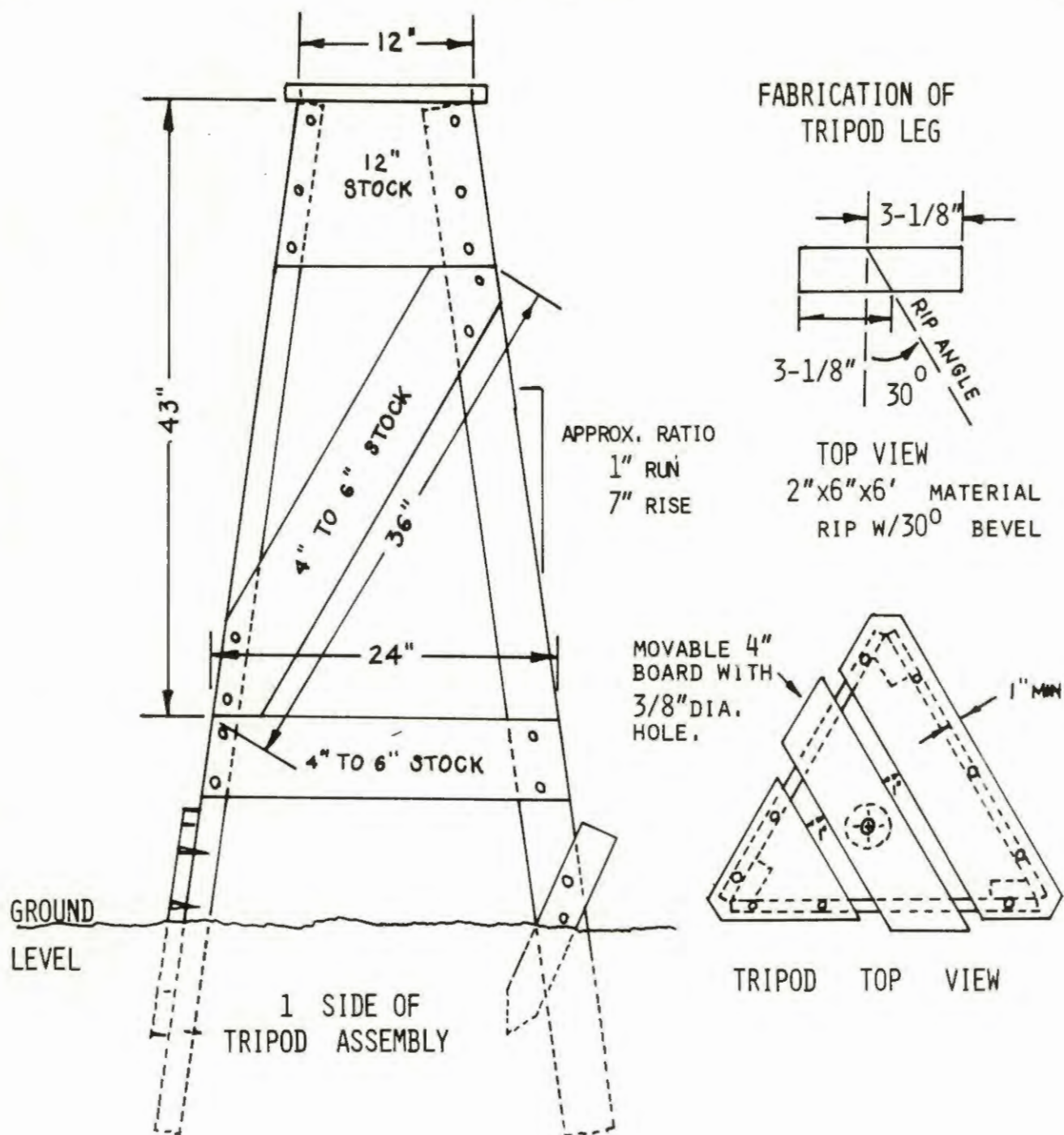
$$[\sigma^2 = (2 \text{ mm})^2 + (1 \text{ mm/km } D \text{ km})^2]$$

b. HP 3800 and HP 3808 manufactured by Hewlett Packard

$$[\sigma^2 = (5 \text{ mm})^2 + (7 \text{ mm/km } D \text{ km})^2] \text{ and } [\sigma^2 = 5 \text{ mm}^2 + 1 \text{ mm/km } D \text{ km})^2], \text{ respectively.}$$

4. **Microwave.** Microwave instruments should not be used for first-order and second-order, class I surveys unless electro-optical instruments are not available.

5. **Related Equipment.** All EDM's require meteorological data to be collected at one or both ends of the line. Thermometers checked against calibrated thermometers and survey altimeters or barometers must be used. Wet and dry bulb temperatures are needed to calculate a humidity correction. A sling or battery powered, self-aspirating psy-



NOTE: NAILS: 7 PENNY BOX NAILS. BRACE MATERIAL: 1 INCH BOARDS OR $\frac{1}{2}$ " MINIMUM PLYWOOD. ALL BRACING ANGLES CUT TO FIT. WHEN ASSEMBLING TRIPOD, DO NOT ALLOW BRACING TO OVERHANG TRIPOD LEGS.

Figure 2.2.5-3.—Sketch for constructing a 1.2-meter wooden stand

chrometer should be used. Incorrect or inaccurate measurements in temperature, pressure, and humidity can result in several parts per million (ppm) error in the atmospheric correction to the measured distance. Each 1°C error in reading the thermometer, or each 2.5 mm error in pressure, can result in a 1 ppm change in the atmospheric correction. Under certain conditions with microwave instruments, an error of 1°C between the wet and dry bulb readings can cause up to a 17 ppm error in the measured distance. The humidity correction for light wave instruments is usually less than 1 ppm.

All red laser light and infrared light instruments used by NGS require retroprisms to reflect the carrier wave. Only reflectors with known constants should be used. The prisms must be kept clean to give consistent results. A soft cloth or cotton balls should be used when cleaning is necessary. If the reflectors have been dropped or their calibration is in doubt, they should be returned to the Instrumentation and Equipment Section for recalibration.

The Instrumentation and Equipment Section has developed a calibration cap for the HP-3800 EDM. This cap is to be used before each set of measurements to obtain an instrument calibration constant. A cap is made for each particular instrument and should not be switched with that of another instrument. Instructions for use of the cap are supplied with the instrument.

The Instrumentation and Equipment Section has developed two different types of offset bars for use with EDM. The first bar is a mirror offset bar 1 meter in length. The bar is made of flat stock metal with three holes, one centered and one near each end of the bar 0.400 meter from the center. The second bar is used to offset the instrument. It has a GDF6 tribach plate which accepts the Hewlett-Packard and other small instruments. The bar can be mounted on a standard instrument tripod. The tribach is centered and plumbed over the station. Measurements are made with the tribach at center and at the offset position at each end of the bar. The offset is 0.150 meter.

2.2.5.5 Azimuth Time Module

1. **General.** The azimuth time module contains all the timing equipment needed for obtaining a first-order azimuth determination in the field. The module contains a crystal controlled receiver to obtain time signals and an electronic digital clock, each with a self-contained power supply. The following instructions should be studied and understood before attempting to operate this equipment.

2. **Receiver Operating Instructions.** The receiver is crystal-controlled to give reliable reception of time signals from WWV, operated by the National Bureau of Standards in Fort Collins, Colorado, and from CHU, Ottawa, Canada. (WWV frequencies 5, 10, and 15 MHz and CHU frequencies 7.3 and 14.6 MHz for Model 1; and 7.3, 5, and 10 MHz for Model 2.)

a. **Antenna.** The receiver contains a front panel mounted telescoping antenna which should be adequate for reception of at least one of the selected frequencies, if operated

outdoors and away from strong sources of radio interference. Swing the panel mounted antenna straight out from the panel. Internal electrical connections will be broken if the antenna is rotated to the side.

The set will often operate indoors depending on the shielding effect of the building. The set also has provisions for the connection of an external antenna via a panel-mounted jack. The ideal length of an external antenna is 46.8 feet for WWV and 32.0 feet for CHU.

b. **Power Supply.** The receiver uses a set of eight size "C" flashlight batteries for a power supply. To replace batteries, remove the five flat headed brass screws holding the front panel and carefully slide entire unit out of the case. The battery tray is exposed in the upper rear of the case. Remove the old batteries and replace with new ones, taking care to observe the correct polarity. The positive end of the battery is placed against the solid contact and the negative or base end against the springs. Make sure the batteries are firmly pressed against the contacts by the springs.

The batteries should last 3 to 4 months in normal usage. **Remove Batteries** if module is to be stored any length of time so that corrosion will not damage the module.

An external power supply plug and cord are provided on the front panel. A 110 VAC power supply is provided with the Model 2.

c. **Controls.** Turn the receiver on by means of the power switch on the volume control. Extend (or connect) the antenna and turn the volume control partway up. Select the frequency by means of the push buttons on the Model 1, and by the rotary frequency switch in the Model 2. Try several frequencies to find the loudest and clearest signal for the time of day. Adjust the volume control to give a comfortable listening level. The sensitivity switch (Model 1) is switched for clearest reception and the tuner control must be carefully rotated to give a fine control over the antenna for clear reception. The volume control should be placed in the "OFF" position when the receiver is not being used.

3. **Digital Clock Operating Instructions.** The digital clock is programed to perform as a 24-hour clock. It may be powered with either a 4.8 VDC Ni-Cad battery pack located in the upper rear portion of the module case or by 110 VAC through the power cord stored in the module case cover.

a. **Function Switch.** The function switch controls the selected power input into the clock and the charging of the battery. When the clock is to be operated in the DC mode, the function switch is placed in the DC position and then the red push button located in the center of the panel is pushed to activate the clock. The switch is wired to disconnect all functions other than the one selected. Always turn it to the "OFF" position when the clock is not being used.

b. **Battery and Charger.** The battery is a 4-cell 4.8 VDC 7 AH sealed Ni-Cad unit. It is connected to the clock through a terminal board on the back of the front panel. If these connections are disconnected, care must be exercised when reconnecting to obtain proper polarity (red to red and blue to blue).

The batteries can be fully charged in 22 to 24 hours with the charger. The charger will charge at approximately 675 Ma until about 90% charged and then trickle charge at approximately 500 mA until fully charged. The clock draws 1310 mA while operating. Five hundred to six hundred charge/discharge cycles can be expected before the battery life is expended.

The battery may be stored in either a charged or discharged state without harm. For field operations the fully charged (90 to 95 indicated on charger meter) battery will operate the clock for a period of 8 hours.

Caution: An intermittent stopping and starting of the "seconds" digits on the clock indicates a low charge condition of the batteries. The clock should be shut off immediately as a continuation of operation will result in a reversal of polarity on the cells, thereby requiring replacement of the battery.

c. **Clock Controls.** The digital clock can be preset from the front panel by placing the "SET-RUN" toggle switch to the "SET" position. This enables the pushbutton switches under the hours and minutes display to be changed and automatically sets the seconds display to zero. Pressing the pushbutton switches allows the digit or digits selected to advance at a rate of one digit per second. Each digit is set independently of adjacent digits such that no overflow into the next higher digit occurs. Positioning the toggle switch to the "RUN" position starts the clock and disables the pushbuttons, eliminating the possibility of disturbing the display.

d. **Pickle Switch.** The cord-mounted pickle switch, stored in the module case cover, is pressed to hold the displayed time at the moment of star intersection while the clock continues to accumulate actual time internally.

Releasing the pickle switch enables the clock to re-acquire and display actual time. The pickle switch is released by again pressing the switch.

When the clock is turned on and a partial lighting of various segments of the digits occurs, the pickle switch is in the depressed position. Release the pickle switch to obtain full lighting of all segments of the digits.

Warning: Snap release of the pickle switch can cause an error in the clock.

2.2.5.6 Signal Lamps

Field parties seldom use the 5-inch lamp pictured in *Special Publication 247*. The Instrumentation and Equipment Section has developed a 3-inch lamp. The latest version is available with a rheostat dimmer, flasher, and timer.

The frame of the lamp is cast epoxy resin. The base of the frame is tapped for both 5/8 11 and 5/16 18 bolts to facilitate mounting on both tripods and towers. The top of the frame is tapped for a 1/4-20 bolt to allow lights to be stacked on one another.

The reflector is a highly polished 3-inch diameter, parabolic bowl. It is mounted in a 10-cm x 10-cm metal bracket. The bracket is bolted to the sides of the frame. The bracket is mounted so the axis of rotation passes hori-

zontally and vertically through the center of the bulb. This is aimed up or down without changing the height of light.

The new lights have bore-sights to make them easier to point and clips to hold extra bulbs and bolts.

2.2.5.7 Tribrach Plate with Optical Plummet

Periodically, check and adjust the bull's-eye bubble and reticle on all tribrachs (such as the Wild GDG6). This section describes the bubble and reticle adjustments.

An adjusting jig is available from the Instrumentation and Equipment Section. This jig consists of a bench level and an aluminum disk which is placed in the tribrach.

1. **Bull's-Eye Bubble Adjustment.** Place the aluminum disk in the tribrach and place the bench level on top of the aluminum disk. Level the tribrach with the 3-foot screws while observing the bench level. After the tribrach is leveled with the bench level, the bull's-eye bubble should be in the center. If the bull's-eye is not in the center, adjust it by using the three adjusting screws below the bubble.

2. **Reticle Adjustment for a Single Tribrach.** After adjusting the bull's-eye bubble, use the following procedure to adjust the reticle:

a. Attach the tribrach to a sturdy tripod or stand. Level the tribrach.

b. Suspend the plumb bob from the leveled instrument and mark a point on the ground exactly under the point of the plumb bob. Remove the plumb bob from the instrument.

c. Check the leveling of the instrument and then look into the eyepiece of the optical plummet. If this plummet is correctly adjusted, the mark on the ground will be centered in the reticle circle or cross hairs of the plummet.

d. If the image of the mark is not centered in the reticle, bring the reticle to center by means of three adjusting screws located near the optical plummet eyepiece. Loosen the checknut. The vertical screw will raise or lower the reticle in the direction that the screw moves. The side screws will move the reticle opposite to the direction of screw travel. Always loosen the screw on the side opposite to the direction of travel and tighten the one in the desired direction.

3. **Reticle Adjustment for More Than One Tribrach.** After the bubbles have been checked and adjusted on two tribrachs, remove the bench level and place one of the tribrachs upside down on the aluminum disk. Make a pencil mark on the ceiling above the tribrach. After positioning the reticle on the pencil mark, rotate the top tribrach 360° while observing the pencil mark. If the reticle does not stay on the mark, adjust it with the three capstan head screws on the eyepiece.

2.2.5.8 Calibrated and Standardized Tapes

Calibrated and standardized tapes are expensive and should be properly cared for to prevent corrosion. Before using the tape, wipe the entire length with a soft dry cloth. To prevent rust, coat the tape with light oil before putting it away. Rust can be removed by gently rubbing the affected section of the tape with very fine steel wool. Any tape that is damaged should be returned to the Instrumentation and Equipment Section.

2.2.6 Distance Measurements

Distance measurements are used in triangulation to establish base lines for strengthening control networks, to make traverse ties to supplemental stations and bench marks, and to make reference measurements to objects and reference marks at the station site. Distance measurements constitute a major portion of data collected in trilateration and traverse where all sides or lengths are measured. (See sections 2.2.10 and 2.2.11.) Currently distances are measured using taping or EDM procedures. Specifications for length measurements by the type, order, and class of work are contained in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

2.2.6.1 Taping

1. **Precise Taping.** The availability of EDM has drastically reduced the number of taped base lines and traverse lengths. Presently, the National Geodetic Survey requires the use of precise taping procedures only for calibration base lines, short traverse ties, and some special projects. For second-order, class II or higher, the tapes should have a low expansion coefficient. Tapes of nickel-steel alloy such as Invar and Invar should be used. The measurements are to be corrected for slope, temperature, catenary, sea level, and standardization values.

Detailed procedures for precise taping are given in *Special Publication 247* (pp. 193-236). Exceptions to these procedures are given in *NOAA Technical Memorandum NOS NGS-8, Establishment of Calibration Base Lines* (p. 17).

Precise taping shall be recorded and the measurements reduced on NOAA Form 76-46, Short-Traverse Observations and Computations (fig. 2.2.6-1). Field parties with terminals should transmit the taped traverse data by computer.

Leveling observations are used to determine the inclination correction over the line. Entry of leveling observations on NOAA Form 76-46 (fig. 2.2.6-1) are indexed here. A sketch of how the observations were made can be useful.

Leveling Observations:

- (1) Date (YYMMDD) of the leveling observations.
- (2) Instrument, instrument code, and serial number.
- (3) Serial numbers or type of level rod(s) used.
- (4) Name of point or station leveled
B/O = bench over
STK = Stake
- (5) Enter backsight rod readings in this column. Note the units of measure.
- (6) Enter foresight rod readings in this column. Note the units of measure.
- (7) Determine the differences in elevations between the end points. Clearly indicate the end points between which the elevation differences were determined, i.e., STATION to B/O, B/O to STK, STK to B/O, B/O to STATION. Note units of measure.
- (8-10) Sights and differences using the second scale or feet scale on the rods.

- (11) Recorder.
- (12) Observer.
- (13) Weather.
- (14-15) Measured heights of the benches over the marks. These measurements should check the elevation differences determined in (7) to less than 3 mm.

Computation of inclination correction:

- (1) List end points of sections measured.
- (2) Distance taped. Note units of measure.
- (3) Difference in elevation determined in (7) of Leveling Observation. Note units of measure.
- (4) Inclination correction determined from the formula,

$$C = -[l - (l^2 - h^2)^{1/2}],$$

where l = the measured length, and h = the difference in elevation between the end points.

- (5) Enter the known or determined elevations. Note the units of elevation.
- (6) Mean of the elevations in (5).
- (7) Any remarks.

Taping Observations:

- (1) Date of taping observations.
- (2) Time and time zone.
- (3-5) Serial number of tape, balance, and thermometers. Instrument codes for the type of tape used.
- (6) Enter the end points of the sections.
- (7) Temperature in degrees Celsius.
- (8-9) Measurements.
- (10) Number of supports.
- (11) Remarks—include type tape, observer, recorder, and weather. Record any comparison measurements made in feet.

Computation of Length:

- (1) Enter the names of the end points of the sections.
- (2) Date.
- (3) Forward (F) or backwards (B).
- (4) Tape serial number from (3) Taping Observations for measurement being reduced.
- (5) Number of supports from (10) Taping Observations.
- (6) Number of uncorrected tape lengths.
- (7) Total meters measurement.
- (8) Temperature: mean of forward and rear temperature in (7) of Taping Observations.
- (9) Temperature correction determine from

$$C_t = C_e \times D \times (t - T),$$

where C_e = Coefficient of Expansion listed in the standardization sheets supplied with the tape,

d = distance,
 t = temperature in °C, and
 T = standardization temperature in °C.

- (10) Tape and catenary correction from standardization sheets.
- (11) Set-up or set-back from (8-9) in Taping Observations.

LEVELING OBSERVATIONS

[illegible]

COMPUTATION OF INCLINATION CORRECTIONS

[illegible]

TAPING

[illegible]

OBSERVATIONS

[illegible]

COMPUTATION OF LENGTH

[illegible]

Figure 2.2.6-1.—NOAA Form 76-46, Leveling Observations

(12) Inclination from (4) Computation of Inclination Corrections.

$$(13) \text{ Sea level correction} = -D \times \frac{\pm h}{(R_{\alpha} + h)}$$

$$\text{or approximate correction} = -D \times h \times 1.57 \times 10^{-7},$$

where

D = distance (meters),

h = mean elevation of the end points (meters), and

R_{α} = mean radius of curvature for the Earth at the latitude of the line and in the azimuth of the line.

(14) Reduced length = sum of corrections from items 7 through 13.

(15) Adopted length.

(16) Any remarks.

2. **Reference Marks.** Measure the distance between the station and its reference marks. Also measure the distance between reference marks with a good quality 30-meter steel tape. The tape should be graduated in meters and millimeters on one side and feet and hundredths on the other. Measurements to reference marks require two independent readings, one in metric units and one in English units. When converted to its metric equivalence, the English measurement should compare within 3 mm of the metric measurements. Measure distances longer than 30 meters forward and backwards with a 300-foot steel tape. Where possible, measure reference mark distances horizontally. If they cannot be measured horizontally, correct them for slope. Note any slope distances which cannot be reduced to horizontal as "SLOPE DISTANCE." Use NOAA Form 75-82 for recording the measurements, conversions, and checks.

3. **Reference Objects.** Measurements from all marks shall be made, if possible, to at least two reference objects. These measurements shall be made to the nearest centimeter and to 0.1 foot and entered on the station description as "xx.xx METERS (xxx.x FEET)."

2.2.6.2 EDM

Electronic distance measuring instruments (EDM's) have made distance measurements more economical. Many different EDM's are commercially available, each with its own operating characteristics. EDM's used by NGS are briefly discussed in section 2.2.5.4. Detailed specifications for electronic distance measurements are contained in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

Detailed operation instructions are supplied with each EDM used by the NGS field parties. In general, measurements will consist of three or four observations. Two of the observations shall be offset both forward and backward along the line-of-sight. Field parties have been equipped with "offset" bars for this purpose. (See section 2.2.5.4.)

Observations shall be recorded on the appropriate form.

Observations from the Model 8 Geodimeter may be recorded on the Model 4 recording form (NOAA Form

76-43) for convenience. NOAA Form 76-33 allows for one determination of length per sheet. A complete measurement requires four recording sheets. All four determinations can be recorded on NOAA Form 76-43. This form may also be used to record observations from "Big Red" and "Big Red Junior."

NOAA Form 76-170 should be used to record observations from all models of the Ranger and the Rangemaster instruments.

NOAA Form	Title
76-19	Hewlett-Packard Distance Meter Observation
76-33	Geodimeter Model 8 Observations
76-43, -43A	Geodimeter Model 4 Observations
76-61	Tellurometer Observations Model MRA3-MK2
76-61A	Tellurometer Observations Model CA1000
76-138	EDM Observations
76-170	Ranger III Observations

2.2.7 Observing and Recording

Observing and recording procedures for first-order work are described in detail in *Special Publication 247* (pp. 110-115, 131-137). References to the Parkhurst theodolite are no longer relevant. Supplemental information and instructions for the use of a Wild T3 equipped with a 60-unit micrometer are contained in this section.

For other instruments, see the manufacturer's instruction manual. No information has been included for lower than second-order work. However, the procedures are similar.

2.2.7.1 Setting Up

In order to obtain results of the highest possible precision, use an umbrella or tent to shade the instrument from direct sunlight. In addition, rotate the alidade and the telescope several times to ensure an even distribution of grease through the bearings. Allow sufficient time for the instrument to become the same temperature as the surrounding air.

1. **Checking Stability.** In *Special Publication 247* (pp. 100-101), a procedure is given to ensure that the observing stand or tower is sufficiently stable. In addition to the procedure given, after pointing on a well-defined object and checking for movement in one direction, rotate the instrument 90° and repeat the process. On a Bilby tower, point on an object, then twist the welded section and check the pointing after the inner tower has returned to equilibrium. If this test fails, check and tighten the bolts on the inner tower, particularly the bottom of the two upper sections.

2. **Leveling the Theodolite.** The procedure for leveling a theodolite should not include adjustment to center of the level bubble in its vial during each set up. The continual adjustment of a level vial to center the bubble not only adds to

the time required to level a theodolite, but also wears the threads of the adjusting screw or nut, resulting in a certain amount of looseness. By determining the "reversing point," discussed below, observations will be unaffected by a bubble vial that is out of adjustment, unless the bubble ends are more than 5 divisions from the last numbered graduation. In this case, see section 2.2.5.1 to adjust the vial.

If the divisions on the level vial have no numbers, they should be numbered sequentially from left to right with the zero end of the vial at the left when the telescope is direct (at the vertical circle end of the vial). The major level vial graduations for a Wild T3 theodolite should be numbered "0", "5", and "10" on the left and "15", "20", and "25" on the right.

Level the theodolite approximately in both directions, then rotate the alidade so that the level vial axis is over one of the foot screws. Using the graduations, note the position of the lower end of the bubble (towards the vertical circle). Now rotate the alidade 180° and note again the position of the lower end of the bubble. The mean of these two readings is the so-called "reversing point" of the bubble. Assume for example that the first reading is 4.6 and the second reading, after rotating 180° , is 7.2. The reversing point then is 5.9. Bring the end of the bubble to this point by rotating the foot screw.

Now turn the alidade 90° so that the level vial axis is parallel to a line joining the other two foot screws. Bring the bubble to its reversing position by rotating these foot screws equally in opposite directions. The entire process may have to be repeated to refine the determination of the reversing position. Once the reversing position is determined, all that is required to relevel the theodolite is to use the foot screws to bring the level bubble to its reversing position in each of the two directions of the alidade, 90° apart.

The key to the method outlined herein is as follows: Once the reversing position of the bubble is well determined and the theodolite is leveled as described, the standing axis about which the alidade rotates is truly vertical and the bubble will remain in the same position, whether centered in the vial or not, no matter which direction the alidade is rotated. The reversing position of the bubble may drift slightly from day to day or even during a period of observation. Thus, it should be checked before each observing period and on plate settings 5, 9, and 13 during each period. It should seldom be necessary to readjust the bubble vial.

2.2.7.2 Zenith Distances

1. **Index Error.** Index error is introduced when the vertical circle level is out of adjustment. Excessive index error will not affect the accuracy of vertical angles if the proper observing program is followed. It will cancel itself when readings are taken in both direct and reverse positions. However, if the vertical circle index error exceeds $20''$ on a Wild T3 theodolite, it should be adjusted. (See section 2.2.5.1.)

2. **Pointing and Reading for Conventional Surveys.** Three direct (circle left, or CL) and three reverse (circle right, or CR) readings are required for each station observed.

An observation to a *single* station with a T3 is obtained as follows: In CL, with the target aligned near the vertical cross hair, set the horizontal cross hair precisely on the target. Align the two ends of the index level bubble. If the bubble ends are already in coincidence, they should always be moved off and realigned, because the bubble could be "hung." Set the vertical circle in coincidence and read it and the micrometer. Reset the vertical circle in coincidence and read the micrometer again. *Do not just repeat the first micrometer reading.* Repeat the above procedure in CR once, CR again, then two CL's, and then the final CR. Be sure to *Rpoint* the telescope and *realign* the vertical bubble for each CL and CR position. (See fig. 2.2.7-1.)

When observing more than one station, use the following sequence.

- (1) CL on all stations.
- (2) CR on all in reverse order.
- (3) CR again on all.
- (4) CL on all in reverse order.
- (5) CL again on all.
- (6) A final CR on all in reverse order.

Time must be recorded for each station during steps (1) and (6).

This procedure may cause some scheduling difficulties because all lights will have to be on at the same time. The procedure is required by the computer programs to obtain a more realistic correction for refraction.

Special Publication 247 (pp. 141-143) explains how to read the horizontal circle on the Wild T3. Reading the vertical circle is identical. Because the index marker is often out of adjustment, the preferred method of determining the minutes is to count the 4-minute subdivisions between diametrically opposed degree markers, and multiply the number by 2, rather than using the index marker. (See section 2.2.5.1.)

3. **Recording.** To avoid confusion, always record the CL (direct) readings above the individual CR (reverse) readings. On this account, you will have to skip around in the recording book as the vertical angles are read. Add 90° to the CR value and subtract its paired CL value from it. This gives the zenith distance for that set. Of the three sets, the spread must not exceed $10''$. Mean the three sets for the final zenith distance. For each object observed, check the index error by adding the first set of CL and CR values. The sums should differ from 180° by about the same amount. If the sum differs from 180° by more than $20''$, the vertical circle level index bubble must be adjusted.

Recorders are reminded to *never* write over any mis-recorded data. Mistakes should be struck out with a single line and the correction written above or below the mistake.

The step-by-step procedure for recording vertical angles (double zenith distances) with the T3 is given below. Step numbers refer to the numbers in parentheses on figure 2.2.7-1.

- (1) Enter name of station occupied.
- (2) Enter observer's name.
- (3) Enter State.

DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
COAST AND GEODETIC SURVEY
Form 252
Rev. Sept. 1966

DOUBLE

ZENITH DISTANCES

46

Station (1) HORIZON State (3) TX
Observer (2) R. BRIGGS County (4) WALLEEHOO

Instrument (5) T-3rd 70473 (123) Date (6) 790902

OBJECT OBSERVED	TIME (CST)	LEVEL		Circle Right or Left	CIRCLE READING	
		O.	E.			
	(13)			(12)	°	'
(9) BARRIGADA	2015			CL	91	08
1933				CR	88	50
					180°	00'
(10) (LIGHT)				CL	91	08
(11) 18.393 m				CR	88	50
				CL	91	08
	2023			CR	88	50
	(13)			CL	89	48
(9) YPAO GG	2016			CR	90	10
1983					180	00'
(10) (LIGHT)				CL	89	48
(11) 1.682 m				CR	90	10
				CL	89	48
	2022			CR	90	10

Do not write in this margin

	VERNIERS			ZENITH DISTANCE	REMARKS
	A	B	Mean		
	"	"	(20)	°	' (21) "
(14)	18.9	18.9	37.8		(7) REC: R. FLOYD
(15)	41.6	41.6	83.2		WX: 00121 HOT
(22)			01.0	87 42 45.4	OVERCAST, 6 Kt WIND.
(17)	20.2	20.2	40.4		STAND 1.440 m
(16)	42.0	42.1	84.1	43.7	TELE .291
					(8) 1.731 m
(18)	18.1	18.2	36.3		LIGHT TO BARRIGADA
(19)	40.5	40.6	81.1	44.8	HT = 0.071 m
				87 42 44.6	FROM 1930 TO 2047
					NO ECC.
	31.3	31.4	62.7		
	31.6	31.7	63.3		LIGHT TO YPAO GG 1963
			06.6	90 22 00.6	HT = 0.140 m
	31.8	31.9	63.7		FROM 1930 TO 2047
	30.9	30.9	61.8		NO ECC.
				21 58.1	
	30.8	30.9	61.7		
	32.2	32.3	64.5	22 01.2	
				90 22 00.0	
					RHB

2.2 Horizontal Control

Figure 2.2.7-1.—Example of form showing the recording of zenith distances

- (4) Enter county.
- (5) Enter type of instrument, instrument code, and serial number.
- (6) Enter date as follows: YYMMDD (e.g., 790902).
- (7) Enter recorder's name, weather, and weather code as specified in the "Input Formats and Specifications of the NGS Data Base." (pp. 2-9 and 2-10). Enter any eccentric instrument or eccentric light data. If neither instrument nor light is eccentric, state that fact.
- (8) Enter heights of stand and instrument telescope. (See section 2.2.7.6.) Also enter heights and times of all lights shown to other stations.
- (9) Enter station being observed.
- (10) Enter object sighted upon.
- (11) Enter height of object sighted upon. (See section 2.2.7.6.)
- (12) Enter circle left (direct) and circle right (reverse).
- (13) Enter time observation began (first CL) and ended (last CR) for each station.
- (14) Enter degrees, minutes, and micrometer units. The observer reads the micrometer two times and both readings are recorded.
- (15-19) Enter degrees, minutes, and micrometer units for the proper points (circle left or circle right). Do not omit the degrees and minutes, and do not prerecord them before the observer calls them out.
- (20) Sum the two micrometer readings.
- (21) Add 90° to circle right and subtract circle left from circle right. The spread between the three values cannot exceed 10". If the spread exceeds 10", reobserve the angle until three values which do not exceed the 10" spread are obtained.
- (22) Sum the first set of CL and CR values to check the index error. The sum should not differ from 180° by more than 20".
- (23) Sum the three angles (No. 21) and divide by 3 to obtain the mean zenith distance for each set. Round the answer off to the nearest tenth of a second. When the last digit in the average is exactly 5 hundredths, round off to the nearest even tenth. For example, 0.45 is rounded to 0.4 and 0.55 is rounded to 0.6.

2.2.7.3 Horizontal Angles

1. **Circle Settings.** Circle settings for the Wild T3 theodolite are specified in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* and are repeated in this section. Settings in table 2.2.7-1 help eliminate blunders in reading the minutes on each pointing.

Table 2.2.7-1.—Circle Settings

Degree	Minute	Units
Four Positions		
0	00	15
45	02	45

Table 2.2.7-1.—Circle Settings—Continued

Degree	Minute	Units
Four Positions		
90	04	15
135	20	45
Six Positions		
0	00	15
30	02	35
60	00	50
90	04	15
120	00	35
150	20	50
Eight Positions		
0	00	10
22	00	25
45	02	35
67	00	50
90	04	10
112	00	25
135	20	35
157	00	50
Twelve Positions		
0	00	10
15	00	25
30	02	35
45	00	50
60	00	10
75	00	25
90	04	35
105	00	50
120	00	10
135	00	25
150	20	35
165	00	50
Sixteen Positions		
0	00	10
11	00	25
22	00	35
33	00	50
45	02	10
56	00	25
67	00	35
78	00	50
90	04	10
101	00	25
112	00	35
123	00	50
135	20	10
146	00	25
157	00	35
168	00	50

2. **Pointing and Reading.** *Special Publication 247* (p. 132) contains information on pointing. Three additional comments are in order. First, use the 40-power eyepiece except in very hazy weather and exclusively when observing astronomic azimuths. Second, the double cross hairs are usually best for pointing on an object or light. And third, it is very important that the instrument be repointed after the plate is reset—this means moving the cross hairs off the target using slow motion screw and resighting, making the last movement toward the spring (clockwise). Looking through the telescope and confirming the position of the target is *not* sufficient because each pointing must be unique in order to obtain 16 independent positions.

Special Publication 247 (pp. 141-143) explains how to read the horizontal circle on the older model Wild T3 (60-unit micrometer). As with vertical angles, it is preferable to use the second method for determining minutes on the circle, i.e., count the number of 4-minute subdivisions between diametrically opposed degree marks and multiply the number by 2. *Be sure to "double mic" the instrument.*

While making the run, check to see that the instrument has remained level by noting the plate level bubble. If it varies from the reversing point by more than one division, releve. Do this before the first, fifth, ninth, and thirteenth positions. Note in the recording book whether or not the instrument was checked or releveled. Read and record the plate or striding level values to the nearest 0.1 unit. These level values are required for every position (direct and reverse) on any target with a vertical angle greater than 5 or greater than 1 if the target is being used as the initial pointing for an astronomic azimuth observation.

3. **Azimuth marks.** Observations to azimuth marks less than 800 meters away must consist of at least four positions with a 1-second or better instrument. For azimuth marks 800 or more meters away, observe at least eight positions. If made in the regular run, they will be the first, fifth, ninth, and thirteenth positions for four positions, and the first, third, fifth, seventh, ninth, eleventh, thirteenth, and fifteenth for eight positions. Alternatively, they may be made while observing reference marks and intersection stations. In this case, attempt to use the same initial object that will be used in the regular run. Also, at least one position in the regular run must be observed on the azimuth mark, and the value must be transferred and averaged with the original values. Check to see that the angle agrees with the others obtained for it. The rejection limit is 5.0". If there is no agreement, the azimuth mark must be continued in the regular run; it should also be determined why the error occurred and whether the reference marks or intersection stations were affected.

4. **Closing the Horizon.** Project Instructions must specify when closure of the horizon is required. The routine for closing the horizon is specified in the project instructions.

5. **Recording.** Form 251A, referred to in *Special Publication 247* (pp. 108-112) shall not be used to record T3 observations. Generally, horizontal control parties use NOAA Form 76-52.

The step-by-step procedure for recording horizontal directions obtained with the T3 equipped with a 2-minute micrometer drum is given below. Step numbers refer to the numbers in parentheses on NOAA Form 76-52 (fig. 2.2.7-2). Figure 2.2.7-3 shows the procedure for recording a T3 equipped with a 1-minute drum.

- (1) Enter name of station occupied.
- (2) Enter observer's name.
- (3) Enter type of instrument, instrument code, and serial number.
- (4) Enter date (YYMMDD).
- (5) Enter heights of stand and instrument telescope. (See section 2.2.7.6.)
- (6) Enter recorder's name, weather, and weather code as specified in *Input Formats and Specifications of the NGS Data Base* (pp. 2-9 and 2-10).
- (7) Enter position number and names of stations being observed for each position. Abbreviated names may be used for all but the first, fifth, ninth, and thirteenth positions.
- (8) Enter direct or reverse (circle left or circle right) instrument pointing.
- (9) Enter starting time of first pointing and time of completion of last pointing on last position. Also include local time zone.
- (10) Enter degrees, minutes, and micrometer units for the initial station. The observer reads the micrometer units two times and both readings are recorded. These readings should not vary by more than 0.3 second, or the readings should be repeated. For simplicity of recording and to make book checking easier, it should be optional for the observer to mentally mean these readings or call them out in sequence order.
- (11-12) Continue to enter degrees, minutes, and micrometer units in the direct positions for each station.
- (13) If plate level readings are required, record them in the remarks column. These level readings should be listed next to the observed direction so that they can be summed and meaned on the same Abstract of Directions (NOAA Form 76-46). Multiply the mean by the tangent of the vertical angle:

$$\frac{1}{4} (\text{sum of bubble readings}) \times (\text{bubble sensitivity}) \\ \times \tan (90^\circ - \text{zenith distance})$$

and apply it as an eccentric correction to the appropriate horizontal direction.

(14-16) Record the reverse readings for all stations, working from the last station back to the initial station.

(17) Sum the two micrometer readings to obtain seconds and enter the column labeled SUM 11. In this example, however, the micrometer readings were "cross added" and the sum was entered in the column labeled "Mean D and R." This provides the same results as step (18) and may be used only if the first and second micrometer readings differ by no more than 0.1.

(17a) For a T3 equipped with a 1-minute micrometer drum, the two direct micrometer readings are meaned, and the two reverse micrometer readings are meaned.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY
NOAA Form 78-52

HORIZONTAL

DIRECTIONS

STATION: (1) HORIZON OBSERVER: (2) R. BRIGGS

INSTRUMENT: (3) T-3^{*} 70473 (123) DATE: (4) 790902

[illegible]

Figure 2.2.7-2.—Example of NOAA Form 76-52 for recording horizontal directions using T3 theodolite equipped with a 2-minute micrometer drum

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY
NOAA Form 76-52

HORIZONTAL

DIRECTIONS

STATION (1) HORIZON		OBSERVER (2) R. BRIGGS					INSTRUMENT (3) T-3 # 70473 (123) DATE (4) 790902					
POSITION (7)	OBJECTS OBSERVED (7)	TIME H (9) M (10)	TEL D OR R (8)	°	'	"	MIC. READING		SUM "	MEAN D AND R	DIREC- TION "	REMARKS (5)
							1ST	2ND				
1	BARRIGADA 1963	05T 2110	D	00	00	(10)	09.0	09.0	(17)	(18)	(19)	(6)
				180	00	(16)	06.4	06.5		07.8		
	ITC RMI		D	78	50	(11)	24.7	24.7				
				258	50	(15)	23.0	23.0		23.8	16.0	(13) 78° 50' (20)
	YPAO GB 1963		D	107	46		25.6	25.6				
				287	46		25.5	25.5		25.6	17.8	107° 46' (20)
2	BARRIGADA 1963		R	191	00	(21)	27.2	27.3				
				11	00	(26)	29.8	29.8		28.6		
	ITC RMI		R	269	50	(22)	12.0	12.0				
				89	50	(25)	13.0	13.0		12.5		
	YPAO GB 1963		R	298	46	(23)	18.2	18.3				
				118	46	(24)	19.3	19.4		18.8		

Figure 2.2.7-3.—Example of NOAA Form 76-52 for recording horizontal directions using T3 equipped with a 1-minute micrometer drum

(18) Mean the direct and reverse sums. Where rounding off is necessary, round to the nearest *even* tenth.

(18a) For a T3 equipped with a 1-minute micrometer drum, the direct and reversed means are measured.

(19) Underline the mean D and R seconds answer arrived at for the initial station. Subtract this amount from the mean D and R seconds computed for each other station observed upon during that position to determine their direction as though the initial were 0 second.

(20) For the first, fifth, ninth, and thirteenth positions, subtract the degrees and minutes from the initial station from each of the stations observed upon to determine the direction in degrees and minutes for all stations.

(21-23) Enter degrees, minutes, and micrometer units in the reverse positions for each station observed upon for the next circle setting.

(24-26) Record the direct readings for all stations from the last station back to the initial.

(27) Continue with steps (17-20.)

NOTE: It is no longer necessary to change initials on the last position when taking the 4 or 8 positions.

6. **Abstract of Directions** (NOAA Form 76-46). An abstract shall be completed for each station occupation as described in *Special Publication 247* (pp. 126-128, 150-151). The rules for rejecting observations are modified as follows:

a. Once an observation is rejected it remains rejected, even though it may return within the accepted limits.

b. If multiple observations of a position were made before rejecting any observations, the mean of the multiple observations shall not be entered on the abstract as a single value for the position. Instead, the multiple observations shall be treated as additional positions.

2.2.7.4 Astronomic Azimuth

The observation of astronomic azimuths presents problems which are more critical than in the observation of horizontal directions. Errors caused by inaccurate determinations of the inclination of the standing axis increase in direct ratio with the tangent of the altitude of Polaris; thus, an accurate azimuth is harder to achieve at 48° latitude than it is at 30°.

There are two prime requisites in an astronomic azimuth: The target must be a circumpolar star (Polaris in northern latitudes) except near the equator where east and west stars are used; and the observing instrument must have a level vial sensitive enough to enable the bubble to repeatedly assume a position perpendicular to the plumb line at the station. The bubble readings must reflect that position as accurately as possible.

To meet the second requisite, all first- or second-order astronomic azimuths will be observed with the Wild T3 or T4 theodolite unless otherwise instructed. As the T3 has no striding level, the standing axis inclination must be determined by the plate level. For recording purposes, the major graduations of the plate level should be numbered "0", "5", "10", "15", "20", "25", reading left to right with the zero

at the vertical circle end of the vial. If the theodolite has a vial numbered in any other manner, the method of marking shall be carefully sketched in the record book. If the value of the plate level vial is not available or is in doubt, it must be determined in the field as described in *Special Publication 247*.

The inclination of the standing axis of a theodolite, in the plane perpendicular to the azimuth of the observed star, can be any readable amount for any position. However, if the inclinations are large and of the same sign throughout an azimuth observation, a secondary systematic error enters into the final azimuth. This error is the result of uncertainties in the value (in seconds) of one division of the level vial. Each division of a vial corresponds to an angular tilt in seconds of arc. This value of one division can be determined experimentally. Therefore, it is important that the sum of the inclinations for any complete azimuth observation should approach zero. Take special care to maintain the standing axis of the instrument as nearly vertical as possible throughout the azimuth observations. This requires keeping the bubble within ½ division of its "reversing point," or the point at which the bubble remains stationary when the alidade is rotated. This condition is achieved entirely by adjustment of the foot-screws and is independent of the plate level adjustment. The latter adjustment merely controls the position of the bubble reversing point and is not critical to the observations as long as the reversing point is fairly centered. See section 2.2.7.1, subsection 2 for instruction on how to determine the "reversing point." If necessary, the bubble can be brought close to its reversing point after each position by a slight "touching up" of the footscrews. **Caution:** Do not relevel the instrument during the observing of any one position.

Bubble readings will be recorded after each pointing on the star and also on the initial or mark stations if the line-of-sight departs more than 1 from the horizontal plane. Allow 1 minute for the bubble to settle. Careful control of the standing axis as outlined above will render unnecessary the recording of bubble readings on inclined sights of less than 1.

The level vial should be read with a line-of-sight perpendicular to the vial. Doing this should eliminate the worst of the apparent changes in length of the bubble between direct and reverse readings. Some of the changes that have been recorded are as much as two divisions. This is an obvious impossibility in the short time between the direct and reverse pointings. A one division error in reading one end of the vial for the direct or reverse position can affect an azimuth by more than 3 seconds.

The observer's professional pride should be directed toward the observation of accurate azimuths rather than fast azimuths. In the past the primary objective in observing horizontal directions for triangulation seemed to be the development of speed, with a consequent sacrifice of some positions as rejections. These rejections could be immediately reobserved with no harm done. In the case of an astronomic azimuth, erroneous results may not be detected until

the office computations are completed. Therefore, speed should be sacrificed for improved accuracy of pointing on the star, allowing time for the bubble to stabilize, and reading the level vial accurately so the computation of the inclination correction for the standing axis will be correct.

The reobservation of an azimuth can sometimes be necessary as a result of bad weather, but this should be the only reason. There have been a few cases where reobservations have been necessary due to a computational blunder that was checked by a second person. Occasional computing errors are unavoidable, but a checker must make it a point not to accept, without checking, any figures set down by the computer, particularly when a night's work is in jeopardy.

The following items are taken from various circulars and memoranda. They are taken from the words of many experienced people and contain the elements of successful azimuth observing at any latitude.

1. Make certain the instrument is in good operating condition, checking for plate slippage by spinning the alidade, and making repeated micrometer readings of the pointing on a target. Check for looseness of any prisms or screws, check tangent screws for wear, and check the focusing ring and parallax adjustment. Use the 40 power eyepiece.

2. Make certain that all parallax is removed from the telescope optics by first pointing to the sky and turning the parallax adjustment until the cross hairs appear sharply defined. Then point at a distant object and turn the focusing ring until the object is clearly seen. Test for remaining parallax by moving the sighting eye, adjusting as necessary until the object is stationary and clearly defined.

3. Focus the micrometer-viewing eyepiece for a sharp image of the micrometer and circle. Check to make certain that both appear stationary when the eye position is changed. If the image of the circle appears to quiver when the instrument is touched, there is a loose or a damaged prism in the system, and the instrument should not be used for astronomic observations.

4. The observations on Polaris should be made with care at all latitudes. This includes timing the direct and reverse pointings in a rhythmic sequence, with sufficient time before each of the timed pointings to allow the plate level bubble to resume its proper position. The star should be centered between the double cross hairs, close to the center of the telescope and its position should not change abruptly when the hands are removed from the tangent screws. The bubble must be read carefully and as accurately as possible after each pointing. Care should be taken to keep the direct beam of the flashlight off the bubble vial in an attempt to eliminate possible heat transfer.

5. In order to ensure sufficient time for the bubble to stabilize, at least 1 minute of time should be allowed prior to the bubble reading after the first pointing on Polaris. Then after reversal, at least 1 minute should be allowed prior to the bubble reading after the second pointing on Polaris. Note: If the astronomic azimuth is to be hand computed, the time between the direct and reverse points should not exceed 5 minutes.

6. The time of the observation may be determined by "tipping" when a whole minute is broadcast, or by reading a chronometer when the observer calls "tip." If a chronometer is used, radio-chronometer comparisons must be made by the same person who determines the time during the observations. The radio-chronometer time check is to be determined to $\frac{1}{4}$ second, since this operation is to establish a constant for the rate of change per minute. Before doing so, the minute hand of the chronometer is to be synchronized with the second hand because most blunders are made in recording the minute. Since there is no adjustment for the second hand, stop the second hand where desired by allowing the balance wheel to strike a single, flexible piece of paper, then move the minute hand in a clockwise direction to synchronize it with the second hand.

The recorder should watch the rhythm of the second hand of the chronometer for several seconds before the "tip" is called. The observed time of the "tip" must be accurate to $\frac{1}{2}$ second.

Some field units have been supplied with Azimuth Time Modules. These self-contained modules were developed by the Instrumentation and Equipment Section and contain all the timing equipment needed for obtaining first-order azimuth observations in the field. Operating instructions are supplied with the module and are also in section 2.2.5.5.

7. Emphasis must be placed upon making observations of directions as accurately as possible. The telescope should *not* be tilted after the tip for ease in reading the micrometer by permitting direct view of it, because it might shift the weight of the instrument to the extent of disturbing the bubble.

8. Minimize readjusting the bubble to a new reversing point, because the adjusting mechanism works against a spring which may not readily accommodate to the new position. If the bubble is far out of adjustment, it is better to use it that way if possible, and readjust it after the night's work. If the bubble must absolutely be readjusted before a night's work, tap the adjusting end block in all four directions with a pencil eraser or with your fingernail after the adjustment is made. This should release any buildup of strain in the spring.

2.2.7.5 Two-Station Traverse Angles

Unless otherwise noted in the project instructions, it is not necessary to switch initial stations when only two stations are being observed for first- and second-order surveys. Use the number of positions specified in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* for the order and class survey being conducted.

2.2.7.6 Observer's Checklist

1. **Leveling.** The theodolite should be leveled according to instructions in section 2.2.7.1, subsection 2. Constant adjustment of the level vials causes the threads of the adjusting screws to wear unnecessarily.

2. **Focus.** Parallax exists when the image of an object is not focused in the plane of the reticle. The image appears to move relative to the reticle. Parallax may be removed from the instrument by focusing the telescope on a light, uniformly colored surface such as the sky, and adjusting the eyepiece so the reticle shows darkest and sharpest. The parallax should then be checked by pointing on a distant object, focusing for the clearest image, and moving the eye laterally to determine if the reticle moves with respect to the object sighted. If there is movement, the eyepiece focus and telescope focus should be slightly readjusted until there is no apparent motion between the reticle and the distant object and they both have sharp images. Preferably, the telescope focus should not be changed during observation of a position. If focusing at short distances, it is better to sacrifice focus rather than continually readjust the eyepiece.

Similarly, parallax must be removed from the micrometer eyepiece. The focus on the micrometer eyepiece should be adjusted so that the scale image appears sharp.

3. **Circle Setting and Reading.** The circle settings must conform to those in section 2.2.7.3.

In bringing the graduated circle (plates) into coincidence, the coincidence knob on the T3 should always be turned in the same direction. Studies of the optical micrometer system show that this procedure eliminates certain systematic errors. Every effort should be made to eliminate any bias in reading the horizontal and vertical circles. If the two micrometer readings deviate by more than three divisions on the micrometer, the observer should reread the scales until proper agreement is reached.

4. **Pointing.** Pointings should be made as smoothly and expeditiously as possible. For horizontal directions, the double hairs are often better to center with than the single hair. The size of the target is the determining factor. Center the target close to the horizontal hair and either on the single vertical hair or between the double vertical hairs.

5. **Collimation.** The collimation of an instrument will probably not change unless the instrument receives a severe blow. Instruments received from storage, or those which have been recently serviced, should have a low collimation (10 seconds or less). If this collimation changes radically, the cause of this change should be investigated. More than likely the instrument has been jolted, and it should be returned for repair.

6. **Reticle.** THE RETICLE SHOULD NOT BE ADJUSTED BY FIELD PERSONNEL. In the past, constant adjusting of reticles by observers has damaged them. Also, the reticle should rarely, if ever, require cleaning. The reticle has a coating that is easily scratched, and may be damaged by unnecessary cleaning. Generally, any dirt or moisture visible in the telescope will be either on the objective lens or on the eyepiece. This may be cleaned with a soft, clean chamois or cloth, lens paper, or a camel hair brush.

7. **Zenith Distance.** The index mark should not be used when reading zenith distance. Count the 4-minute graduations from the upright degree number on the left to the corresponding inverted number on the right and multiply this number by 2 to obtain the proper minute value. When

the upright degree number is on the right, count the 4-minute graduations to the corresponding inverted number on the left, multiply by 2, and subtract from 60 to obtain the correct minute value.

8. **Heights of Instrument and Objects.** For all surveys, the height of towers, stands, and tripods should be measured to the nearest millimeter. Do not rely upon the designated height of a tower or a height of light plate above the welded section—measure them. This procedure is necessary to obtain accurate results from the vertical adjustment program. In addition, all linear measurements should be made independently in feet and meters and compared in the field.

For precise three-dimensional surveys, such as those performed at radio-telescope observatories, the instrument and target height measurements are extremely critical. Instrument height should be measured after each relevelment and recorded to the nearest millimeter. Never rely on generalized heights (0.290 meter for height of telescope, or 0.100 meter for the No. 1 light and 0.250 meter for the No. 2 light)—measure them.

2.2.8 Lightkeeping

Lightkeeping is an important duty on a horizontal control party. The collected data can only be as good as the accuracy at which the lights or mirrors are positioned over the mark and pointed. *Special Publication 65*, Instructions to Lightkeepers on First-Order Triangulation, contains much of the information and instructions pertinent to lightkeeping. It is no longer printed. The duties of the lightkeepers are outlined in *Special Publication 247* (p.137).

1. **Equipment List.** The lightkeeper should be properly trained and equipped to do the job. The following is a list of items needed for lightkeeping:

a. **Station Description.** The station description should be used to reach the station. It should be checked for accuracy. The field office should be notified of any omissions or discrepancies. The reconnaissance description should be used if the station description is not yet available.

b. **Sketches.** Sketches of the reconnaissance and reference marks are very useful in quickly orienting the lightkeeper. Distant towers may not be discernible when they are close to the horizon or located among trees. The reconnaissance sketch has all main scheme points and landmarks plotted. The sketch of the reference marks is a simple line drawing graphically depicting the list of directions from one station.

c. **Magnetic Compass.** The compass is very useful for orienting sketches, locating towers, and checking descriptions. A compass direction from the tower may be in error because of attraction between the compass needle and the steel tower. Locate magnetic north from the ground using the compass well away from the tower. Pick a distant object that is approximately north. Locate several towers or landmarks to verify the direction to the correct tower.

d. **Signal Lamps.** Signal lamps and show lights are synonymous terms for the lamps used in horizontal mea-

surements. Several different types of lights exist. (See section 2.2.5.6.) The lightkeeper should be thoroughly familiar with each type of light, replacement parts, and accessories. Accessories needed for lights are lamp cord (used to make the electrical connection between the tower, lights, and batteries), bolts and thumb-screws, extra bulbs, and dry cell batteries. The lightkeepers should always carry extra lights and accessories. This precaution may prevent the loss of a schedule or long delays in establishing a usable signal.

e. *Collimators*. Tower collimation should be checked each time a tower is used for lightkeeping. The lightkeeper should be familiar with the use of vertical collimators and the collimation techniques outlined in *Special Publication 247* (pp. 42-101).

f. *Tripods*. The lightkeeper should have one tripod for the collimator and a sufficient number of tripods for setting up lights over any auxiliary stations. All tripods should be in good condition and equipped with plumb bobs.

g. *Radio*. The lightkeeper should be familiar with the operation and transmission procedures for two-way radios. (See section 1.9.) Although NGS does not use Morse Code regularly, the lightkeeper should be familiar with it as a back-up tool in case radio transmission is impossible. (See fig. 2.2.8-1.)

INTERNATIONAL MORSE CODE

ALPHABET

A . _	J . _ _ _	S . . .
B _ . . .	K _ . _	T _
C _ . _ .	L	U . . _
D _ . .	M _ _	V . . . _
E .	N _ .	W . _ _
F	O _ _ _	X _ . . .
G _ _ .	P _ . . .	Y _ . _ _
H	Q _ . . . _	Z _ _ . .
I . .	R _ . _	

NUMERALS

1 . _ _ _	6 _
2 . . _ _ _	7 _
3 . . . _ _	8 _
4 _	9 _
5	0 _ _ _ _ _

INSTRUCTIONS FOR USE OF CODE

BT _ . . . _ used between angles in place of "stop."

Question (?)

Transmit all angles by numerals.

Before sending numerals send "NF" to signify "Numerals follow."

When finished transmitting numerals send "LF", meaning "Letters follow."

A series of one-half-second dots mean "I have made a mistake and will begin again."

A series of one-second dots mean "I understand your message."

"R" means "Repeat your message, I could not get it."

SIGNALS TO BE USED BY OBSERVERS TO LIGHTKEEPERS

A	Wait a while.
AA	Stand by. Will need you soon.
N	Your light is too faint. Brighten it.
M	Your light is too bright. Moderate it.
Z	The distinctive letter of the O-party. It means, "We are about to start observing on you." The lightkeeper on receiving a Z (_ _ .) will acknowledge it by answering to the O-party in reverse (. _ _).
ZZ	The letter of the OO-party. It is returned as follows: . . _ _ . _ _
ZZZ	The letter of the 000-party. Returned: . . _ _
4-0	The letter of the 4-0 party. Sent as follows: _ _ _ Returned: _ _ _
DONE	You can turn off your light to this observing party. Continue to show to other parties until they signal you that they are finished. However, you must continue to look for calls and must not leave station until DG is sent you. (_ . . _ _ _ .)
DG	The finished signal for the night. It means all observing parties are through and everyone may return to camp (_ . . _ _ .)

Figure 2.2.8-1.—International Morse Code—Continued

h. *Tools*. The lightkeeper should have wrenches and screw drivers to set the light plate on towers and connect the light cords to the tower. The lightkeeper should also have an ax or saw for clearing lines of sight.

i. *Pack*. A sturdy pack is necessary for carrying the equipment.

j. *Binoculars*.

k. *Flash or signal mirror*.

l. *Lightkeeper's Report*. This can be a form similar to the one shown in *Special Publication 247* (p. 140). If eccentric lights are shown, the lightkeeper's report must include a labeled drawing of the eccentricity. All measurements must be read and recorded to the nearest millimeter. Because additional assistance is needed to measure eccentric distances and angles, if a light is shown from an eccentric position, the eccentric point should be marked in the most permanent manner possible for future angle and distance measurements.

m. *Instructions for use of code*. Dots should be short, just long enough to permit the light to be seen clearly. For dashes, the light should shine for about 2 seconds.

Figure 2.2.8-1.—International Morse Code

The duration of darkness between elements of letters should be 1 second; between letters, 3 seconds; and between words, 5 seconds. It is not important that these periods be absolutely observed, but the relative period should be maintained. Moreover, a uniform speed should be maintained in sending because varied speeds make receiving messages difficult.

2.2.9 Trigonometric Leveling

Trigonometric leveling is discussed in *Special Publication* 247 (pp. 4, 15-16, 103-106, 123, 139, 143-144, 148, 184-189, 275-276, and 285-287). Most of that information is still valid. Computational and recording procedures for the Wild T3 theodolites are included in section 2.2.7.2. Supplemental information is included here.

Zenith distance observations will be made between all interconnected stations on a horizontal control scheme. Zenith distance observations or third-order, class I differential level ties will be made to bench marks and other nearby stations as outlined in section 2.2.19.

The heights of instruments, lights, and other targets should be measured above stations as outlined in sections 2.2.7.2 and 2.2.7.6.

Modern calculators make the reduction of zenith distance observations simple. For this reason, and to assure that blunders do not exist in field records, all zenith distance observations taken on a project will be computed. The "minute check" discussed in *Special Publication* 247 (p. 15) should be made by parties without computer terminals.

If accurate elevations are to be expected, one of the most important factors to be carefully weighed is timing the observations. When plotted, the intensity of refraction vs. local apparent time roughly approximates a sine curve; the minimum occurs from noon to 3 p.m. and the maximum occurs from 9 p.m. to midnight. It is during these periods that refraction remains relatively constant, a condition essential to the best results. The worst periods for observations are between 8 and 9 a.m. and 6 and 7 p.m. (sunrise and sunset). It is then that refraction is changing most rapidly and is least predictable. The early afternoon period is best since refraction is nearly constant then and probably returns closer to the same value from day to day than at any other period. Following are combinations of technique and local apparent time listed in order of decreasing accuracy of results:

- A. Simultaneous reciprocal observations, noon to 3 p.m.
- B. Reciprocal observations, noon to 3 p.m., different days.
- C. Simultaneous reciprocal observations, 9 p.m. to midnight.
- D. Reciprocal observations, 9 p.m. to midnight, different days.
- E. Simultaneous reciprocal observations at any other time.
- F. Reciprocal observations with no coordination in time.
- G. Nonreciprocal observations,
 1. Noon to 3 p.m.
 2. 9 p.m. to midnight
 3. At any other time.

Item (A) is the best, but it is difficult to arrange the simultaneous feature and to use targets that can be seen over long distances. At this time, however, it is better to point on a hilltop or an 0-tent, than to observe under condition (F). Combinations (B), (C), and (D) are acceptable in that order of preference, although (C) may be better than (B) at times. Item (D) is probably the most commonly used and has the great advantage of making possible the observation of vertical angles, usually after the horizontal angle program is completed. In case the horizontal angle observations are not completed by 9 or 10 p.m., these can be resumed after the vertical angles are measured. However, item (D) should not be seized upon to the complete exclusion of the better combinations. If the observing party must stay more than one night on a station, or if it arrives early, every effort should be made to observe from the 12 to 3 p.m. period. Combinations (F) and (G), especially (G) 3, should be avoided on main scheme lines if at all possible.

If case (A) or (B) is used and there is uncertainty as to the object pointed upon, it would be well to employ also (C) or (D) as a check. If the uncertainty is not resolved, reject the doubtful observations.

2.2.10 Trilateration

Trilateration is an alternate method of establishing horizontal control. In trilateration, all sides in a figure are measured with few angles observed. EDM makes this procedure economical.

Trilateration does not have the various internal checks inherent to arc and area triangulation as practiced by the National Geodetic Survey. Since the so-called "braced" quadrilateral and central point polygon have been adopted as the conventional geometric figure for trilateration, certain requirements with respect to the standard errors of length determinations and the size of the angles contained within the figures must be rigorously adhered to when a project is specifically undertaken to satisfy higher geodetic requirements. These restrictions are given in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (table 2, trilateration).

2.2.11 Traverse

Taped traverse procedures are discussed in *Special Publication* 247 (pp. 115, 122, 235). Updated material is contained in section 2.2.6.1.

2.2.11.1 EDM Traverse

During the past few years, major advancements have been made in the field of distance measuring equipment. Although it is now possible to measure longer lines quickly and accurately, traversing does not provide the checks that are inherent in triangulation. Traversing may be used to establish second- and third-order supplemental stations when a strong first-order network is present.

Accuracy requirements are given in *Classification, Standards of Accuracy, and General Specifications of Geo-*

etic Control Surveys (p. 6). Requirements for EDM are given in *Specifications to Support Classifications, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

2.2.11.2 High Precision Traverse

The history, configuration, requirements, and general specifications for conducting a high precision traverse are contained in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

2.2.11.3 Computations and Adjustments

Geographic position computations should be completed as outlined in *Special Publication 247* (pp. 245-248). Programs and documentation for the HP-97 and HP-41CV programmable calculators are available from the National Geodetic Information Center, N/CG174. Field parties equipped with computer terminals should compute positions and make adjustments using the WRKGPN and ADJNET commands.

2.2.12 Azimuth Marks

2.2.12.1 General

Wherever possible, establish azimuth marks at all main scheme and supplemental stations. Valid information about azimuth marks is contained in *Special Publication 247* (pp. 14, 89, 106, 108, 122, and 237). Sections 2.1.1, 2.1.2.5, 2.1.2.9, 2.1.2.10, 2.2.4, 2.2.7, and 2.2.19.1 contain information about setting, naming, observing, and describing azimuth marks.

2.2.12.2 Procedures

Azimuth marks should be positioned to second-order, class II specifications. The procedures outlined in section 2.2.13.2 for using the single-leg, open-ended traverse method should be used. Where possible, the azimuth mark should be occupied to observe positioned landmarks or other visible from ground (VG) stations to provide a stronger solution.

Separate descriptions (NOAA Form 75-82) should be submitted for each positioned azimuth mark. Descriptions should be written and submitted as outlined in section 2.2.4.4.

2.2.13 Supplemental Control

Information about establishing supplemental control is contained in *Special Publication 247* (pp. 3, 13, 110, and 235). The following paragraphs update the requirements and specifications for observing and positioning supplemental stations.

2.2.13.1 Specifications

Project instructions will indicate the order and class to which supplemental control will be established. In most

projects, supplemental control must meet second-order, class I specifications.

Supplemental stations should be spaced and observed such that the 20-percent rule is not violated (section 2.2.20).

2.2.13.2 Methods

Supplemental stations may be located by triangulation, trilateration, or traverse methods. Traverse methods are most commonly used by NGS. Recent developments in EDM have made traversing more accurate than before and faster to accomplish.

Single-leg, open-ended traverse (also called a side shot or spur traverse) is an acceptable method of positioning supplemental stations. However, this method produces a "no-check" position. A stronger solution can be obtained by observing single triangles or closed loop traverses.

2.2.14 Intersection and Landmark Stations

Prominent landmarks should be intersected as part of all horizontal control projects unless otherwise directed by the project instructions. Information about geometric requirements, observing procedures, and computations is contained in *Special Publication 247* (pp. 4, 13, 106-109, 158, and 163). Information about choosing landmarks for intersection stations during reconnaissance is contained in section 2.2.3.4. Naming intersection stations and coding descriptive text are given in *Input Formats and Specifications of the National Geodetic Survey Data Base* (pp. 18-22).

NOTE: Historically, NGS has used the term "intersection station." The terms "landmark" and "intersection station" are used synonymously in this manual. "Landmark" is defined in *Input Formats and Specifications of the NGS Data Base* as an "unmonumented recoverable horizontal control point (usually an intersection station) such as a flag-pole or church spire." *Special Publication 247* defines intersection station as "prominent objects such as church spires, water tanks, standpipes, towers, beacons, tall chimneys, and prominent mountain peaks."

Intersection stations shall be observed from at least three main scheme stations to third-order, class I specifications. Although three lines to an intersection station are sufficient to obtain a check, four lines observed from divergent compass directions will ensure a stronger solution. Observations should be made from the stations nearest the intersection station. Whenever a landmark is close to a triangulation station and a distance measurement needs to be performed, that measurement should be made on the ground to a point directly below the top of the landmark that is observed from the distant triangulation stations.

Field parties should be careful and thorough when identifying landmark stations, especially when observing from a station that is not included in a triangle with the landmark. (See fig. 2.2.14-1.) Geodetic inverse computations should be computed and the difference in azimuths should agree with the observed angle to within 10 seconds.

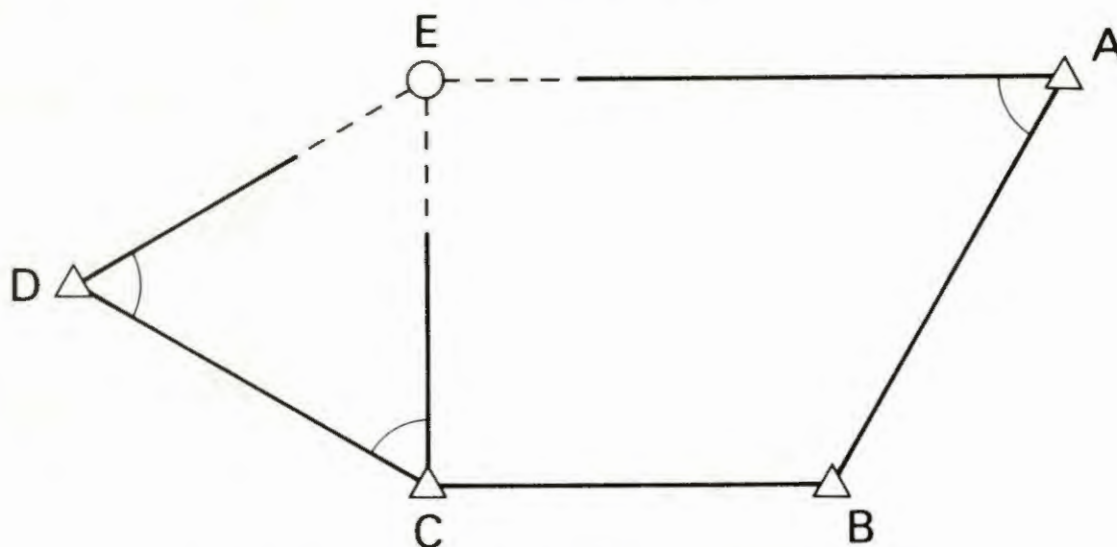


Figure 2.2.14-1.—Verifying the identification of an intersection station

When observing from a station that does not form a direct triangle with the intersection station, special care must be taken to assure proper identification of the intersection station. Observations from stations C and D are used to compute the position of intersection station E. Station A is occupied to check that position, but triangle ACE is not observed. Compute azimuth between A and B and between A and E. If the difference between these azimuths is not within 10" of the observed angle at A, station E may have been misidentified. To avoid a return trip, this check should be completed while still in the field.

Descriptions of intersection stations shall be submitted on NOAA Form 75-82A. The descriptive text shall clearly state what feature on the landmark was intersected.

Computation of positions shall be done as outlined in *Special Publication 247* (pp. 158-159). Field parties with computers should use appropriate programs.

2.2.15 Eccentric Stations

2.2.15.1 General

At times it may be impractical to occupy or to show lights from a station. An eccentric set-up is necessary. The use and measurement of eccentricities are given in *Special Publication 247* (pp. 100, 114, 134, 139, and 151). The computations for reduction to center are explained in *Special Publication 247* (pp. 154-157), *Special Publication 138* (pp. 7-8, 18-24), and NOAA Form 76-158, Reduction to Center.

2.2.15.2 Use

Eccentric stations are sometimes necessary when a ground set-up is used for measuring directions and simultaneously showing lights, or when old marks can no longer be observed from or built upon (because of powerlines, new buildings, property owner's request, etc.) Occasionally a station on top of a building may need an eccentric set-up close to the

edge of the roof when making a connection to a station on the ground near the building.

Unnecessary eccentricities will not be tolerated and can be avoided by collimating the light plate and instrument prior to their use. The occupation of a reference mark is preferred to the use of unmonumented eccentrics. If a reference mark is not occupied, the eccentricity should be marked by a temporary hub.

2.2.15.3 Measurements and Observations

When an eccentric station or light must be used, extreme care should be taken in measuring and recording the eccentricity. A sketch showing directions and distances should be recorded in the Observation of Horizontal Directions book. The instructions, given in *Special Publication 247* (p. 114), for measuring eccentricities are hereby amended. Measurements of 100 meters or less will be performed using two standardized 30-meter tapes and traverse procedures. Distances in excess of 100 meters should be measured with a short-range EDM, using the same procedures for measuring distances to azimuth marks. (See sections 2.2.12.2 and 2.2.13.2.)

2.2.15.4 Computations

The equation $c = \sin^{-1}(d \sin a/s)$,

where

- c = the reduction to center in degrees,
- d = the distance from center to the eccentric,
- s = the distance between the true stations involved,
- a = the clockwise angle from the true station to the distant station as measured at the eccentric,

gives the required reduction to center. This computation can be done on hand-held calculators without the use of logarithms.

The resulting correction, c, is to be applied to the observed direction as discussed in *Special Publication 247* and *Special*

Publication 138. The correction should be entered on the appropriate Abstract of Directions.

2.2.16 Air Navigation Facilities and Hazards

The horizontal control parties shall establish a station at all commercial airports within the project area. In addition, the parties shall also determine the geodetic position of certain classes of aids to air navigation. Aeronautical aids of types other than those listed in this subchapter need not be located unless indicated in the project instructions.

Each party will be furnished with aeronautical charts of the project area. Existence of new or revised aids should be determined by consulting with local Federal Aviation Administration (FAA) officials. Authority to enter FAA property should be obtained at the same time.

The positions of the following classes of aids to air navigation will be determined to third-order, class I specifications. Elevations should be determined using trigonometric leveling techniques.

a. *Very High Frequency Omni-Directional Range (VOR and VORTAC).* The VOR is the primary radio facility for guiding aircraft along the Federal airways. It has a vertical antenna located in the approximate center of the transmitting building.

If the VOR and VORTAC were previously positioned, use the name exactly as listed in the data base. If not listed in the data base, the facility should be identified by type, charted name, and three letter code as listed in the box adjacent to the facility symbol on the chart. For example:

VOR TERRE HAUTE RADIO HUF
VOR SCOTLAND SCJ

In accordance with *Input Formats and Specifications of the National Geodetic Survey Data Base*, volume I, names of facilities are limited to 30 letters and spaces. The word "RADIO" in the name indicates voice on the transmitting frequency of the facilities.

b. *Radio Beacons (RBN).* The design of this type of antenna varies considerably. Frequently the antenna cannot be seen for any great distance. It usually consists of two vertical poles with an antenna wire strung between the two poles and a small building. The position of either pole may be determined. These facilities should be named similar to the VOR. For example:

RBN CHERRY POINT NKT
RBN NEWBURN RADIO EWN

c. *Obstructions.* The position and elevation of obstructions near the airport greater than 200 feet above ground should be determined to third-order, class I specifications. Radio masts, television and microwave relay towers, tall smokestacks, etc., are important as obstructions since they are often constructed on high points and in areas adjacent to airports.

2.2.17 Photogrammetric Control

Photogrammetric control is used to densify the NGS horizontal control network and to support hydrographic survey operations. Project instructions shall indicate when control is to be established in support of photogrammetric operations.

Control established in support of photogrammetry shall meet second-order, class I specifications. Required specifications shall be given in the project instructions.

2.2.18 Positioning Marks of Other Agencies

Whenever possible, marks of other agencies shall be tied to the NGS network. The marks shall be positioned to second-order, class I specifications. Measurements of 100 meters or less shall be performed using two standardized 30-meter tapes as outlined in section 2.2.6.1. Distances in excess of 100 meters will be measured with short-range EDM using the procedures outlined in section 2.2.6.2.

Marks of other organizations that need repairs shall be repaired but not replaced. Descriptions shall be written and submitted on NOAA Form 76-82 as outlined in section 2.2.4.4.

2.2.19 Ties to Bench Marks

2.2.19.1 General

When making a connection to a bench mark of any organization to bring vertical control into a project, horizontal directions will be observed in addition to the vertical angle (zenith distance) observations and distance measurements. This subsection outlines the procedure for horizontal positioning of bench marks. Pertinent information may be found in *Special Publication 247* (pp. 3, 4, 14, and 89).

Reconnaissance and horizontal control parties involved in a project in the proximity of previously established level lines will consider bench marks to be supplemental stations, and will position these marks with the current scheme of work. Bench marks are used to provide elevation ties in order to meet the minimum requirement for the number of stations between known elevation for observing vertical angles. (See *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.) Elevation ties shall be made to allow for more accurate reduction of EDM lines.

2.2.19.2 Criteria

1. Bench marks in a given project area need not be positioned more frequently than one every 2 miles along the level line.

2. Only bench marks that have an existing ground-visible (VG) azimuth reference will be positioned. This reference may be an intersection station (landmark) or a previously positioned horizontal or vertical 2300 control station.

3. Do not set reference or azimuth marks at bench marks unless the bench mark is part of a main scheme network.

4. Bench marks between 400 and 3,200 meters from a main scheme station may be used as an azimuth mark. For distances less than 400 meters, the bench mark can be used as an additional reference mark and should be positioned by precise traverse methods.

5. Towers are not to be built for positioning bench marks. Only bench marks that require tripods or 1.2-meter stands shall be positioned.

2.2.19.3 Procedures

Bench marks should be positioned by triangulation, trilateration, traverse, or methods for positioning azimuth marks outlined in section 2.2.12. The difference in elevation must also be determined. This may be accomplished either by observing reciprocal zenith distances or by third-order differential leveling.

2.2.20 Connection Between Nearby Stations

2.2.20.1 General

This section outlines the procedure for determining the minimum acceptable distance between two triangulation stations without direct connection.

2.2.20.2 Twenty-Percent Rule

Make direct observations between two stations whenever the distance between them is less than 20 percent of the shortest distance as measured over the proposed and/or established survey lines. The only exception to this rule is a situation where topographic or man-made conditions make the connections impossible or highly impractical. Such situations can usually be avoided during the reconnaissance by proper selection of station sites. All departures from the 20-percent rule should be discussed in the project report.

2.2.21 Field Computations and Checks

This section describes the computations and data checks to be done by horizontal control parties. These computations and data checks are necessary to ensure that specifications are met.

2.2.21.1 Field Records and Abstracts

1. **General.** The observer should check all recorded data and abstracts before submitting them for processing. The observer or recorder should double check all arithmetic, mark ($\checkmark$ or X) all verifications, and initial each page of the book or abstract. The checker should strike out (do not erase, obliterate, or write over) any incorrect original recorded value and write the correct value above it. A second person should recheck all corrections.

The observer or recorder should check all data transcribed from field records to abstracts to detect blunders.

2. **Observation of Horizontal Directions.** As observations are made, the recorder should compare the direct and reverse readings taken on each target. The direct and reverse readings should differ by 180° . The recorder should compute

and record the degrees and minutes for the first, fifth, ninth, and thirteenth positions (fig. 2.2.7-2). For lines-of-sight inclined more than 5° , the plate level readings should be recorded, and the inclination correction computed as outlined in section 2.2.7.3.

All observations which are summed and meaned in the field that do not meet specifications should be rejected and reobserved that night. Upon completion of the night schedule, the observer should check all arithmetic in the recording volume and on the abstract (NOAA Form 76-46).

3. **Observations of Zenith Distances.** Zenith distance observations should be checked as shown in figure 2.2.7-1. The first observation (CL and CR) to each object should be checked for closure. The sum of CL and CR must equal $180^\circ \pm 10''$. The height of the instrument and height of the objects should be doublechecked.

4. **Taped Distances.** Measurements should be made independently in both feet and meters. The conversion of the measurement in feet to meters should not differ from the metric measurement by more than 3 mm. The conversion factor of 0.3048 m/ft should be used to complete this conversion. The conversion should be recorded in the description book, checked, and initialed.

5. **Electronic Distance Measurements.** Parts per million (ppm) and humidity correction computations should be checked and initialed. The units for temperature and pressure should be changed to the units required in the formulas. Check all conversions. All input to the programmable calculator for the reduction of distances obtained with the Model 4 or 8 geodimeters should be checked and initialed.

6. **Differences in Elevation.** The level rods used by most horizontal control field parties are graduated in meters on one face and feet on the reverse. The differences in elevation, not differences in English and metric rod readings, should compare within 3 mm when the conversion from feet to meters is made. Differences between the English and metric rod readings should not be used as a check because it is possible for the rod readings to compare within 3 mm but the difference in elevation for a single setup to differ by as much as 6 mm. All conversions and checks will be shown in the record book.

7. **Descriptions.** The recorder should check the description as it is written. When visiting a station after the description has been written, an observer or lightkeeper should recheck the description for errors and gross omissions.

8. **Terminal Input.** The party computer or delegate should check the "hard copy" from all data transmitted on the computer terminal. All typographic and transmission errors should be corrected using the appropriate program to alter the data files.

2.2.21.2 Computations

1. **General.** The availability of programmable calculators and the ability to transmit and manipulate data with remote computer terminals have made the field computations easier. *Special Publication 247* and *Special Publication 138* discuss the computations to be done in the field. Howev-

er, most of the material is outdated only because it is no longer necessary to use logarithms to do the calculations. All computations can easily be done using the natural function keys on modern calculators. All new programs developed in the field should be sent to the Horizontal Network Branch, N/CG12, for approval before using.

Parties with computers have been supplied with program documentation, input formats, and examples of data input. Any questions should be directed to the Operations Branch, N/CG16.

2. Triangle Computations. Upon completion of a schedule where the observations close a triangle, the closure should be checked. Triangle closure is equal to 18° plus the spherical excess, minus the sum of the observed angles of the triangle. Spherical excess can be approximated as outlined in *Special Publication* (p. 274). Permissible closures are listed in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. If these specifications are not met, the station should be reobserved.

Accurate triangle computations should be done in the field office. Personnel without computer terminals should use programmable calculators or the method outlined in *Special Publication* 247 (pp. 159-164). Forms 24A and 25 were renumbered after *Special Publication* 247 was published. These forms are now NOAA Form 76-72 and NOAA Form 76-102 respectively.

3. Forward and Inverse Position Computations. Forward position computations and inverse position computations are discussed in *Special Publication* 247. Both types of computations may be completed with programmable calculators.

4. Elevations from Zenith Distance Observations. The computation of elevation differences from zenith distance observations is outlined in *Special Publication* 247 (pp. 184-189), *Special Publication* 138 (pp. 159-175), and Publication G-56, Elevations from Zenith Distances.

5. Eccentric Reductions. Reduction-to-center computations for eccentric lights and/or instruments must be completed using a calculator and the methods outlined in sections 2.2.15.1 and 2.2.15.4, and entered on the Abstract of Directions as eccentric corrections.

6. Taped Traverse. The procedure for entering and computing taped traverse data reductions is given in section 2.2.6.1.

2.2.21.3 Data Checks

1. General. Data checks are necessary to ensure that observations meet the specifications in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* and *Specifications to support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. These checks indicate which observations may be in error. Explanations and worked examples are given in *Special Publication* 247. The examples are done using logarithms. The checks can now be done on the computer terminals and hand-held calculators using natural functions.

2. Triangle Closure. Triangle closure is the first check that can be made on the observed data. Triangle closure is discussed in section 2.2.21.2.

3. Length Tests. The lengths of common sides of triangles in the figures as computed through various chains must agree within the limits specified in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. An additional explanation is given in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (p. 10).

4. Side Equation Tests. Side equation tests are discussed in *Special Publication* 247 (p. 165). Additional material is included in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* and *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

5. Base Comparisons. Bases from previous surveys should be remeasured and comparisons listed in the project report. Base measurements must check to 1 part in 1,000,000 for first-order and 1 part in 900,000 for second-order, class I surveys.

6. Check Angles. Work accomplished during current projects should be checked against historic data when occupying recovered stations. All comparisons should be shown in the project report. If the new observations fail to check the previously observed value by more than 2 seconds, the observations should be repeated. Also, all field conditions that might cause such changes (grazing lines, instrument and light or target collimation, old station disturbed, incorrect eccentric distance or computation, etc.) should be investigated. (See *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.)

2.2.21.4 Adjustments

1. General. *Special Publication* 138 discusses the theory and mechanics of triangulation adjustments. These adjustments help isolate problems that exist in the field data. The methods in *Special Publication* 138 accomplish the adjustments by using logarithms. Although these methods are still valid, the same calculations can be made using natural functions on modern calculators and computers.

2.2.22 Data, Records, and Reports

This section deals with data, records, and reports that apply specifically to horizontal control. More general information on data, records, and reports can be found in chapter 1.7. *Special Publication* 247 (pp. 16-146, 189-192) contains some applicable information on this topic. However, as methods of computation have progressed from long-hand to programmable calculators to the use of computer terminals, many of the references to certain forms have become outdated.

2.2.22.1 Automated Data

The ability to access complex computerized systems through remote terminals has given rise to new methods of data management. The intermediate and end products of geodesy have already taken on a new form. Soon, raw data may also be collected in new ways. Due to these innovations, data that can be forwarded over telephone lines will be transmitted daily/regularly.

2.2.22.2 Protection of Data

All field records transported with the party during party moves must be protected from unrecoverable loss or damage by duplication or separation of data. The Project Director has full responsibility for assuring that the data are properly protected.

2.2.22.3 Submission of Data

Project data other than that forwarded daily via computer will normally be submitted to the Quality Control Section, N/CG164, within 30 days after completion of the project (or season's work). This will include the project report, sketch, observation data, abstracts, and computer printouts specified in section 2.2.22.1. Progress in meeting this requirement must be reported in the remarks section of NOAA Form 76-92, Field Party Monthly Report and Journal, which will also include the percent completion of processing for any backlogged projects.

When first- and second-order leveling is performed in conjunction with horizontal control activities, the leveling data should be submitted under a separate transmittal letter.

Sufficient information must be included with the data to determine the elevation of all horizontal control points in the project area including those not observed. This will provide input necessary for future adjustments, and will aid in determining the present status of the network. The data required to determine elevations of stations not observed include the following:

- (1) An outline map depicting the area for which recovery was performed. This map may be a simple grid showing the completed 7-½ minute quadrangle areas.
- (2) Recovery information for all marks in the area unless the marks were recovered within the preceeding year.
- (3) Topographic maps (preferably 7-½ minute USGS quadrangles) on which all stations have been plotted within 6 seconds of the correct position. For marks not recovered, or destroyed, the most probable location should be plotted.

2.2.22.4 Sketches

Instructions for preparing reconnaissance and progress sketches may be found in *Special Publication 247* (pp. 6-191). The following guidelines are to be followed when drafting sketches to ensure that reproductions and film reductions of tracings maintained by NGS Headquarters continue to be of optimum quality. Figure 2.2.22-1 shows a typical progress sketch.

1. **Tracing Medium.** The preferred medium for all sketches is linen tracing cloth (Federal Stock Number 7510-

00-257-3413). Second and third choices are Mylar and vellum. Folded tracings which were drawn on linen more than 80 years ago are still in good shape, but vellum tracings 10 years old are already brittle and tear at the folds. Mylar cannot be folded and unfolded without tearing. Storing Mylar tracings in tubes is inconvenient. Blueprints and diazo processed paper copies are unacceptable.

2. **Size.** No individual sketch should be larger than 36" x 48". A 36" x 48" tracing will yield a resulting reproduction 48 percent of original size when reduced at NGS Headquarters. Sketches on standard plan size 24" x 36" are preferred.

Use multiple sheets to cover an area that would result in a sketch larger than 36" x 48" (preferably 24" x 36") using "neat lines" to show where the sketches join.

If more than two stations are clustered so closely that the station symbols overlap, observations between the clustered stations should be clarified by the use of an enlarged inset.

3. **Symbols.** Symbols and notations explained in *Special Publication 247* (pp. 6 and 191) will continue to be used. Progress sketches will not be drawn on maps. However, reconnaissance sketches should be drawn on road or county maps, but precautions must be taken to ensure that lines, symbols, and descriptive text are at least as dark as the map base. To aid in the identification of material drawn on the map, the map will be masked out for at most 1.5 mm (1/16 inch) on each side of a drafted line, symbol, or text. Intersection stations will be masked at least 1.5 mm (1/16 inch) from the intersection station symbol. Intersection station symbols, on both progress and reconnaissance sketches, require short rays or ticks to indicate the direction to the stations from which the intersection stations were or should be positioned.

4. **Title Blocks.** Title blocks of progress sketches shall be mechanically lettered (e.g., Leroy) using standard black drafting ink. The blocks of reconnaissance sketches may be neatly hand lettered. The format shown in *Special Publication 247* (pp. 6 and 192) has been revised to reflect organizational changes. The typeface on the title block should be approximately the same size as shown in figure 2.2.22-2.

Title Block shall include a *graphic scale*. Note: On all sketches submitted by NGS field units, the agency conducting the survey shall be listed as Charting and Geodetic Services. The name of the current director of Charting and Geodetic Services shall be listed below the agency.

5. **Tick Marks.** Tick marks indicating latitude and longitude should be used and labeled along the borders of the sketch. It is suggested that 30-minute intervals be shown on sketches of 1:250,000 scale, 10-minute intervals on sketches of 1:125,000 scale, and 5-minute intervals on sketches of 1:62,500 scale.

6. **Names.** The names of main scheme stations will be placed adjacent to the station symbol. Main scheme stations will not be numbered and then cross-referenced by a list of names. Intersection stations may be numbered for

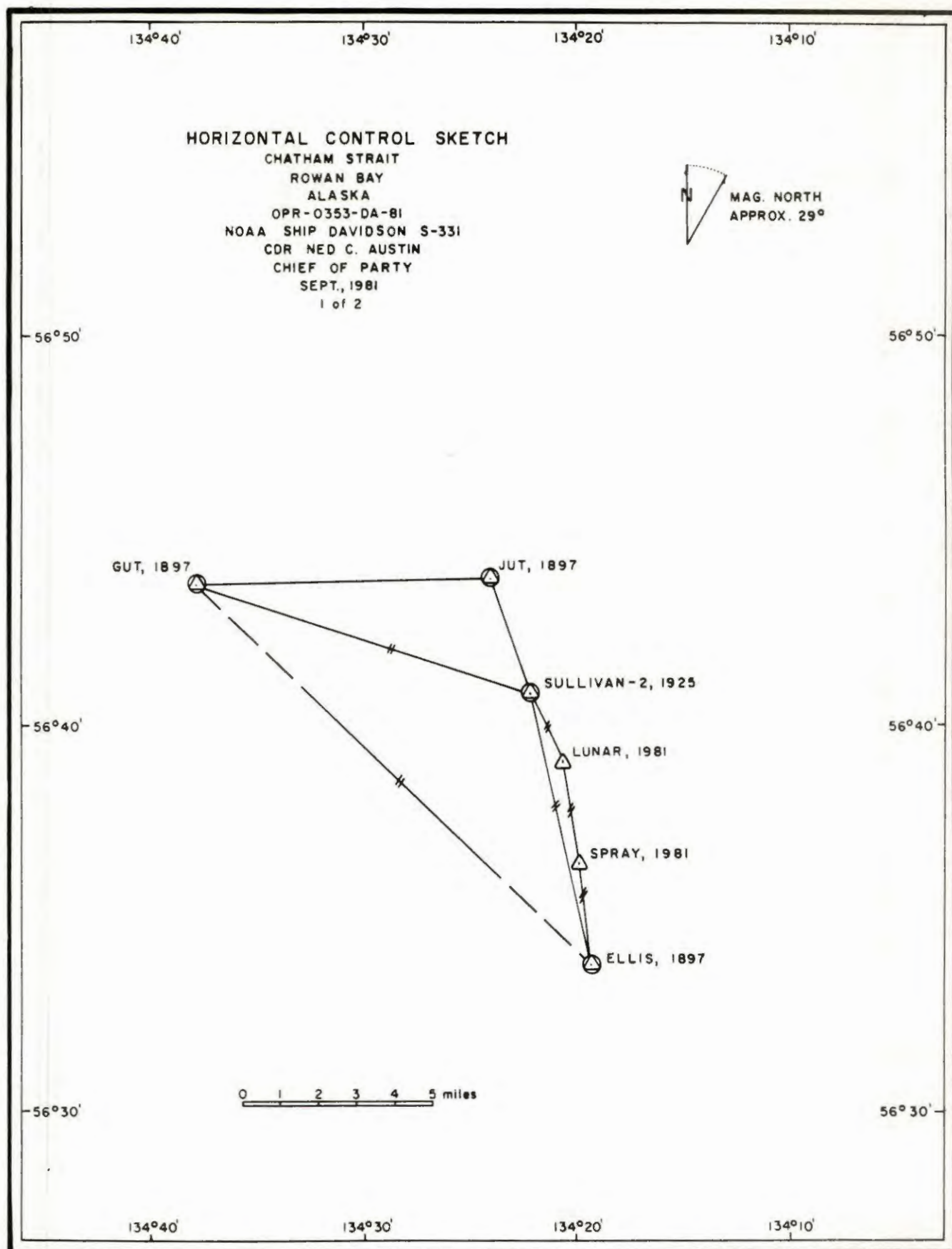


Figure 2.2.22-1.—Example of progress sketch

DEPT

BRANCH

AGENCY

DIRECTOR

HEADING

TITLE

STATES

TASK

COP

DATES

NUMBERS

BAR SCALE

UNITS

SKETCH

US DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
CHARTING AND GEODETIC SERVICES
RADM JOHN D. BOSSLER - DIRECTOR

PROGRESS SKETCH
EL PASO

TEXAS - NEW MEXICO - CHIHUAHUA

TASK NO. 83621125
DANIEL C. FRAZIER - PROJECT DIRECTOR

OCTOBER 1983 - DECEMBER 1983



GRAPHIC SCALE IN KILOMETERS

SKETCH 2 OF 3

Figure 2.2.22-2.—Preparation of title block for progress sketch

reference to a list of names placed elsewhere on the sketch. Long lists of intersection points do not have to be lettered by Leroy or other mechanical means. Neat hand lettering using standard black drafting ink is acceptable. Horizontal guidelines can be easily provided by placing graph paper under the linen where the lettering is to be done. Typing directly on the tracing linen should be discontinued unless clear black typing can be achieved.

2.2.22.5 Project Report

The project report is an important historical document. These reports provide the only summary available of the field operations for a project and are circulated to appropriate management personnel. Then, they are circulated to the concerned areas. The reports are constantly used as references to resolve problems and clarify why a particular approach or method was taken.

Figure 2.2.22-3 illustrates a typical cover for a horizontal project report.

PROJECT REPORT OUTLINE

- I. Introduction
 - A. Authority
 - B. Purpose
 - C. Scope
 - D. Time Period
- II. Location
 - B. Area Covered
 - C. Limits
 - D. Junctions
- III. Conditions Affecting Progress
 - B. Climate
 - C. Concurrent Projects
 - D. Equipment Failures
- IV. Organization of Party
 - A. Party Personnel
 - B. Liaison and State Personnel
 - C. Equipment Available
 - D. Transportation
 - E. Trailers
 - F. Towers Available
- V. Field Work
 - A. Chronology
 - B. Specifications
 - C. Methods
 1. Angulation
 2. EDM
- VI. Discussion of Results
 - A. Changes from Reconnaissance
 - B. Status of Records
 - C. Computations
 - D. Deviation from Specifications
- VII. Statistics
 - A. Monumented Stations Positioned/Tied (This can be a simple table.)
 1. New main scheme stations
 2. Old main scheme stations
 3. Old main scheme stations not occupied
 4. New first-order station (non-main scheme)
 5. Azimuth marks positioned
 6. Long reference marks positioned
 7. Bench marks positioned
 - B. Landmarks Positioned
 - C. Triangles Closed
 1. Main scheme first-order triangles
 - a. Average closure
 - b. Maximum closure
 2. Non-main scheme first-order triangles
 - a. Average closure
 - b. Maximum closure
 3. Total of first-order triangles
 - a. Average closure
 - b. Maximum closure
 4. A similar summary for all other order and classes of work subdivided by order.
 - D. Bench Mark Ties (give elevation and source)
 1. USC&GS or NGS
 2. USGS
 3. State
 - E. Astronomic Azimuth Determinations
 1. First order
 2. Second order
 - F. Reoccupations
 1. Theodolite reoccupations
 - a. For triangle closure, side and pole checks
 - b. For astronomic azimuth
 - c. For additional lines
 - d. For blocked lines
 - e. For other reasons
 2. EDM Lines remeasured
 - a. First order
 - b. Second order
 - c. Azimuth, reference, bench marks
 - d. Other
 - G. Types and Numbers of Structures Used
 1. Bilby towers
 - a. 37 Foot
 - c. 64 Foot
 - d. 77 Foot
 - e. 90 Foot
 - f. 103 Foot
 - g. 116 Foot
 2. Number of super structures erected
 3. Truck mounted observing tower (TMOT)
 4. Trailer mounted tower (TMT)
 5. Number and height of Pek towers
 6. Number and height of signal poles
 7. 1.2-meter wooden stands
 8. Tripods (at azimuth, reference, and bench marks)

9. Total number of structures (not including tripods)
 - a. Average height of Bilby towers
 - b. Average of signal poles
10. Other
- H. Check Angles
 1. List all check angles giving differences (new-old)
 2. Average difference
 3. Maximum difference
- I. Check Distances
- J. Position Closures
(List of stations and type of tie)
- K. Instrument Calibrations and Frequency Counts
- VIII. Recommendations & Special Features
- IX. Project Instructions/Supplemental Instructions
- X. Photographs Of Project
- XI. Location Diagram
- XII. Project Sketch
- XIII. Miscellaneous

G - 16499

U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL OCEAN SERVICE

Charting and Geodetic Services
Rear Admiral John D. Bossler, Director

Project Report

Horizontal Party NBL61F

West Litchfield - Stamford, Connecticut

Lower Half Sketch Number 7

Task Number 8K6D1B00

May 1983 - November 1983

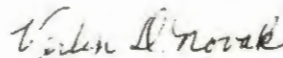
Verlin D. Novak
Project Director
Party NBL61F

Figure 2.2.22-3.—Example of cover for project report involving horizontal survey

2.3. VERTICAL CONTROL

2.3.1 Classification, Standards of Accuracy, and General Specifications

The Federal Geodetic Control Committee (FGCC) has published the classifications and standards for vertical control in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. Additional information about the classes of vertical control surveys and geodetic leveling instruments is contained in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* and in *NOAA Manual NOS NGS 3, Geodetic Leveling*.

2.3.2 Party Structure

Each position in a vertical field party is described in *NOAA Manual NOS NGS 3*. Chapters 2, 3, and 5 of the leveling manual describe mark setting personnel, leveling personnel, and project office personnel. The Field Operations Section, N/CG161, maintains a file with up-to-date job descriptions of all field party positions.

2.3.3 Recovery

Bench mark recovery procedures are given in *NOAA Manual NOS NGS 3* (section 2.4.1).

The mark setting units should recover all vertical and horizontal control stations on the 7-1/2 minute topographic quads through which the level lines run. The mark setters should use the correct description forms for each mark as follows:

1. Use NOAA Form 76-186, Bench Mark Description, to describe all bench marks and all horizontal control stations that have been or will be leveled to.

2. Use NOAA Form 75-82 or 75-82A, Station Description, to describe all horizontal control stations and those bench marks that have been previously connected to the horizontal control network.

NOTE: Use both NOAA Form 76-186 and NOAA Form 75-82 or 75-82A to describe bench marks and horizontal control stations that have been tied to both the horizontal and vertical control networks.

It is not necessary to submit recovery descriptions for any mark if: (1) the mark is not part of the present leveling project has been recovered within the past 2 years, or (2) the mark requires more than 1 staff-day to recover.

2.3.4 Bench Marks

NOAA Manual NOS NGS 1, Geodetic Bench Marks, explains how and where to set bench marks for maximum stability and calls attention to the factors that can lead to vertical instability.

2.3.4.1 Location of Level Lines and Monuments

1. **Level Lines.** Recommended line spacings are listed in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (table 3). Routing specifications are given in *NOAA Manual NOS NGS 3* (section 2.3.3). Project instructions will list proposed line locations and any deviation from these specifications.

2. **Monuments.** The spacing of monuments along level lines is given in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (table 3). The location of junction points and requirements for spacing between Quality A monuments are given in *NOAA Manual NOS NGS 3* (section 2.3.3). Project instructions will authorize any deviation from these specifications.

2.3.4.2 Specifications for Monuments

Specifications for mark setting are given in *NOAA Manual NOS NGS 1*. This section lists the design modifications for class B rod marks and the monumentation quality codes to be entered in the bench mark description.

1. **Modification of Class B rod marks.** The design of the Class B Rod Mark is explained in *NOAA Manual NOS NGS 1* (p. 25). This design has been modified for improved reliability and quality.

Discontinue the use of 4" PVC pipe, 4" PVC plugs, and bench mark disks with class B rod marks. Instead, crimp a stainless steel datum cap to the top of the rod. Use a 5" PVC pipe set in concrete, topped with an aluminum logo cap as a surface casement. This is identical to the surface configuration for a class A rod mark. (See *NOAA Manual NOS NGS 1*, step 10, page 18 and steps 13 through 15, page 19.)

Before crimping the datum cap to the top of the rod, stamp the datum cap with the bench mark designation. This will serve as backup identification in case the logo cap is damaged or removed. Stamp the designation around the top of the datum cap, just below its rounded portion. The cap must be attached to the rod by means of a definite indentation of the cap into the rod. The recommended method is to use the cutter head on the hydraulic crimper and make a firm

impression about halfway down the cap after it has been slipped over the rod.

2. Monumentation Quality Codes. Published descriptions of bench marks contain the codes for monumentation quality which indicate the probable stability of the various types of bench marks. The code is needed by users of vertical control data who must know how well individual bench marks can be expected to hold their published elevation. This section describes the basis for assigning monumentation quality codes at NGS Headquarters and explains how field personnel can override the office-assigned code when necessary.

The setting classification code (*26* Code) is used to determine one of four monumentation quality codes. The four monumentation quality codes are:

- A—Monuments of the most reliable nature (are expected to hold their elevations very well). Generally these monuments are affected only by crustal motion or widespread subsidence.
- B—Monuments that probably hold their elevations well.
- C—Monuments that are commonly subject to surface ground movements, such as frost heave or the shrinking and swelling of certain clays.
- D—Monuments of questionable or unknown reliability.

Table 2.3.4-1 shows the "default" monumentation quality codes corresponding to the various benchmark setting classifications.

Override the default monumentation quality code when this code is incorrect. For example, an unsleeved class A rod mark (setting classification 24) would be given a default monumentation quality code of "B" because it is identical in appearance to the class B rod mark. The default monumentation quality code for an unsleeved class A rod mark must therefore be overridden, changing the code from "B" to "A." For another example, a tower foundation (setting classification 45) would be given a default monumentation quality code of "C." If the mark setter knows the foundation rests directly on solid bedrock, it would be more correct to assign a quality code of "B" or possibly "A." Do not deviate from the standard code without ample reason.

The procedure for overriding the default monumentation quality code is to note the required change on NOAA Form 76-186 by writing "Quality A" or "Quality B," etc., in the space below the *27* code on the form. Then, when the description is entered into the terminal, a corresponding "A," "B," "C," and "D" is typed when prompted for the override. (Strike the skip key if the quality code is not to be overridden.)

2.3.4.3 Designations

Input Formats and Specifications of the National Geodetic Survey Data Base (Annex D) lists the guidelines for vertical control point names and designations. The designations should be unique in each State. See sections 2.3.4.4 and 2.4.4.5 for designations of tidal and water level bench marks and tide or water level staffs.

1. Designations of Bench Marks Previously Leveled. For bench marks with previously established elevations, use

Table 2.3.4-1—Default monumentation quality codes for various bench mark classifications

<i>Setting Classification</i>	<i>Monumentation Quality Code</i>
00—Unspecified	D
SHALLOW SETTINGS (less than 10 ft):	
10—Unspecified Shallow	D
11—Metal Rod with Base Plate	C
12—Concrete Post	C
13—Shallow-set Pipe	D
14—Shallow-Set Metal Rod (without base plate)	D
UNSLEEVED DEEP SETTINGS:	
20—Unspecified Deep	C
21—Copper-Clad Steel Rod	B
22—Galvanized Steel Pipe	B
23—Galvanized Steel Rod	B
24—Stainless Steel Rod	B
25—Aluminum Alloy Rod	B
ROCK AND BOULDERS:	
30—Unspecified Rock	B
31—Rock Outcrops, Rock Ledge, Rock Cut, or Bedrock	A
32—Boulder	C
LIGHT STRUCTURES:	
40—Unspecified Light Structure	D
41—Pavements Such as Streets, Sidewalks, Aprons, Curbs, etc.	D
42—Retaining Walls and Bulkheads, including Headwalls and Wingwalls of Culverts and Small Bridges	C
43—Piles and Poles (e.g., spike in utility pole)	D
44—Footings and Foundation Walls of Small or Medium Size structures	C
45—Mat Foundations (bearing surface same size as structure) Such as Landings, Platforms, Steps, Floors, Tower Foundations, Bases of Semaphores, etc.	C
MASSIVE STRUCTURES:	
50—Unspecified Massive Structure	B
51—Massive Retaining Walls, Including Headwalls and Wingwalls of Very Large Bridges	B
52—Abutments and Piers of Very Large Bridges, Including Overpasses and Underpasses	B
53—Tunnels	B
54—Massive Concrete, Masonry, or Steel Structures with Deep Foundations	A
55—Large Concrete, Masonry, or Steel Structures with Foundations On Bedrock	A
SLEEVED DEEP SETTINGS:	
60—Unspecified Rod/Pipe in Sleeve	B
61—Copper-Clad Steel Rod in Sleeve	B
62—Galvanized Steel Pipe in Sleeve	A
63—Galvanized Steel Rod in Sleeve	A
64—Stainless Steel Rod in Sleeve	A
65—Aluminum Alloy Rod in Sleeve	A

the designation listed in the data base. Use a corrected designation if an error is found in the data base or if additional information is needed. (See Annex D of *Input Formats and Specifications of the National Geodetic Survey Data Base*). For newly established bench marks, use the designations assigned by the computer program "BMDESIG."

2. Ordering New Bench Mark Designations. The program "BMDESIG" helps to prevent the duplication of bench

mark designations within a State. BMDESIG prompts the field party for necessary information and creates the job control language (JCL) needed to submit the job to the computer. The field party must follow these procedures after logging onto the computer system:

1. Type in the command: BMDESIG
2. Answer the following prompts:
 - a. YOUR TWO INITIALS =
Ex: RT (CR)
 - b. CHIEF OF PARTY-ROCKWALL BIN =
Ex: WILLIAMS-51 (CR)
 - c. REQUESTING FIELD PARTY =
Ex: G-37 (CR)
 - d. TYPE IN NAME OF MARKSETTER AS FOLLOWS: LAST, FIRST INITIAL. NAME =
Ex: TAYLOR, RONNIE L. (CR)
 - e. INPUT THE STATE FOR WHICH DESIGNATIONS ARE NEEDED
Ex: MASSACHUSETTS (CR)
 - f. HOW MANY SERIES OF DESIGNATIONS WOULD YOU LIKE?
Ex: 3 (CR)

A series consists of 24 designations: A-Z, excluding I and O. Request a maximum of three series per mark setter. Resubmit the request as needed.

- g. DO YOU NEED TO REQUEST DESIGNATIONS FOR ANOTHER STATE?

Respond by typing YES or NO. If YES, the program will repeat prompts d, e, f, and g. Enter the name of the next mark setter, State, and request up to three series.

3. The terminal will print the input under a column number heading. It will also print the following statements.

LISTED ABOVE IS THE INPUT INFORMATION PROVIDED. IF THERE ARE ANY ERRORS PLEASE CORRECT THEM, MAKING SURE THAT THE DATA REMAIN IN THE CORRECT COLUMNS AS OUTLINED. TO SUBMIT THE JOB TO THE COMPUTER, ENTER "GO".

Correct any errors by using the line editor. Ensure that the input is in the proper columns.

Columns (1-20)—Name (left justified)
Columns (22-25)—Field Party (use all 4 columns)
Columns (31-45)—Full State Name (left justified)
Columns (54-55)—Number of Series Requested (right justified)

The example would print out as follows:

```
123456789A123456789B123456789C123456789D
123456789E123456789F
TAYLOR, RONNIE L.   G-37 MASSACHUSETTS   3
MCCREADY, MAX      G-37 VERMONT          2
```

4. After making corrections (if needed) and verifying the input, enter "GO". This will provide a job number and run the job.
5. Fetch the job by typing "FET.BMDESIG". The terminal will list the requested designations.
6. Print the job immediately after it has been run. The output of the job will be a permanent record kept at

Headquarters. If an error is detected after the job has been executed, contact the Scientific Applications Section, N/CG151. After the files are corrected, rerun the job. *Never purge a job after it has been executed.*

7. The final printout will list the designations reserved for the field party. The party should retain the terminal printout and submit it with the project report at the close of the project.

Ex:

THE STATE FOR WHICH THE REQUEST WAS
MADE IS: MASSACHUSETTS
THE SERIES ASSIGNED DURING THIS EXECUTION ARE:

A	51-Z 51	EXCLUDING I AND O
A	52-Z 52	EXCLUDING I AND O
A	53-Z 53	EXCLUDING I AND O

3. **Duplicated Bench Mark Designations.** Make every effort to ensure that bench mark designations are not duplicated within a State. If the duplication on a disk is discovered before it is leveled to, stamp an "X" after the designation and correct the description. If the duplication is not discovered prior to leveling, note the duplication in the description and provide sufficient information in the *13* code designation to make the designation unique. Add (in order of importance) the year or county name or name of the nearest town to the *13* code designation.

Examples:

(1) Bench mark M 109 was set in 1979 and the same designation used again in 1980. If the duplication was discovered after the leveling was done, the *13* code in the description for the 1980 mark should include the year, "M 109 1980", and the duplication should be noted in the description text.

(2) Bench mark F 109 was set in Carbon County. Later the same year the same designation was used in Centre County. If the duplication was discovered after the leveling was done, the *13* code designation should be changed to "F 109 CENTRE CO" and the duplication noted in the description text. *Under no circumstances should a mark be restamped after it has been leveled to.*

In the case of a mark with a logo cap, the cap should be restamped prior to submitting the project data to Headquarters. The description must be corrected to reflect the change in stamping.

2.3.4.4 Tide and Water Level Bench Mark Designation

In 1976, the National Ocean Service (NOS) initiated a new system for designation of tide and water level stations. A unique seven-digit station number is now assigned to each tide and water level station operated by NOS, where the first three digits indicate the State or body of water in which the station is located. (See table 2.3.4-2.) Tide and water level bench marks established after 1976 have the last four digits of the station number stamped on the disk. A letter A, B, C, etc., is stamped after the four-digit number to identify individual marks at a station, e.g., 8912 A. In order to make designations for tidal and water level bench marks leveled by NGS compatible with the NOS system,

Table 2.3.4-2—Numbering system for NOS tide and water level bench marks

Channels			
St. Lawrence River		831	1xxx
Niagara River		906	3xxx
Detroit River		904	4xxx
St. Clair River		901	4xxx
Saginaw River		901	xxxx
Grand River		908	xxxx
Chicago River		896	1111
Fox River		902	01xx
Milwaukee River		903	03xx
St. Marys River		907	6xxx
Rainy River		911	05xx
Lakes			
Lake Champlain		843	1xxx
Lake Ontario		905	2xxx
Lake Erie		906	3xxx
Lake St. Clair		903	4xxx
Lake Huron		907	5xxx
Lake Michigan		908	7xxx
Lake Winebago		902	02xx
Lake Superior		909	9xxx
Rainy Lake		911	01xx
Lake of the Woods		911	09xx
Country		Code	
United States		83	
State	Code	State	Code
Alabama	873	Montana	931
Alaska	945	Nebraska	924
Arizona	938	Nevada	936
Arkansas	881	New Hampshire	842
California	941	New Jersey	853
Colorado	934	New Mexico	937
Connecticut	846	New York	851
Delaware	855	North Carolina	865
District of Columbia	859	North Dakota	922
Florida	872	Ohio	892
Georgia	867	Oklahoma	927
Hawaii	161	Oregon	943
Idaho	932	Pennsylvania	854
Illinois	896	Rhode Island	845
Indiana	895	South Carolina	866
Iowa	912	South Dakota	923
Kansas	925	Tennessee	882
Kentucky	883	Texas	877
Louisiana	876	Utah	935
Maine	841	Vermont	843
Maryland	857	Virginia	863
Massachusetts	844	Washington	944
Michigan	901	West Virginia	864
Minnesota	911	Wisconsin	902
Mississippi	874	Wyoming	933
Missouri	884		

NGS will use the following standardized designations when describing these bench marks:

1. **Tide Stations.** At old tide stations (built before approximately 1976), the designation for tidal bench marks shall consist of the seven-digit station number, the word "TIDAL," and the stamping (without the year unless reset).

For example: At old tide station 872 8912, a bench mark was stamped BASIC 1937. In the NGS description for this bench mark, the designation would be 872 8912 TIDAL BASIC.

2. **"Old" Water Level Stations.** At old water level stations, the designation for water level bench marks shall consist of the seven-digit station number and the stamping (without the year unless reset).

For example: At old water level station 906 3000, the bench mark was stamped POOL 1937. In the NGS description for this bench mark, the designation would be 906 3000 POOL.

3. **"New" Tide Stations.** At new tide stations (built after the new NOS system was implemented in 1976), the designation for tidal bench marks shall consist of the first three digits of the station number, the stamping (without the year unless reset), and the word "TIDAL."

For example: At new tide station 872 8912, a bench mark was stamped 8912 A 1977. In the NGS description for this bench mark, the designation would be 872 8912 A TIDAL.

4. **"New" Water Level Stations.** At new water level stations, the designation for water level bench marks shall consist of the first three digits of the number and the stamping (without the year unless reset).

For example: At new water level station 896 1111, a bench mark was stamped 1111 A 1978. In the NGS description, the designation would be 896 1111A.

5. **Unstamped Bench Marks at Tide and Water Level Stations.** If an old tidal or water level bench mark is unstamped, its designation should consist of the seven-digit station number and the old (published) designation.

For example: At tide station 872 0576, a chiseled square used as an old tidal bench mark and previously designated as "TIDAL 5" should be designated "872 0576 TIDAL 5."

6. **When an existing bench mark, established for other than gage control purposes, is selected for a tidal or water level bench mark, an alias designation should be added to the regular designation.** The alias will include the seven-digit number and, in the case of a tide station, the word TIDAL following the seven digit number.

For example: At tide station 872 0587, a USN bench mark disk stamped "H 322 1939", which was later used as a tidal bench mark, should be designated as "H 322 USN" with an alias of "872 0587 TIDAL."

If adding a seven-digit station number to a designation causes it to exceed 25 characters including imbedded spaces, then either (1) abbreviate and/or edit the designation to meet this limit or (2) use the stamping (without the year unless reset) as the designation and indicate the seven-digit station number in an alias.

For example: At tide station 872 4392, a C&GS tidal disk stamped "SUGARLOAF GUAGE BM 2" was designated "SUGARLOAF GUAGE 2" with an alias of "872 4392 TIDAL 2."

See *Input Formats and Specifications of the National Geodetic Survey Data Base*, Volume II, Vertical Control Data (annex D).

2.3.4.5 Tide or Water Level Staffs

All staffs and electric tape gage reading marks shall be considered to be temporary bench marks (TBM). This section outlines the procedure for writing the descriptions for these marks.

Prepare bench mark descriptions on NOAA Form 76-186. Complete only the SPSN, the approximate latitude, and the approximate longitude entries of the *10* code. Do not complete the DRC entry. In addition to the *10* code, complete the *13* code. No other data should be entered in the description.

The *13* code must have "TBM," as the first three characters of the designation as shown in the following examples:

1. Designation for a staff located at tide station 941 8568; leveling rod held at the 6-foot mark:

TBM 941 8568 STAFF 6 FT

2. Designation for an electric tape gage reading mark at tide station 941 8568:

TBM 941 8568 ETG READ MK

3. Designation for a staff located at water level station 905 2076; leveling rod held at the 6-foot mark:

TBM 905 2076 STAFF 6 FT

4. Designation for an electric tape gage reading mark at water level station 905 2076:

TBM 905 2076 ETG READ MK

Note: For *all* bench marks at a station, a hyphen (minus) should not be placed anywhere in the designation (except as its first character when indicating a negative elevation). Also, "TIDE" should not be used as part of the designation for a staff or electric tape gage reading mark. However, do not eliminate "TIDAL" from the tidal bench mark designations.

Because there are only two lines of entries, key all TBM descriptions directly into the computer by adding them to the end of the HA file instead of using the prompt programs.

2.3.4.6 Descriptions

All vertical control stations must be described on NOAA Form 76-186. Description writing is discussed in detail in *NOAA Manual NOS NGS 3* (section 2.4.4) and in *Input Formats and Specifications of the National Geodetic Survey Data Base* (chapter 7) which includes the following changes to past description procedures:

1. In reference to the *18* code, indicating the distance and direction from the nearest city or town, whenever a distance is indicated in metric units (km), the English equivalency must immediately follow in parentheses. For example:

000040*17*ROCKVILLE *18*3.4 KM (2.1 MI) EAST
Notice that the direction follows the distance specified in English units.

2. Another field has been added to the *26*, *27* record. This field will be known as the "origin" field which is defined as: "The acronym or abbreviation of the agency whose name is precast on the monument." This information will be contained in columns 55-80 of the *26*, *27* record. Note that column 54 has been left blank. In the event the agen-

cy's name cannot be determined, indicate this by placing 'UNK' in columns 55-57.

The DESC program will prompt the terminal operator for this new field as described below.

After the terminal operator is prompted for:

MON QUALITY CODE=

The operator will enter either A, B, C, D, or press the skip key. Next, the operator will be prompted with:

ORIGIN=

Here the operator will enter the agency's abbreviated name as listed in *Input Formats and Specifications of the National Geodetic Survey Data Base* (annex C) that is precast on the monument. The *26*, *27* record may look like this:

000070*26*12/ *27*D01B NGS

If the field for the monumentation quality override is left blank, then two blanks would exist between *27*D01 and NGS.

Please be aware that the *26*, *27* record is required for all original and recovery descriptions.

3. Summary of Specifications for Descriptions

a. For all recovered marks with archive numbers which are "recovered as described," the minimum codes required are: *10*, *13*, *23*, *24*, *25*, *26*, *27*, *28*, and *30*.

b. For marks which are not recovered (disk is NOT FOUND), the *26*, *27*, and *28* codes should not be entered because the requested information cannot be verified.

c. For recovered marks, the DESC program will not allow the origin field to be left blank. Enter UNK where the agency's name cannot be determined.

d. Use *Input Formats and Specifications of the National Geodetic Survey Data Base* (annex C) for the agency abbreviations used on the *20*, *23*, and *27* codes.

e. The "origin" may not be the same agency indicated in the designation or in the *20* code. For example, a USGS mark reset by NGS using a NGS disk might be as follows:

000020*13*3000 USGS Reset 1976
000030*20*1/NGS
000040*26*12/ *27*D01 NGS

or a NGS disk set by another agency may be as follows:

000020*13*A 176
000030*20*9/GSC
000040*26*62/ *27*D01 NGS

f. The RUNJOB program (vertical description edit program) has been modified to conform to these changes.

2.3.4.7 Plotting and Scaling Positions

The location of bench marks must be plotted accurately on USGS 7½-minute (or best available) topographic maps and the coordinates scaled to the nearest second of latitude and longitude. These geographic coordinates are used in processing and publishing the vertical control data. This section lists the guidelines for plotting and scaling bench marks. See *NOAA Manual NOS NGS 3* (section 2.4.3).

1. **Plotting Bench Mark Location.** Plot the position of the bench marks while at the bench mark sites. Have the

maps independently checked by a second person, when available, to ensure that blunders were not made in plotting the locations.

2. **Scaling and Reporting Positions.** From the smooth maps, scale the coordinates for each bench mark to the nearest second. Use the published coordinates instead of the scaled position for marks previously located by horizontal control survey methods. Record the position in the *10* code on NOAA Form 76-186, Bench Mark Description. The coordinates reported in the description will supersede any published scaled coordinates.

Do not record coordinates for marks searched for but not found. Instead, record the quad number in the *11* code of the description.

3. **Checking the Data.** Have the leveling units compare the log maps with actual field locations and report any discrepancies to the field office on NOAA Form 77-82 (back-up recording sheets).

At the field party office, rescale the positions of all marks without archive numbers. Compare these scaled positions with the positions listed in the HA-file as a check. Make any corrections listed by the level units on NOAA Form 77-82.

Use CKSPSN to check the scaled position against positions listed in the SYNOPTIC file. After checking the scaled positions of the questionable bench marks, note all discrepancies in a letter submitted with the project data.

The final check is made using program ABSTRA (EXABS). This program compares the observed stadia distance with the computed (inverse) distance between bench marks. Resolve all "****" flags by rechecking the plotted and scaled positions.

2.3.5 Instrumentation and Equipment

The instruments and equipment used by NGS field units are discussed in *NOAA Manual NOS NGS 3, Geodetic leveling* (chapter 3).

2.3.6 Observing and Recording

Observing and recording procedures are discussed in chapter 3 of *NOAA Manual NOS NGS 3*. The following sections either emphasize or list any changes to those procedures. Recording procedures for systems other than the Monroe recording system will appear in a new section (section 2.3.6.4) as they are developed.

2.3.6.1 Specifications and Technical Considerations

1. **Specifications.** Except as modified by the project instructions and in section 2.3.6.2, leveling shall be performed according to first-order, class II standards set forth in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (1974) and in *Specifications to Support Specifications of Geodetic Control Surveys* (1975, revised June 1980).

Tolerance limits are given in table 6 (hereafter called the Table of Tolerances) of *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. For the NI002, the tolerance limits (in millimeters) for low-high scale elevation differences are relaxed as follows:

First-order, Class I	First-order, Class II	Second-order, Class I	Second-order, Class II	Third-order
0.40	1.00	1.00	2.00	2.00

The direction of the running on single-run lines must be reversed on alternate workdays to reduce the accumulation of small systematic errors. When more than 10 km of leveling is observed per day, reverse the direction of running at midday.

Spur lines shall be run in both directions (forward and backward). Lines forming loops shall be run in one direction only. If the loop closures exceed the allowable limit given in the Table of Tolerances, follow these procedures:

(1) Verify the new leveling by comparing elevation differences between the old and the new surveys at common bench marks. (See *NOAA Manual NOS NGS 3*, chapter 3). If additional verification is needed, rerun those sections which are suspected for error or which were observed under bad or unusual conditions.

(2) Call the NGS Project Manager for instructions.

2. **Other Technical Considerations.** The following considerations also apply to all leveling operations:

a. **Observing sequence:** Level observations are to follow the sequence: (1) backsight low scale, (2) backsight low-scale stadia, (3) foresight low scale, (4) foresight low-scale stadia, (5) then reverse the compensator for Ni 002 instruments or off level and relevel other compensator instruments with the foot screws, (6) foresight high scale, and (7) backsight high scale. These observing procedures minimize the effects of rod and tripod settlement during setups, errors caused by changes in refraction, and the accumulation of small compensation errors caused by hysteresis.

The observations for each section are to begin and end with rod A on the bench mark (i.e., an even number of setups). (For exceptions, see section 2.3.6.2.) With unmatched rods, rod A is the rod with the smaller constant between high and low scales. If this procedure is not followed, rod index errors from sections with an uneven number of setups can accumulate over long distances. A single setup section is permitted only on spurs when the distance between bench marks is less than 100 meters.

After a setup is completed, the instrument and back rod are moved forward. "Leap-frogging" eliminates accumulation of systematic errors caused by index errors, etc.

b. The last two digits of the rod readings are read from the optical micrometer (nearest 0.1 mm for full-centimeter rods and nearest 0.5 mm for half-centimeter rods).

c. The maximum disagreement allowed between low- and high-scale elevation differences $\Delta\Delta h$ for each setup listed in the Table of Tolerances has been changed to 0.4 mm for first-order, class I, and to 1.0 mm for first-order, class II surveys, without applying a collimation error cor-

rection. The complete setup is to be reobserved when this requirement is not met. The length of sight is to be reduced as necessary to avoid reobserving setups frequently (section 2.3.6.2).

d. Backsight and foresight distances are to be balanced. Maximum differences allowed are given in the Table of Tolerances.

e. The line of sight should not be nearer to the ground than 0.5 m at any point.

f. Tabulated factors to be multiplied by the square root of K for computing the maximum tolerances of forward and backward runnings of a section ($f+b$) are given in the Table of Tolerances. (K is the section length in kilometers.) For sections less than 100 meters, or those having one setup, the maximum tolerance is computed by multiplying 0.316 by the tabulated factor.

When multiple runnings are required to achieve agreement between backward and forward leveling in a section, the "factors from simple mean" given in the Table of Tolerances will be used to determine the allowable difference from the simple mean. That is, the number given in the Table of Tolerances multiplied by the square root of the section length (in km) gives the maximum limit (in mm) any running can differ from the indiscriminate mean of all forward and backward runnings.

g. Rod turning pins with driving caps will be used where the ground is suitable. Turning pins will be driven vertically into the ground to provide a firm support for the rods. Heavy (at least 7 kg) turning plates ("turtles") will be used only on concrete and hard-packed gravel surfaces where pins cannot be driven. When soft or marsh ground cannot be avoided, wooden stakes should be driven to a firm depth, and a double-headed nail should be driven into the top of each stake to provide a turning point.

h. Steel tape measurements are not to be substituted for normal level rod observations; however, level observations are permitted with 1-meter, double-scale, invar tapes when necessary to level to bench marks set vertically in walls, bridge abutments, etc. When observations are made on a hanging (upside down) tape, subtract the micrometer reading from the rod reading and change the sign of the result to "-" before recording the reading on the Monroe recording system.

i. The leveling instrument's collimation error "c" is to be determined daily for the NI1, NI2, N3, and NI 004 and weekly for the NI 002 and NI A31 using the method outlined in "Documentation for Monroe Recording Programs 7811 and 7812." Collimation error is to be recorded in millimeters/meter.

j. A weekly compensation check is to be made on instruments with compensators, using the method outlined on the reverse side of NOAA Form 77-81. No compensation check is required for the NI 002.

2.3.6.2 Changes to Micrometer Leveling Observation Procedures

The leveling rods listed in table 2.3.6-1 have been calibrated at every graduation by the National Bureau of Stan-

dards. When leveling with these rods, use the procedures listed in section 2.3.6.1, but with the following change:

Table 2.3.6-1—Serial numbers of rods calibrated on every division

119351	269722	277920
120898	269723	277921
121176	270711	277922
129481	270712	277923
132181	270713	277924
241600	270714	277925
241601	270715	277926
241603	270716	277927
269718	270718	277928
269719	270719	277929
269720	277918	277931
269721	277919	277932

Start each section with rod A (rod 1) on the bench mark. However, it is not necessary to have an even number of setups between bench marks.

The following changes in procedure apply to all leveling with the NI002 instrument, regardless of whether or not the rods have been calibrated at every division.

Modify the Monroe recording program to allow $\Delta\Delta h$ checks of 0.4 mm for first-order, class I and 1.0 mm for first-order, class II surveys, without applying a correction for collimation error. Remove the Q-factor subroutine from the program, and do not compute and enter a Q-factor. Also, modify the program to allow imbalances of 5 m per setup and 10 m per section for first-order, class II surveys.

2. If $\Delta\Delta h$ checks cannot be obtained, even after shortening the sight lengths, check the collimation errors. If the range between C_1 and C_2 exceeds ± 0.20 mm/m (40") the instrument should be adjusted. However, until another instrument is available, continue leveling but balance the sight distances within 2 m.

3. The current limit on mean collimation error remains in effect.

2.3.6.3 Air Temperature Measurement

Systematic refraction errors on the order of 1 cm/km have been detected by NGS refraction tests. They can cause failure of section checks if proper corrections are not applied. To obtain the most reliable refraction corrections, it is necessary to observe multiple temperature measurements at each setup, at the same time the leveling observations are made.

This section gives the sensor check procedures, sensor locations, the observing and recording procedures for air temperature measurement, and the equation for determining the approximate refraction correction. The air temperature sensors are described in *NOAA Manual NOS NGS 3*, Geodetic leveling (Chapter 3).

1. **Sensor Check Procedures.** To check the sensors, mount them at the same height and point them in the same direc-

tion. Turn on the aspirator fans and allow them to run for at least 3 minutes. Read the temperature from both sensors in degrees Fahrenheit. If the readings do not agree within 0.2°F, check to make sure the aspirator fans are moving air past the thermistors at about the same velocity. This can be done by holding your hand in front of the aspirators. Replace the aspirator fan batteries if their voltage drops below 4.5 VDC as indicated by the built-in voltmeter. Replace the entire sensor if necessary. Record the results of these sensor checks on NOAA Form 77-82 (back-up recording sheets).

The digital display unit contains its own internal battery. The display unit monitors the condition of the internal battery and indicates when the battery should be replaced by displaying 'LOW BATTERY' or a similar message. If this occurs, or if the display begins to fade, replace the display unit's battery immediately. A 'low' display unit battery can cause the readout of the temperature sensors to be in error by several degrees. This would ultimately lead to erroneous corrections being applied to the observed leveling data.

If the sensors do not check, and replacements are not available, continue leveling without recording temperatures at each setup.

2. **Sensor Locations.** Set up the tripod at the normal observing height. Adjust the sensors so they are 0.3 meter and 1.3 meters above the ground. If the observer and recorder share the observing, mark on the tripod leg the sensor locations for each person observing. If the tripod must be set at other than a normal height while observing, reset the tripod at the normal height after making the observations and allow the sensors to stabilize for 1 minute before reading the temperatures. The sensors *must* be at 0.3 meter and 1.3 meters above the ground for *all* temperature observations.

3. **Observing and Recording Procedures.** A gradual apparent movement of the reading line or wedge with respect to rod graduations sometimes occurs when performing leveling operations. The apparent movement is such that reading checks can be satisfied and an error is not detected. The error often occurs when the temperature gradient is positive, i.e., the air temperature near the ground is less than the air temperature above, as indicated by the tripod-mounted sensors. This situation is not as serious in double-run leveling because checks are made between forward and backward runnings under different atmospheric conditions, although it may increase the number of reruns. The error is potentially serious in single-run leveling, where such checks are not available.

General guidelines to minimize this source of error are listed here:

a. Attempt to schedule the observing of level lines for times when the ground is not likely to be frozen or covered with snow.

b. If practical, delay the start of the daily work schedule to avoid leveling when temperature gradients are most likely to be positive. Generally avoid observing within the first 1½-hours after sunrise or within 1½-hours before sunset, especially if the ground becomes very cold at night.

NOTE: Make "C value" determinations only when the temperature of the lower sensor is greater than the temperature of the upper sensor.

c. When planning reruns because of poor loop or line closures, treat sections that were observed with many positive or zero temperature gradients with suspicion. Rerun the sections where more than 50 percent of the setups were observed with positive or zero temperature gradients (e.g., double-run bridges which have to be leveled in the early dawn because of daytime traffic or safety considerations).

While leveling, let the sensor fans run continuously. Observe and record the temperatures in degrees Fahrenheit. Record the temperature scale used (F=code 6) in the *40* record. Fahrenheit is used because one negative and one positive temperature (as might occur, near freezing, with Celsius units) cannot be recorded on the Monroe system.

Allow the sensors to stabilize at least 1 minute while observing each setup. After completing the leveling observation and reading check (zero flag on Monroe recorder), the observer will read the top and bottom sensors. The recorder will enter four digits for the top temperature, then a decimal, then four digits for the bottom temperature. For example, if temperatures from the top (1.3 m) and bottom (0.3 m) sensors are 98.3 and 99.3°F respectively, record them on the Monroe system as 983.0993. (It is not necessary to record the leading zero for the top temperature; it is necessary to include the leading zero for bottom temperatures less than 100°F.)

At the beginning and end of each section, record the air temperature from the top sensor in the *41* record, unless another sensor is available to measure the *actual* invar temperature.

4. **Equation.** The refraction correction is computed for the data in the RECOMP program. The approximate refraction correction for a single setup is:

$$r = -0.000033 s^2 dt dh$$

where

r = refraction correction in millimeters,

s = sight distance in meters,

dt = temperature difference (top minus bottom) in °F, and

dh = elevation difference in meters.

2.3.7 Leveling Errors

Leveling errors are discussed in detail in *NOAA Manual NOS NGS 3* (chapter 3). Any changes or additions will be listed in that manual.

2.3.8 Computations

Computations are discussed in detail in *NOAA Manual NOS NGS 3* (chapter 5). Any changes or additions will be listed in that manual.

2.3.9 Releveling for Closure

Releveling for closure (rerun) is discussed in *NOAA Manual NOS NGS 3*, chapter 3.

2.3.10 River Crossings

Detailed instructions for river crossings are given in *NOAA Manual NOS NGS 3*, chapter 4.

2.3.11 Data, Records, and Reports

2.3.11.1 Transmittal and Security of Vertical Control Data

General instructions for the transmittal and security of data are given in chapter 1.7, Field Records and Data. This section lists additional requirements for handling vertical control data.

1. The following data will be accumulated at the party (on a line or project basis) and transmitted to the Quality Control Section, N/CG164, within 30 days of completion of the line or project. All data transmitted to the Rockville office must be documented by a Letter Transmitting Data (NOAA Form 61-14). A copy of the letter is to be sent to N/CG161.

- a. Bound rod reading printouts for each HG file.
- b. Bound NOAA Form 77-82 (40-41 back-up recording sheets).
 - c. Miscellaneous hand-recorded rod readings.
 - d. Field records and computations from river crossings.
- e. Bound compensation check records.
- f. Bound original (hand-recorded) field descriptions for each HA file.
- g. Rough plots and smooth bench mark plots on USGS topographic maps.
- h. "New minus Old" tabulations.
- i. Project report, any supporting supplemental sketches, any supporting computations (such as loop closure computations), and a copy of the original project instructions.

2. Printouts of the following computer data files will be accumulated in a specified bin on a project or line basis. A release letter from the field party to N/CG164 will precede the release of these files. The release letter will contain the exact designations (DSN) of all files to be released. N/CG164 will transfer the released files from the field party's work space to the office work space. N/CG164 will

advise the Vertical Network Branch, N/CG13, by letter of those files released and transferred.

a. The printout of the HA file (descriptions) generated by RUNJOB (only one per file).

b. The printout of the observations (books) and field abstracts generated by RECOMP and ABSTRA programs.

3. Original raw data tapes are to be retained by the field office and protected against accidental destruction until their composite back-up tape has been completed, dumped, and checked by the RECOMP program, after which time the tapes may be reused.

4. The composite backup data tapes (TIXOFF data tapes) are to be retained by the field office and protected against accidental destruction until written notification is received from N/CG164 stating that the tapes are no longer necessary, after which time the tapes may be reused.

5. All data transported by the field party during a party move shall be protected from any unrecoverable loss by ensuring that hard copy (i.e., rod reading printouts and original field description drafts) are transported in a different vehicle than the vehicle transporting data tapes. Original data tapes that are being retained because their composite backup data tapes have not yet been verified should be transported separately from either the hard copy or the composite tapes. All the above items are extremely susceptible to heat damage and should be protected accordingly.

6. No material should be sent through the U.S. mail unless a backup copy exists either at the party location or at NGS Headquarters. Hard copy should be sent only if composite data tapes are still retained by the party or if written proof exists that the tapes have safely arrived at NGS Headquarters. The only exception to the above is that original data tapes may be mailed from remote unit locations without any back-up as long as the tapes are enclosed in specially made aluminum cases. When data tapes are mailed from the remote unit, no more than one tape should be sent per day.

7. The Project Director has full responsibility for ensuring that requirements for transmittal and security of data are met. See Chapter 1.2, Project Director's Responsibilities.

2.3.11.2 Project Reports

Prepare and submit a project report for each project or season's work. This report should accompany the data when they are transmitted to NGS Headquarters. See *NOAA Manual NOS NGS 3* (chapter 5.2.4) for details. Figure 2.3.11-1 shows an example of a project report cover.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Charting and Geodetic Services
Rear Admiral John D. Bossler, Director

Project Report

Vertical Control Party G-36

San Lorenzo Via Union City to Warm Springs, CA

L24743

First-order, class II levels

January 1983 to March 1983

Bob W. Martine
Project Director

**Figure 2.3.11-1.—Example of cover for project report
involving vertical survey**

2.4 SATELLITE GEODESY

This chapter lists the requirements for Doppler satellite surveys.

2.4.1 Party Structure

NGS has two parties that perform Doppler observations. Party G-01 is staffed by one surveying technician at the POLARIS Richmond, Florida station. Party G-02 is staffed by geodetic technicians who perform Doppler and global positioning system surveys.

The Field Operations Branch, N/CG161, maintains a file with up-to-date job descriptions.

2.4.2 Station Site Requirements

2.4.2.1 General

Site requirements are briefly discussed in *Specifications to Support Classification, Standards of Accuracy and General Specifications of Geodetic Control Surveys* (1975, revised June 1980). These requirements are repeated in more detail here. Project instructions will list any special site requirements for certain projects.

2.4.2.2 Terrain

The satellite signal is an electromagnetic wave which can be absorbed or refracted if objects block the ray path between the satellite and the ground receiver. Therefore, the antenna must be located where there are no obstructions 10° above the horizon.

The antenna should be positioned at normal tripod height to avoid ground reflection of the satellite signal.

Under special circumstances, the antenna may be elevated above trees and other obstructions by mounting it on a mast. Successful observations are possible by using such a mast, provided the antenna ground plane is effective in minimizing multipath problems.

The antenna must not be placed near metal structures. A metal structure may reflect the signal, causing the receiver to receive two signals whose phase relationship would change during the observation and produce poor quality data.

The antenna may be placed on a flat-roofed building if it is placed at least 2 meters from the edge of the building.

2.4.2.3 Electronic Interference

The antenna should be located where there will be a minimum of radio interference. Areas with radio transmissions at 150- and 400-MHz frequency ranges must be avoided. Medium frequency radar and high power transmission antennas must be avoided because they may emit sufficient radio energy to damage receiving equipment. High voltage

power lines and transformers, microwave relay towers, or excessive noise from automotive ignition systems, must also be avoided. A gain reading higher than 10 when no satellite signals are being received indicates a potential problem with electronic interference.

2.4.2.4 Geodetic Control

Each Doppler station shall be monumented with a standard NGS monument and disk and described on NOAA Form 75-82 or 75-82A. The description shall include the Doppler station number. At least two reference marks shall be located within 30 meters of the station monument. Distances, horizontal angles, and differences in elevations must be measured to facilitate future recovery and verification of the Doppler station.

If the Doppler station is to be tied to local geodetic control, the Doppler station monument must be located so that local survey marks are intervisible. When ties to local geodetic control are performed, include a written report with the survey data and sketches. This report will describe the survey(s), stations occupied, methods and procedures used, and, when pertinent, reasons certain observations could not be performed, e.g., Polaris observations could not be made due to cloudy weather.

2.4.2.5 Electrical Power

Each model receiver has its own power requirements. See the manufacturer's instruction manual for each instrument. Follow the instructions exactly to prevent damage to the receiver.

Additional power may be required for heating, lighting, air conditioning, etc. Use heavy gauge wire (No. 14 or larger) to connect the receiver to the power outlets.

As a precaution, check power outlets with a voltmeter to ensure that the equipment is properly grounded. Many two-wire systems have been replaced with three-prong boxes without connecting the third prong to ground. If a three-wire hookup is not available, connect the ground wire to a separate ground potential such as a water pipe, radiator, or ground rod.

2.4.2.6 Security

The receiver assembly, antenna, and other equipment must be protected at all times from theft, vandalism, and curious people.

2.4.3 Instruments and Equipment

NGS has two different models of Doppler receivers: the Magnavox Geociever and the Magnovox MX 1502. See the manufacturer's instruction manuals for operating procedures. (Note: For the MX 1502 receivers, use Report R-5807C (No. 60029) for receivers with software version 015, and Report R-6245 (No. 60025) for receivers with software versions 104, or 113.)

1. **Equipment Log and Failure Report.** Form NGS C152-4, Equipment Log, shall be maintained for each MX 1502 Doppler receiver. This log will be kept with the receiver at all times. Appropriate entries will be made at the beginning and ending of a station occupancy and once about every 3 days for each occupation. (See fig. 2.4.3-1.)

An MX 1502 Equipment Failure Report must be completed whenever a problem occurs that affects the Doppler observations. (See fig. 2.4.3-2.) This same form may be used for reporting failures of the Geociever.

2. **Meteorological and Survey Instruments.** NGS teams are equipped with devices that measure meteorological data. These include psychrometers, hygrometers, barometers, thermometers, etc. The teams are also equipped to make survey ties to the local control networks.

2.4.4 Observing and Field Data Processing

2.4.4.1 Setup

1. **General.** Upon arrival at the station site, monument the station if necessary and set up the equipment as described in the manufacturer's instruction manuals.

2. **Antenna.** Mount the antenna on a T2/T3 or similar type tripod using the special adapter that connects to the base of the antenna. It should be leveled and plumbed to within 1 mm of the center of the mark. The antenna must be vertical to ensure that no eccentricity is introduced. Guy the antenna in place and recheck that it is plumbed over the mark. Measure the antenna height to the nearest 1 mm and record it on figure 2.4.4-1. Submit this form with the Station Occupation Report. The antenna height must not be changed for any reason during the observing period. **CAUTION:** If it is necessary to reoccupy a station during a project, setup and plumb the antenna within 5 mm in height of the first occupation. Contact N/CG142, Astronomy and Space Geodesy Section, concerning any deviation from these requirements.

3. **Obstruction Survey.** Sketch the horizon on Form NGS C152-7. Figures 2.4.4-2 and 2.4.4-3 show how this is done.

2.4.4.2 Reference Frequency Standards

To achieve optimum quality for the Doppler observations, it is important that a stable reference frequency standard be used during the station occupation. If the internal crystal oscillator is used for the reference, power must be applied to the oscillator at least 72 hours before commencing observations. An internal 5-ampere-hour battery is provided in the receiver to maintain power to the oscillator for up to 24 hours during transportation between sites.

The date and time that power is applied to the oscillator shall be recorded on Form NGS C152-2, Observation Log. (See fig. 2.4.4-4.)

A precise or ultra stable frequency standard may be specified for some projects. These standards may be a rubidium, maser, or high performance cesium systems.

2.4.4.3 Equipment Tests

After the receiver has been set up, perform the equipment tests as outlined in the manufacturer's instruction manuals. Most receivers have a self-test feature which simulates a satellite pass to test all parts of the circuitry. The test must be performed at the commencement of the observations at a station and daily at manned stations.

2.4.4.4 Pass Selection

See *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

Observe all operational satellites of the TRANSIT system. The Astronomy and Space Geodesy Branch (N/CG142) will notify the observing teams if any satellites should be deleted from the observing schedule. With the MX 1502, all observations will be performed in the automatic mode of operation on a continuous basis, 24 hours per day, and 7 days of the week.

Observe all passes that are 10° or above the horizon at closest approach. (Note: Unless the MX 1502 receiver software has been modified, only passes at elevations greater than 15° can be observed). In order to clear obstructions above 10°, it will be acceptable to mount the antenna on a tower or mast.

The number of acceptable passes will depend on the distribution of the passes about the observer's meridian (reasonable balance between passes east and west of the meridian and north- and south-going passes to achieve a minimum of two passes in each quadrant).

2.4.4.5 Loading MX 1502

When loading the cassette in the MX 1502, **DO NOT FORCE**. This will help to prevent breaking any of the sprocket teeth on the cassette.

Before removing the cassette from the MX 1502, **rewind to beginning of tape**. Use Code 49.

2.4.4.6 Meteorological Data

See *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*.

Weather data shall be recorded for each pass or at 1- or 2-hour intervals at each base station. The data may be entered and recorded on the data cassette or recorded on Form C152-1, Record of Meteorological Observations. (See fig. 2.4.4-5.)

Weather data collected on a continuous chart recording device should be extrapolated and recorded on Form NGS 152-1. Data should be recorded at 1-hour intervals.

ORM NGS C152-4 (9-27-81)

EQUIPMENT LOG
MX-1502

RECEIVER S.N. _____

ANTENNA S.N.

PREAMP S.N.

YEAR

[illegible]

Figure 2.4.3-1.—Form NGS C152-4, Equipment Log, for MX 1502 Doppler receiver

ANTENNA MEASUREMENTS

Station # _____ Station Location _____

Date _____ Station Name _____

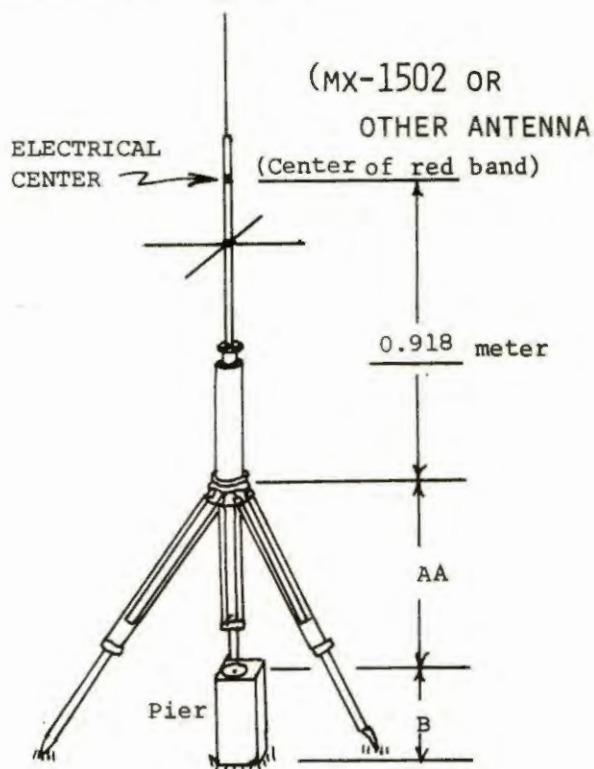
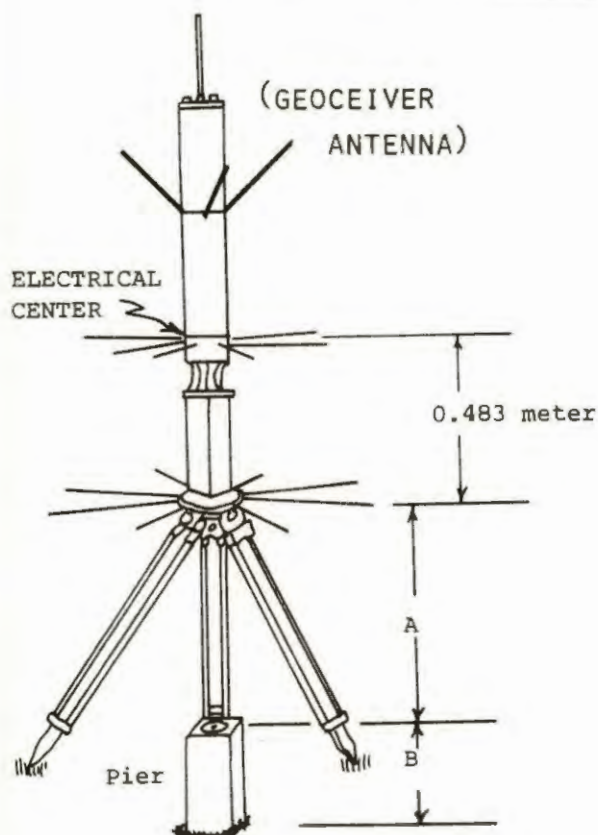
Period for when measurements are applicable (Time-UT/Day/Date):

From: _____ To: _____

Measurements: A = _____ meter B = _____ meter

Total height of electrical center (reference point for position information):

= A + (constant) = _____ + _____ = _____ meter



Distance "A" is from top of station mark to the bottom surface of the preamplifier, not including the 'adapter' plate.

Distance "AA" is from top of station mark to the bottom surface of the 'adapter' plate attached to the preamplifier.

Distance "B" is the height of the pier or monument above (or below) the ground surface.

Figure 2.4.4-1.—Form used to record relation of antenna to bench mark dish

Form NGS C152-7 (11-19-81)

Attachment # _____

OBSTRUCTION SURVEY

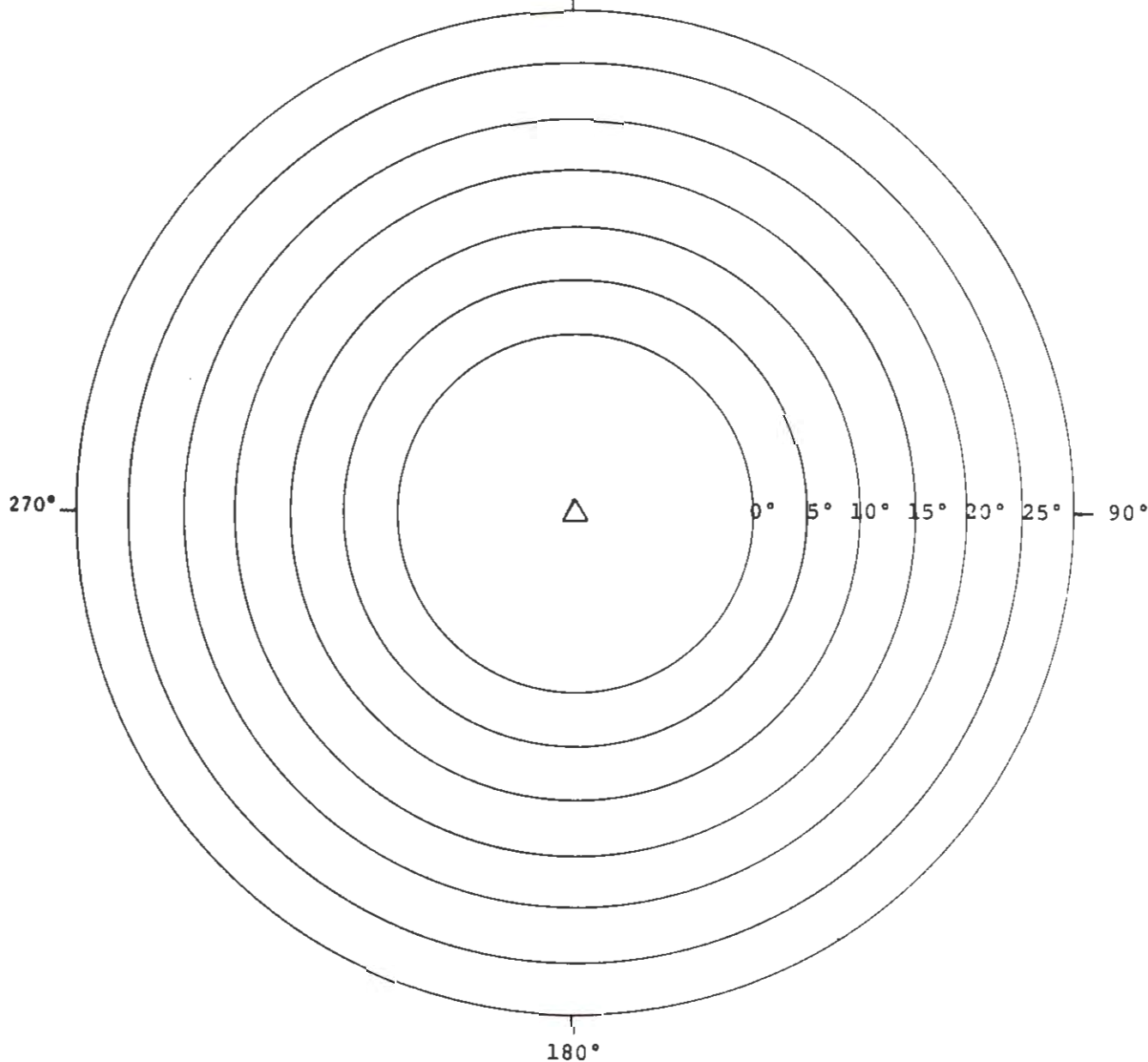
Station Number _____

(NORTH)

Location _____

Date _____

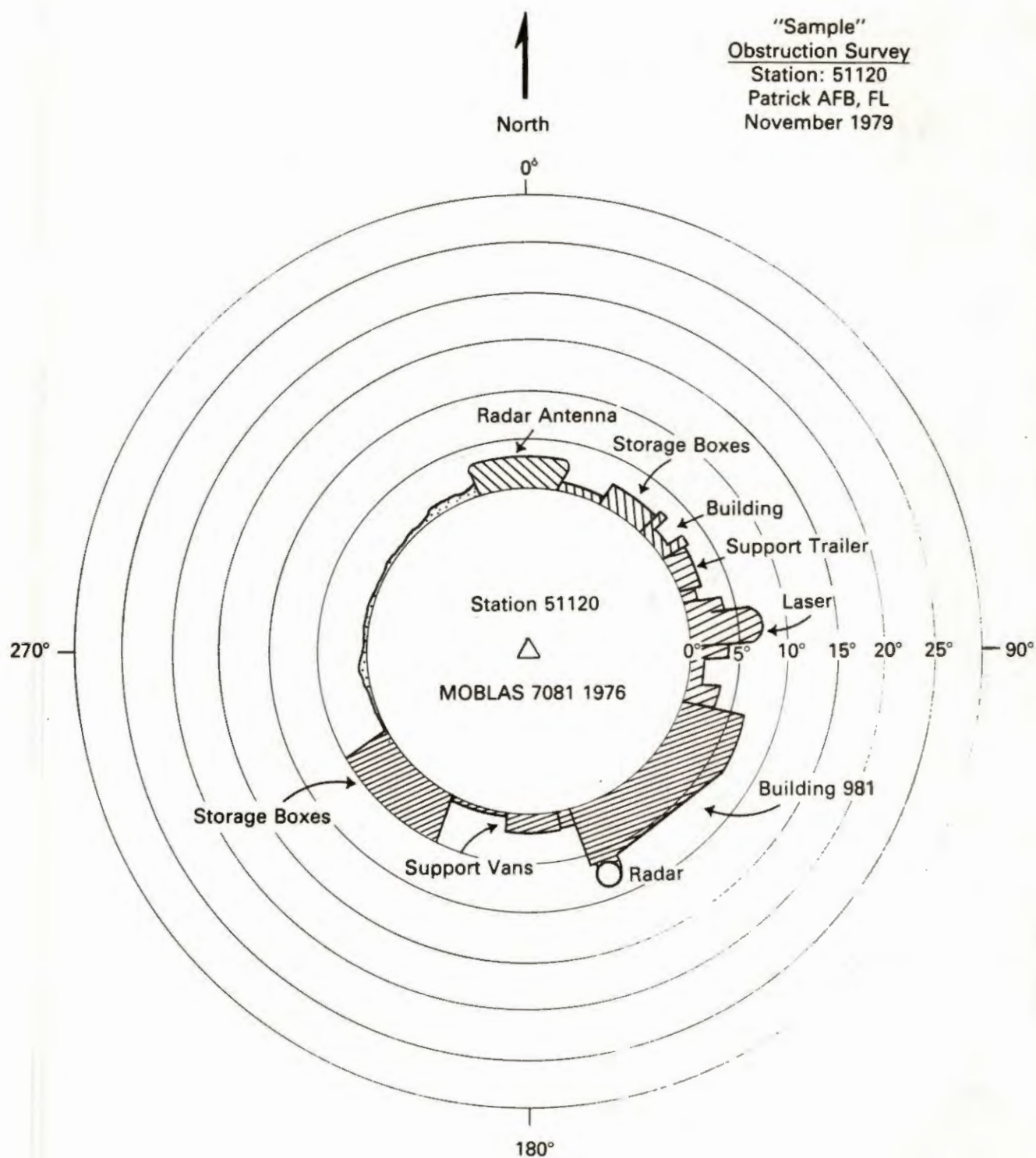
0°



Height of theodolite (Telescope) = _____ m

Height of antenna phase center = _____ m

Figure 2.4.2.—Form NGS C152-7, Obstruction Survey



Height of Telescope = 1.655 m
Height of Antenna Electrical Center = 1.960 m

Figure 2.4.4-3.—Example of Form NGS C152-7 completed for a satellite survey

Form NGS C152-2 (Rev. 9-27-81)			PAGE	YEAR	LOCATION	STATION NUMBER	
DOPPLER STATION OBSERVATION LOG MX-1502 RECEIVER			STATION NAME		BASE STATION ☐ YES ☐ NO	SITE NUMBER (Code 20) ②	
			PROJECT		SOFTWARE TYPE (Code 8:ADDR 46)	SOFTWARE VERSION (Code 8:ADDR 47)	
RECEIVER S.N. (Code 26)	PREAMP S.N. (Code 84:VAR1)	ANTENNA S.N. (Code 85:VAR2)	ANT. HT. (Code 28:SP2) ③ (m)	AGENCY CODE (Code 27:SP1) ④		DATE/GMT REC/OSC on PWR. ⑤	
EST. LAT. (Code 21) N/S ° ' "		EST. LONG. (Code 22) E/W ° ' "		EST. ELEV. (Code 23) (meters)	DATUM SHIFTS (SATELLITE to LOCAL) (Code 100) ΔX = (m) ΔY = (m) ΔZ = (m)		
STATION OBSERVATION RECORD							
CODE	DISPLAY ⑦	INITIAL or INTERMEDIATE ①	INTERMEDIATE ①	INTERMEDIATE ①	INTERMEDIATE ①	INTERMEDIATE or FINAL ①	
	Observer (Initials)						
80	Met. Data (mb/ °C /RH)	(Enter in MX1502)					
	Battery Ext./Int.	/	/	/	/	/	
	Internal Temp. of Rec. (°C)						
16/50	SELF TEST PERFORMED/STATUS	/ /	/ /	/ /	/ /	/ /	
18/19	SATS ALRTD/SATS DSRD	/	/	/	/	/	
24	GMT						
25/35	GREENWICH DATE/JULIAN DAY	- - /	- - /	- - /	- - /	- - /	
48	TAPE USED (m) (LIMIT < 75m)						
54	400 TUNE/SIGNAL LEVEL/GMT	32kHz/ /	32kHz/ /	32kHz/ /	32kHz/ /	32kHz/ /	
94	150 TUNE/SIGNAL LEVEL/GMT	/ /	/ /	/ /	/ /	/ /	
66	PASSES (TOTAL/2D/3D)	/ /	/ /	/ /	/ /	/ /	
	"2D" PASSES/TP #/TP C.N. ⑥	/ /	/ /	/ /	/ /	/ /	
63	3D POS. (STATUS/PASSES/D)	/ /	/ /	/ /	/ /	/ /	
	LATITUDE	- -	- -	- -	- -	- -	
	LONGITUDE	- -	- -	- -	- -	- -	
	GEODETIC HT. (m)						
	S.D. LAT/LONG/HT (m)	/ / /	/ / /	/ / /	/ / /	/ / /	
	N-WE/S-WE	- / -	- / -	- / -	- / -	- / -	
53	2D CS/EL /ITER/DOPCTS/SAT #	/ / / /	/ / / /	/ / / /	/ / / /	/ / / /	
	GEOMETRY/S.D. of RES.	/	/	/	/	/	
	GMT/DATE	/ - -	/ - -	/ - -	/ - -	/ - -	
56	REF. OSC. FREQ. OFFSET (Hz)						
	ANT. CHKD. (PLUMB & LEVEL) ?						

NOTES: (1) Make entries for each station visit and after troubleshooting error codes. (2) Last 4 digits of Doppler Sta. Nr.
 (3) Height of antenna ref. point (ctr. of red band) above sta. mark; use 0.918 m. as constant for ctr. of red band to bottom of preamp. Enter in millimeters. (4) First digit of Doppler Sta. Nr. (5) If external frequency standard used, indicate type and S.N. (6) Record approx. number of passes on cassette; tp. number for occupation; and, control number (C.N.) found on 'Side B'.
 (7) Some information may not be available depending on software version.
 "REMARKS: (OVER)"

Figure 2.4.4-4.—Form NGS C152-2, Doppler Station Observation Log, MX 1502 Receiver

If practical, weather measurements should be obtained at the secondary stations occupied during a project. These data may be augmented with data obtained from any available source located nearby (preferably within 50 km) such as from a National Weather Service station, military base, or other scientific observing facility. The position and elevation of these observing stations must be included with the data.

So that weather data obtained from other sources can be adjusted to be reasonably consistent with actual station conditions, weather measurements should be recorded whenever the station site is visited.

The units for the meteorological data should be in °C for temperature, millibars for station pressure, and percent for relative humidity. It will be acceptable for data to be submitted in alternate units: °F for temperature and inches of HG or millimeters of HG for station pressure. Instead of relative humidity in percent, the wet-bulb/dry-bulb temperatures may be submitted or the moisture content may be given as water vapor pressure in any of the units acceptable for station pressure.

Copies of the meteorological observing records from the observing stations may be submitted in the original format or transferred to Form NGS C152-1.

2.4.4.7 Observation Log

When using an MX 1502 Doppler receiver, complete Form NGS C152-2, Doppler Station Observation Log, (fig. 2.4.4-4), for each station occupied.

2.4.5 Data and Reports

2.4.5.1 Data

1. **General.** Two types of data are collected at Doppler sites. These are the Doppler observation data and the ground survey tie data. The Doppler data are recorded on magnetic tape or punched paper tape depending on the type of receiver.

Ground survey tie data consists of the horizontal and vertical control survey observations necessary to connect the Doppler station with the local control network.

2. **Data Transmittals.** The collected data should be forwarded to the Quality Control Branch, N/CG164, on a regular basis. All data should be forwarded by registered mail-return receipt requested to:

Quality Control Branch, N/CG164
National Geodetic Survey, NOAA
Rockville, MD 20852

NOAA Form 61-29, Letter Transmitting Data, must accompany all data. See chapter 1.7.

Each tape cannister or cassette must be labeled as follows:

Sta# (1) In Date (2) GMT
Loc. (3)
SN (4) Out Date (5) GMT
Ant. Ht. (6) m Tape (7) of

(1) Station Number: The Doppler station number assigned to the occupied station.

(2) In Date—GMT: The date and Greenwich Mean Time of the first data entry on the tape.

(3) Location: The name of the State, nearest city or town, or other geographic name.

(4) SN: Serial Number of the receiver.

(5) Out Date—GMT: The date and Greenwich Mean Time of the last data entry on the tape.

(6) Antenna Height.

(7) Tape Number.

2.4.5.2 Reports

1. **Monthly Report and Journal.** NOAA Form 76-92 must be submitted to and received by the Field Operation Branch (N/CG161) by the tenth of each month.

In block 15, "Remarks and Recommendations," list the satellites which were tracked, the number of passes recorded for each satellite, and the total number of passes.

2. **Station Occupation Report.** NOAA Form NGS C152-6, Station Occupation Report (fig. 2.4.5-1), must be completed for each occupation of any Doppler station. A copy of the first two pages of this report (items 1-4) must accompany data tapes. If additional space is needed, use blank paper and reference the item, e.g., 1c, etc. If more than one receiver is used simultaneously at the same site as in collocation, complete a Station Occupation Report for each receiver.

For reoccupations where there have been no significant changes to the information in the original Station Occupation Report, or for secondary satellite Doppler stations of a relative positioning project, only a "short-form" version needs to be completed for each station. (The "short-form" version includes items 1 through 4 only.)

Form NGS C152-6 (Revised 11-19-81)

STATION OCCUPATION REPORT

SATELLITE DOPPLER

The Station Occupation Report (SOR) will be completed for each occupation of a Doppler station. A copy of the page of this report must accompany data tapes. If additional space is needed, use blank paper and reference the item, e.g. l.c., etc.

When there hasn't been significant changes to the information given in the original SOR for stations reoccupied, or for secondary stations of a relative positioning project, only a "short-form" version needs to be completed for these stations. The "short-form" version includes items 1 through 4 only.

DATE _____

1. STATION INFORMATION

- a. Station # _____ Station Location _____
Station Name (as stamped or designated) _____
- b. Is the station on established geodetic control? Yes ___ No ___; If no, will it be tied to established geodetic control? If yes, give details.
- c. Was the station a base station for simultaneous observations? Yes ___ No ___
If yes, list by phase, the station numbers observed simultaneously with the base station on a separate attachment. Attachment # _____.
- d. Geodetic Position: Lat. _____ Long. _____ Elev. _____ m
Source for geodetic information: _____
- e. Agency and names of party personnel who occupied station:
- f. Name, mailing address, and phone number for Chief of Party:
- g. Name, address, and telephone number for owner of site:
- h. Total occupation period: _____ thru _____
Day No./Time (UT)/Sat #: (1st Obs.) _____, (last Obs.) _____
If a base station, list period of occupation for each phase of simultaneous observations on attachment for Item l.c.

2. EQUIPMENT INFORMATION

- a. Type of Tracking equipment: _____ Model _____ Serial # _____
If applicable, give serial numbers for the following: Recorder _____
Antenna _____, and, Preamp _____.
- b. Was an external frequency standard used: Yes ___ No _____. If yes, give type, make, model and serial number.

-1-

Figure 2.4.5-1.—Form NGS C152-6, Station Occupation Report

2. EQUIPMENT INFORMATION (Cont'd)

- c. Height of antenna electrical center (reference point) above mark: _____ m.
 Geociever antenna: Station mark to base of preamp _____ m + 0.483 m = _____ m
 MX1502 antenna: Station mark to base of preamp _____ m + 0.918 m = _____ m

(see Page 6)

- d. Was the antenna move from original location during the period of occupation?
 Yes _____ No _____. If yes, explain and give dates and applicable satellite numbers and times.
- e. Equipment down time during this occupation. List time and period of each failure.
- f. Have any other satellite observation teams had equipment in the vicinity?
 Yes _____, No _____. If yes, give details.

3. LOCAL GEODETIC SURVEY TIES

- a. Include a sketch showing (proposed) (completed) site survey of monuments, antenna, photo points, and their relationship to local control. Attachment # _____.
 (This sketch is not required for established stations that do not require additional survey work by the Doppler team).
- b. What agency (will perform) (performed) survey?

4. THE FOLLOWING DESCRIPTIVE DATA ARE ATTACHED:

- a. Station (Description) (Recovery Note), Attachment # _____.
 b. Vicinity sketch (showing location of all monuments and photo points),
 Attachment # _____.
 c. Photo of Doppler station mark: Attachment # _____.
 d. Photographs of horizon from station mark: (Optional for secondary or reoccupied
 stations), Attachment # _____.
 e. Obstruction Survey (showing angle above horizon of obstructions around horizon):
 (Use form NGS C152-7) Attachment # _____.
 f. Photographs of station from cardinal points from about 50 meters:
 Attachment # _____.
 g. Report any circumstances that may prevent reoccupation. (If antenna occupies a
 monumented point such as the roof of a building, provide a detailed sketch
 including distances from the edge of the roof, etc., so the antenna could be
 replaced in exact location). Attachment # _____.
 h. Report circumstances that prevented acquisition of any of the above items if
 not attached. Attachment # _____.

5. COMMUNICATIONS AND POSTAL SERVICES AT SITE: (Are all the facilities basically standard U.S. Services? Yes _____ No _____. If yes, proceed to Section 6. If no, describe only those aspects which differ from standard services).

- a. Local (Type of Communication, Quality and Cost, etc.):
- b. Overseas
- (1) Telephone, radio telephone, or radio (Operating hours, cost, local regulations, etc.):
- (2) Teletype (Operating hours, cost, etc.):
- (3) Mail (frequency of delivery, type service, weight/dimension limits, costs, etc.):

6. TRANSPORTATION: (Type of service available with any special addresses, phone numbers and names of contacts).
- Air (Government and Civil):
 - Ground (Government and Civil):
 - Transportation used during occupation and its acceptability.
7. LOCAL CONTACTS (Names, titles, address, phone numbers, of individuals providing assistance; list type of assistance provide):
8. POWER: (Were batteries used as the sole power sources? Yes ____ No _____. Or were generators required? Yes ____ No _____. If yes to either, proceed to Section 9.)
- Type AC Power (indicate voltage variance and frequency stability):
 - Distance from power source to location of tracking equipment:
 - Connection, service requirements, and costs:
 - Special equipment (such as provided by installing firm):
 - Installing Firm:
9. HOW WAS TRACKING EQUIPMENT PROTECTED FROM WEATHER AT SITE?
____ Government vehicle; ____ Other (specify)
10. ARE OFFICE AND STORAGE SPACE AVAILABLE AT THE SITE (Excluding use of Government vehicle):
____ Yes ____ No. If no, give information on any other arrangements made.
11. ARE REPAIR, MAINTENANCE, AND SERVICES AVAILABLE AT SITE (i.e., construction, materials, electronic, rentals, etc.)? Yes ____ No ____.
12. HOUSING (Are housing and subsistence facilities adequate? Yes ____ No _____. Are costs of above facilities about average? Yes ____ No _____. Comment on inadequate facilities about average? Yes ____ No _____.)

Figure 2.4.5-1.—Form NGS C152-6, Station Occupation Report—Continued

13. MEDICAL FACILITIES: (If important)
Distance to nearest medical facilities _____.
Emergency evacuation procedures:

Other comments:
14. MILITARY INSTALLATIONS THAT CAN BE OF ASSISTANCE (If applicable).
15. GROUND ENVIRONMENT: List abnormal weather conditions peculiar to the station site and any temperature extremes which may affect personnel or equipment.
(Do not comment on normal seasonal variations.)
16. OTHER PERTINENT AND USEFUL INFORMATION:
- a. Banking Facilities: (Location and Distance)

(1) Will the bank cash Government checks? Yes _____ No _____
(2) Will the bank cash personal checks? Yes _____ No _____
- b. Community Customs (Pertinent to the occupation of the site and related activities):
- c. Regulations, Conditions, Practices, Customs, etc (That could adversely affect operations and suggested procedures for reducing or eliminating their impact):
- d. Precautions (Required by station personnel for local sanitation, drinking water, diseases, wild animals, etc.):
- e. Other Information (Of an unusual nature which would assist in the efficient operation of the station.):

Figure 2.4.5-1.—Form NGS C152-6, Station Occupation Report—Continued

2.5 ASTRONOMIC SURVEYS

Astronomic surveys performed by NGS are used in conjunction with gravity and leveling surveys to maintain correct scale and orientation of the National Geodetic Horizontal Network. For a detailed discussion on the objectives of geodetic astronomy, see Coast and Geodetic Survey *Special Publication* 237, Manual of Geodetic Astronomy.

Section 2.2.7.4 covers specifications and observing procedures for astronomic azimuth.

2.5.1 Party Structure

NGS has one astronomic field party, consisting of two surveying technicians who perform astronomic observations for the conterminous States. Responsibility for so vast an area necessitates a highly mobile party, rarely located at one site longer than 2 weeks. Both party members, namely the Project Director and the senior observer, share equally in the observation program at each site. The party size is increased for special projects and training programs as the need arises.

A file of current job descriptions is maintained by the Field Operations Section, N/CG161.

2.5.2 Station Site Requirements

2.5.2.1 General

Specific triangulation stations requiring astronomic determinations are generally designated in the project instructions. Vehicular accessibility is a basic prerequisite in the station selection process. Special site requirements involving portage will be explicitly covered in the project instructions.

2.5.2.2 Instrument Site Selection

Astronomic observations require an unobstructed view of the sky in the plane of the local meridian. This line-of-sight should extend 30 to 45 degrees, both north and south of the zenith. The ground must be firm enough to support the weight of the instrument and the observer.

Generally the instrument will be positioned over the station mark. With property owner approval this may require some pruning and removal of other obstacles. If the station mark is not suitable for occupation, one of the existing reference marks may be utilized. As a last resort, an unmonumented point can be established.

2.5.2.3 Eccentric Setups

Eccentric setups will be used only when conditions make it impossible to occupy the station directly or would adversely affect the quality of the observations. The distance between station and eccentric point should not exceed 30 meters.

The eccentric measurements should be made immediately after the instrument has been set up, adjusted, and oriented to the local meridian.

Distance measurements will be made independently in both meters and feet. The distance will be remeasured if the two measurements disagree by more than 1 centimeter.

The horizontal direction is to be measured from true north to the station mark. A single direct and reverse measurement is sufficient for obtaining the 1 arc-minute accuracy required.

A vertical angle will be required if the taped distance is not measured in a horizontal plane. Again, a single direct and reverse measurement is adequate.

All eccentric measurements are entered in the proper columns on the longitude record and coding form. (See fig. 2.5.2-1). Computation of the eccentric reduction need not be made in the field.

2.5.3 Station Specifications

The specifications for latitude determinations by the Horrebow-Talcott method are given in *Special Publication* 237. This subchapter gives the specifications for latitude determinations by the Sterneck method and longitude determinations by the meridian transit method.

2.5.3.1 General Specifications

Azimuth orientation of the theodolite with respect to the local meridian should not exceed 15 arc-seconds.

The theodolite eyepiece will remain in the longitude position for all observations.

Temperature and barometric pressure should be carefully recorded at approximately 30 minute intervals, beginning immediately before and ending immediately after the observation program.

Periodic calibration of barometers and thermometers, not to exceed 120 days, will be made at local (National Weather Service) weather stations. Be sure to use correct terminology when requesting pressure information from the weather station. A request for *STATION PRESSURE* will ensure that the value furnished has not been reduced to sea level.

Determinations of the mean width of contact strips and lost motion of the micrometer screw will generally be made every 4 months. Additional determinations will be made immediately following any repairs made to the micrometer in the field.

Observations should be spaced no less than 3.5 minutes of time apart so that adequate time is available for reading micrometer, levels, etc.

2.5.3.2 Latitude Specifications

Observations will consist of stars equally distributed north and south of the zenith. Star selection will be taken from the *Apparent Places of Fundamental Stars* (APFS), prepared by Heidelberg Astronomisches Institut, under auspices of the Int. Astronomical Union (publisher: Grossohaus Wagner and Co., Hamburg, P.R.G.), except when a computer generated list of candidate stars is provided by the Astronomy and Space Geodesy Section, N/CG142. The stars selected for observation must meet the condition that the algebraic sum of the zenith distances is no greater than twice the total number of stars observed. In addition, zenith distances should be less than 35 degrees, but in no case can they exceed 45 degrees.

The zenith distance of a star will be measured in both ocular positions. Observations should be made approximately 10 arc-minutes before and after star transit to allow sufficient time for instrument reversal. This is equivalent to making the observations at the sixth and fourteenth line of the Wild T4 theodolite.

Timing records are to be obtained for each zenith distance measurement by incorporating a momentary contact switch in the transit circuit of the digital recorder. The time event should be made by the observer at the instant of stellar bisection.

A first-order latitude determination will depend on observations of a minimum of 32 stars. These observations can be obtained in a single night by one observer. The standard error of the mean latitude shall not exceed 0.15 arc-seconds.

A modified first-order latitude determination will depend on observations of a minimum of 24 stars. The standard error of the mean latitude shall not exceed 0.20 arc-seconds.

2.5.3.3 Longitude Specifications

A set of six to eight time stars, bracketed within two radiochronometer comparisons, will constitute a longitude determination. Additional time comparisons will be made if the longitude set exceeds 1 hour. Every effort should be made to observe eight stars per set, divided equally north and south of the zenith. A three-four combination will be used when seven stars comprise a set.

A time star is here defined as one with an azimuth factor less than 0.75. Preference should be given to stars with azimuth factors less than 0.50.

Each star should be tracked through three complete revolutions, beginning at the fifth (or fifteenth) line and ending at the eighth (or twelfth) line. Figure 2.5.3-1 illustrates the reticle pattern as seen through the telescope eyepiece.

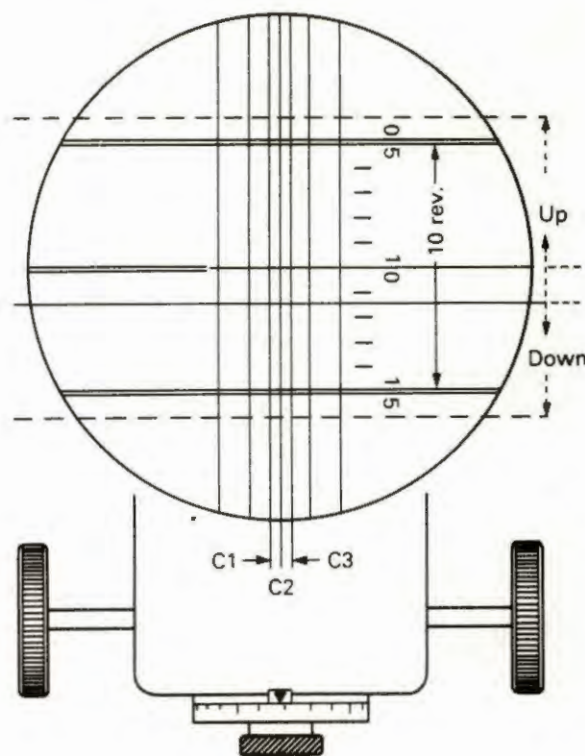


Figure 2.5.3-1.—Eyepiece reticle pattern

The inclination or dislevelment of the theodolite axes must be kept as small as possible so that errors in the level value are minimized. A running sum of the inclination measurements should be maintained by the notekeeper to facilitate releveing, if necessary. Leveling adjustments must be between sets, never within a set. To further reduce the effect of inclination errors on the longitude, the sum of the inclinations should be as small as possible (ideally zero).

A first-order longitude determination will consist of a minimum of five sets, two of which must be observed on a different night. Every effort will be made to obtain six sets, three per night. Both observers should make observations each night using a 2 to 1 and 1 to 2 combination to minimize errors associated with personal bias and fatigue.

A modified first-order longitude determination will generally consist of three longitude sets which can be obtained in a single night. A minimum of two longitude sets will be acceptable under unusual conditions; however, the party chief should consult with the Astronomy and Space Geodesy Section before moving to a new location. Both observers will participate in the observation program in the same manner as specified for first-order determinations.

The standard error of the mean longitude should rarely exceed 0.15 arc-seconds for first-order stations and 0.20 arc-seconds for modified first-order stations.

2.5.4 Instrument and Equipment

2.5.4.1 Theodolite Specifications

NGS currently uses the Wild T4 universal theodolite exclusively for astronomic position determinations.

The Wild T4 theodolite of bent (or broken) telescope design weighs approximately 107 kilograms including accessory and transport boxes. The telescope is transported separately from the instrument base.

The following technical data have been taken from the "Wild T4 Universal Instrument Instructions," published by Wild Heerbrugg, Ltd.

"Telescope: Clear objective aperture ... 60 mm ; Field of view ... 46 arc-seconds; Magnification ... 70x; focal length ... 540 millimeters; Shortest focusing distance ... 100 m; Eyepiece micrometer range ... 30 arc-minutes.

"Horizontal circle: 360 degrees; Graduation interval ... 2 arc-minutes; optical coincidence micrometer with graduation interval ... 0.1 arc-seconds; Circle settings by means of drive knob.

"Horizontal setting circle: Graduation interval ... 1 degree; Reading by estimation ... 0.1 degree.

"Vertical circle: 360 degrees; Graduation interval ... 4 arc-minutes; Optical coincidence micrometer with graduation interval ... 0.2 arc-seconds; Circle settings by means of drive knob.

"Vertical circle index level (Sterneck): 1 arc-second per 2 mm run; Reading by estimation ... 0.1 - 0.2 arc-seconds.

"Zenith angle setting circle: Graduation interval ... 1 degree; Reading by scale microscope; Graduation interval ... 10 arc-minutes; Reading by estimation ... 1 arc-minute.

"Suspension (cross) level: Sensitivity ... 1 arc second per 2 mm run. Reading by estimation ... 0.1 - 0.2 arc seconds.

"Voltage requirements: 3 - 6 volts maximum, varied by rheostat."

NGS modifications include: Telescope pointing light; Sterneck level assembly; counterweight for the Sterneck level assembly.

2.5.4.2 Theodolite Adjustments

After the theodolite is set up on the observing stand, the bearing surfaces of both instrument and levels should be cleaned with light machine oil. The surfaces are then wiped dry with soft tissue paper to avoid dust accumulation. Check carefully to ensure that there is no rust or other foreign matter on these surfaces. Any surface rust should be removed with fine emery cloth only. If the bearing surfaces become pitted or scored, the theodolite should be returned to the Instrument and Equipment Section, N/CG163, for repair. The various exposed lenses should be periodically cleaned and tightened as needed. Only a soft camel hair brush or special lens paper should be used for lens cleaning.

Not all of the following adjustments are required at each station site; however the observer must examine and correct all of these adjustments as often as necessary to ensure that the errors are always within allowable limits:

1. **Eyepiece focus:** The eyepiece should be focused by turning the telescope to a light surface such as the afternoon sky, and rotating the milled eyepiece adjusting ring until the most distinct image of the reticle pattern is obtained.

2. **Objective focusing:** The objective is focused by pointing the telescope to a well defined object, not less than 2

kilometers away, and sliding the eyepiece micrometer draw tube in and out until there is no perceptible relative movement (parallax) of the reticle and the target image when the eye is shifted in front of the eyepiece. The final focusing must be done at night using a faint (4-5 magnitude) star.

3. **Micrometer focusing:** The vertical and horizontal circle micrometers are focused by rotating the milled eyepiece adjusting ring until the most distinct image is obtained and all parallax has been removed. Lighting for the circles should be adjusted for uniform brightness for this purpose.

4. **Reticle cross-line centering:** Normally this adjustment will only be done in the NGS Instrumentation and Equipment Section, which has the necessary equipment for this task. For general information, the test for cross-line eccentricity is accomplished by centering the reticle cross-line on a well defined object such as a collimator or theodolite focused at infinity and rotating the eyepiece through a half circle. During this rotation, the target should remain centered on the cross-line; if this does not happen, then an adjustment is made using the four capstan screws located on the draw tube collar.

5. **Horizontal collimation adjustment:** The center fixed line is set in the line of collimation by the customary method of first making direct and reverse pointings on a well defined distant object and then correcting for half the error (sum of D & R readings minus 360). The axial mirror, located at the intersection of the telescope and horizontal axes, is adjusted using the two opposing capstan screws. Access to the mirror is obtained by removing the cover plate attached by two milled screws. No adjustment is necessary if the error is 5 arc-seconds or less.

6. **Zenith point adjustment:** The zenith point is the corrected reading of the vertical circle when the line-of-sight of the telescope stands vertically. If the zenith point error (the vertical collimation) is greater than five arc-seconds, an adjustment is made in the following manner: The zenith distance of a distant-fixed object is observed in both circle right and circle left positions and the mean zenith distance computed. The index (Sterneck) level is centered for the two measurements. Next, the mean zenith distance is set on the reading micrometer and then coincidence of the vertical circle graduations is effected by means of the vertical circle fine-adjustment screw. Finally the level bubble is centered in the vial using the level adjusting capstan screw located at the base of the level fixture.

7. **Setting circle adjustment:** This adjustment should be made, if necessary, immediately after the zenith point adjustment, utilizing the vertical circle. Set the vertical circle to read some arbitrary value, preferably an even degree. Bring the setting circle to the same zenith reading as the vertical circle and then adjust the setting circle level bubble to the center of the vial. This completes the adjustment.

8. **Horizontal axis adjustment:** The horizontal axis must be perpendicular to the vertical (standing) axis. One bearing support (ocular side) is adjustable in height for achieving

this objective. With the alidade firmly clamped, the inclination of the horizontal axis is measured by reversing the hanging level. If the inclination is within two level vial graduations, no adjustment is necessary.

9. **Hanging level adjustment:** If the hanging level is not parallel with the horizontal axis, the level is said to have "wind." Wind falsifies the inclination correction and therefore must be removed. To test for wind, a cord is firmly attached to the level housing and the level assembly is slowly raised from the normal at-rest position. If the level bubble moves in excess of two divisions when the level is raised, an adjustment is required. The two laterally opposing capstan screws located at one end of the level assembly are used for this purpose.

10. **Reticle adjustment:** The three center most lines (C1, C2, C3, fig. 2.5.3-1) define two paths an equatorial star will follow if the reticle is properly adjusted. If an equatorial star does not move parallel to these lines as it crosses the field-of-view, an adjustment is made by means of the small capstan screw and the draw tube locking clamp.

11. **Tracking micrometer adjustment:** When the movable (tracking) line is in coincidence with one of the fixed reticle lines, the micrometer drum should read zero, and the zero reference strip on the contact drum should just touch the spring loaded contact point. These adjustments, if required, are best made with the eyepiece micrometer removed from the telescope. To adjust the contact drum, first remove the round nut which secures the measuring drum using the spanner wrench from the tool box. Next the protective cover is opened and the small screw, located between the drum and the casing, is loosened by half a turn. With the movable line still in coincidence with the fixed (5th or 15th) line, the contact drum is rotated to the proper position and the screw tightened. The measuring drum is then set to read zero and the retaining nut is replaced.

CAUTION: Excessive force must never be used in making any instrument adjustment. Screws should be tightened only to the point where moderate resistance is encountered; otherwise stresses are induced or, even worse, damage to the instrument may result.

2.5.4.3 Determination of Instrument Constants.

The following procedures are used to determine instrument constants.

1. **Determination of equatorial value of the micrometer:** The approximate equatorial value of one revolution of the Wild T4 micrometer screw is 10.2 seconds of time. For both latitude and longitude observations it is not necessary to know this value more accurately because it is not used in the computations. A more precise value required for some special purpose may be obtained directly by a linear fit of the longitude observations using the method of least squares.

2. **Determination of mean width of contact strips:** The contact strips and the associated contact point have a physical width which must be taken into account when reducing the longitude observations. The total effective width is understood to be the combined surface width of point

and strip. It is further assumed that electrical contact is always made at the same place on the strip, independently of turning speed. The measurements for the determination of the contact strip widths are then made as follows: An ohmmeter is first attached to the outer two poles of the three-poled socket of the eyepiece micrometer. The ohmmeter function switch should be set to the highest resistance range available. (*NEVER USE EXTERNAL BATTERIES AND A VOLTMETER FOR THIS PURPOSE.*) The micrometer screw is turned very slowly and is stopped at the instant that the meter needle deflects toward the low (zero) end of the scale. The micrometer drum is then read and recorded. Continue turning the micrometer screw in the same direction and again stop at the instant that the meter needle deflects toward the high (infinity) end of the scale. The micrometer drum is again read and recorded. The difference between these two readings gives the total width of the contact strip in terms of divisions of the micrometer drum. This is repeated by always turning the screw in the same direction for all ten strips, and constitutes one determination. The two identification strips are not included in the measurements. The mean of 10 such determinations will define the adopted mean strip width. It should be noted that this prescribed method for determining the width of the contact strips supersedes the method outlined for the Bamberg transit, given in Coast and Geodetic Survey *Special Publication 237*, Manual of Geodetic Astronomy.

3. **Determination of lost motion of the micrometer screw:** A screw, such as used in the Wild T4 micrometer, has a certain amount of play when the direction of screw travel is reversed. Ideally, this lost motion should be measured at tracking speeds normally obtained in the stellar observations. This requires elaborate equipment not usually available in the field; therefore, a simpler method of determining the so-called static lost motion is employed. If the true lost motion is relatively small, then the static lost motion should provide a reasonable approximation of the desired quantity.

The lost motion is determined at three different parts of the screw for each of three different zenith distance settings. Measurements will be made at the fifth, tenth, and fifteenth line for zenith settings of 0, 45, and 315 degrees. The lost motion is measured in terms of the micrometer drum graduations by first bringing the movable line down (fig. 2.5.3-1) until centered between the double fixed lines. The micrometer is read and recorded, and after the movable line has been moved (down) past the the fixed lines the screw motion is reversed and coincidence is made from the opposite (up) direction. The micrometer is again read and recorded, and the difference between these two readings in the sense "down minus up" is the lost motion. Ten determinations of lost motion for each of the three fixed lines should be made at each zenith distance setting.

2.5.4.4 Determination of Level Value

The angular value of one division of the theodolite level vials should be determined by the Instrumentation and

Equipment Branch as part of the annual equipment maintenance program. These determinations are made under controlled environmental conditions using a precision level trier. For a full discussion of level trier determinations, see *Special Publication 237* (p. 23).

Field determinations of the level vials are currently restricted to the Sterneck level only. These determinations are made nightly, either immediately before or immediately after the latitude observations. Figure 2.5.4-1 shows the proper arrangement of the field determinations. Figure 2.5.4-2 shows the method of recording the level bubble position and the corresponding vertical circle reading. Temperature and barometric pressure must be recorded during the time of the determinations. Computations for the level value need not be made in the field.

2.5.5 Observing Lists

2.5.5.1 Latitude Star List

Generally, the Astronomy and Space Geodesy Section provides a computer-generated star list from which suitable stars can be selected. The field party should request needed lists no later than 3 weeks prior to their expected use. The request, in the form of a telephone call, should include the station name, approximate latitude, date of planned site occupation, and length of list in hours. Normally a 6- to 8-hour list is adequate.

Figure 2.5.5-1 is a sample list, similar to that used for field observations. The stars are grouped in pairs, giving the FK4 star numbers, magnitudes, times of local transit, direction of star (north or south) and eyepiece (east or west), circle settings for both ocular positions, and the difference in declinations of the star pair.

As seen in the sample list, a particular star may be paired with more than one other star. Caution must be used to ensure that all pairs selected for observation are unique. Since each pair of stars will not generally follow one after the other in time, the notekeeper should use some means of identifying the stars so that they may be quickly found.

2.5.5.2 Longitude Star List

These lists are generally compiled by the field party in a form similar to figure 2.5.5-2. Columns 1 through 4 contain information taken directly from the *Apparent Places of Fundamental Stars*. Columns 5 and 6 contain the zenith distance and *A* factor, respectively.

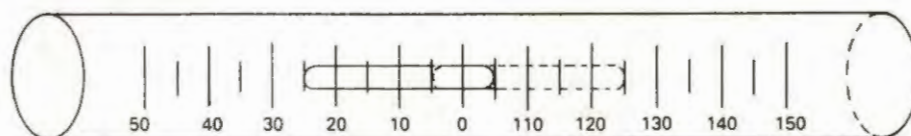
2.5.6 Observing Procedures

2.5.6.1 General

The quality of astronomic observations depends on many factors, most of them controllable by the observer. Data of the highest quality can be obtained only by taking all precautions needed to ensure that the instrument is correctly adjusted and firmly supported for maximum stability, and by following correct observing procedures. The observer's physical and mental attributes are equally important in maintaining the high level of concentration and dexterity required for the observations.

2.5.6.2 Equipment Setup

The equipment should be removed from the vehicle and the transport boxes opened upon arrival at the station site. This will allow adequate time for the equipment to adjust to ambient temperature before beginning the observations.



Arrangement of Level Vial Determinations

Bubble Moves from Left to Right		Bubble Moves from Right to Left	
Read (div)	Read (div)	Read (div)	Read (div)
(Group 1)		(Group 2)	
25.0 ± 1	105.0 ± 1	125.0 ± 1	05.0 ± 1
20.0 ± 1	110.0 ± 1	120.0 ± 1	10.0 ± 1
15.0 ± 1	115.0 ± 1	115.0 ± 1	15.0 ± 1
10.0 ± 1	120.0 ± 1	110.0 ± 1	20.0 ± 1
05.0 ± 1	125.0 ± 1	105.0 ± 1	25.0 ± 1
(Group 3)		(Group 4)	
22.5 ± 1	107.5 ± 1	122.5 ± 1	07.5 ± 1
17.5 ± 1	112.5 ± 1	117.5 ± 1	12.5 ± 1
12.5 ± 1	117.5 ± 1	112.5 ± 1	17.5 ± 1
07.5 ± 1	122.5 ± 1	107.5 ± 1	22.5 ± 1

Figure 2.5.4-1.—Collimation level as viewed from instrument eyepiece. (Tabular data show the proper arrangement of the field determination)

DETERMINATION OF LEVEL VALUE WITH VERTICAL CIRCLE
(NOTE: INITIAL BUBBLE LENGTH SHOULD BE APPROXIMATELY 30 DIVISIONS)

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

STATION NAME

OBS.

REC.

INST. TYPE & S/N

TEMP (1ST)

PRESS (1ST)

TEMP (2ND)

PRESS (2ND)

LOCAL DATE

M	D	Y

LEVEL READINGS

LEFT

RIGHT

CIRCLE READS

MIC (1)

MIC (2)

2	3	4	5	7	8	9	10	11	13	14	15	16	18	19	20	21	23	24	25	26	27	28
---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Figure 2.5.4-2.—Form used to record the level bubble position

SALVO 1933				35. 32.		19.30. 0.		7.30. 0.		10/25/82	
TIME WINDOW IS				60. MINUTES		DEC WINDOW IS		120.0 MINUTES		T-4	
STAR NO	MAGN.	R.A.		DIR	CIRC	DIR	CIRC	DELTA DEC(N-S)			
711	4.25	18	54	45.32	NW 351 36	NE	8 23	15.3			
1498	5.46	19	5	52.40	SE 353 3	SW	6 56	0.0			
711	4.25	18	54	45.32	NW 351 36	NE	8 23	16.0			
732	3.24	19	29	57.23	SE 352 23	SW	7 36	0.0			
711	4.25	18	54	45.32	NW 351 36	NE	8 23	18.2			
1515	5.45	19	42	55.43	SE 350 11	SW	9 48	0.0			
713	3.30	18	58	13.86	SE 357 7	SW	2 52	-5.4			
724	4.46	19	15	42.41	NW 357 26	NE	2 33	0.0			
713	3.30	18	58	13.86	SE 357 7	SW	2 52	-4.6			
740	5.02	19	43	35.38	NW 358 13	NE	1 46	0.0			
712	4.21	18	58	45.53	SE 339 30	SW	20 29	-42.9			
1507	6.46	19	25	26.04	NW 337 32	NE	22 27	0.0			
716	3.02	19	4	32.12	SE 338 18	SW	21 41	-44.2			
1507	6.46	19	25	26.04	NW 337 32	NE	22 27	0.0			
719	5.13	19	6	37.32	NW 359 27	NE	0 32	1.7			
1510	4.85	19	31	3.84	SE 358 52	SW	1 7	0.0			
719	5.13	19	6	37.32	NW 359 27	NE	0 32	1.0			
1521	4.03	19	55	35.50	SE 359 29	SW	0 30	0.0			
723	3.24	19	12	33.09	NW 327 54	NE	32 5	64.6			
730	3.44	19	24	32.34	SE 327 32	SW	32 27	0.0			
724	4.46	19	15	42.41	NW 357 26	NE	2 33	3.7			
1510	4.85	19	31	3.84	SE 358 52	SW	1 7	0.0			
725	5.14	19	16	55.40	SE 336 1	SW	23 58	-46.4			
1507	6.46	19	25	26.04	NW 337 32	NE	22 27	0.0			
726	3.98	19	16	39.73	NW 342 12	NE	17 47	35.9			
1513	4.45	19	40	11.66	SE 341 53	SW	18 6	0.0			

Figure 2.5.5-1.—Example of computer-generated latitude star list

After selecting the instrument site (section 2.5.2.2), the adjustable aluminum tripod is temporarily positioned over the mark with the flat side north. After marking the location of the tripod legs, remove the tripod and dig three holes approximately 6 to 12 inches deep (the depth depends on soil conditions), and approximately 10 to 12 inches in diameter. If spiked metal plates are used, they are to be firmly implanted in the holes, using a heavy maul; otherwise, a wet mix of plaster of paris is used to provide the necessary tripod base by filling each hole with a minimum of 4 inches of plaster. The tripod is then repositioned over the mark within 1 centimeter or less. The tripod legs are bonded

to the bases by pouring liberal amounts of plaster around each leg. If a plaster base is used, allow adequate time for curing before the final positioning of the tripod.

The weight of an observer moving about the instrument can seriously affect the stability of the instrument; therefore, duckboards must be used whenever possible to minimize this effect. Generally three boards, capable of safely supporting 250 pounds, are used in a triangular pattern around the instrument tripod. Three cross beams, approximately 3 to 4 feet in length with 4-inch square blocks attached at each end are used to support the duckboards.

$$A = \sin \phi - \tan \delta \cos \phi$$

STATION: MOBILAS 7086

 $\phi = 30^{\circ} 40' 36.74$ $\sin \phi = 0.5102$ $\cos \phi = 0.8601$

STAR #	MAG	R.A.			δ DEC.			Z.D.	A
		h	m	s	o	i	n		
1141	6.0	5	08	37	28	00	31	S02 40	+ .053
192	4.8	5	12	12	38	27	52	N07 47	- .173
195	3.7	5	16	44	-6	51	47	S37 32	+ .614
1145	4.8	5	17	52	40	05	04	N09 24	- .214
201	1.7	5	24	10	6	29	04	S24 20	+ .415
1148	5.3	5	26	07	17	56	52	S12 43	+ .232
1150	6.5	5	30	01	57	12	36	N26 32	- .825
1151	4.9	5	31	33	32	10	48	N01 30	- .031
208	4.5	5	33	50	9	28	42	S21 12	+ .367
211	3.0	5	36	34	21	07	57	S09 33	+ .178
216	5.5	5	44	30	49	49	11	N19 09	- .508
218	5.5	5	46	23	17	43	24	S12 57	+ .235
221	4.2	5	50	14	39	08	40	N08 28	- .190
1158	4.5	5	52	12	27	36	33	S03 04	+ .060
1161	5.2	5	57	54	0	33	08	S30 07	+ .502
225	3.9	5	58	03	54	17	05	N23 36	- .686
227	2.1	5	58	12	44	56	49	N14 16	- .348
1162	6.8	5	59	03	33	08	12	N02 28	- .051
1163	4.3	6	03	01	23	15	56	S07 25	+ .140
230	5.7	6	04	01	4	09	38	S26 31	+ .448

Figure 2.5.5-2.—Example of longitude observing list as compiled in the field from *Apparent Places of Fundamental Stars*

After setting up the instrument and making the necessary electrical connections, all circuits should be checked for proper operation. The required theodolite adjustments (section 2.5.4.2) are checked and corrected as necessary. Make sure all bearing surfaces are clean and the oil film removed. Attach the hanging level so that it is centered on the telescope axis and is positioned to the observer's left when facing the micrometer eyepiece. The Sterneck level assembly is mounted firmly by hand tightening the two captured milled screws. The high numbered graduations on the vial should be to the observer's right when facing the micrometer eyepiece.

2.5.6.3 Setting the Chronometer

There are two timing systems required for the proper operation of the astronomic party: a standard mechanical sidereal chronometer for providing the approximate times of local stellar transits and a Datametrics time printer system for the precise timing of the latitude and longitude observations.

The mechanical chronometer is set by the customary method of computing the local sidereal time for a selected instant of mean solar time and then setting the chronometer to this sidereal value.

The following example gives the steps for computing the local sidereal time (LST) given the date and the observer's longitude. If necessary, the longitude scaled from a suitable map will suffice for this purpose.

It is desired to compute the LST corresponding to a UTC of 02^h 33^m 00^s on October 2, 1982, at 77° 32' 41" west longitude.

02 ^h	33 ^m	00 ^s	UTC
		25.134	Cor., sol. to sid. time (APFS, table III).
00	41	32.315	Sid. time at 0 hr U.T. (APFS, table II)
03	14	57.	Greenwich sid. time (round to second)
05	10	11.	longitude in time (round to second)
22	04	46.	LST

Although it is not essential to the accuracy of the observations, it is recommended that the Datametrics time printer system be set (or synchronized) to the radio time signal using the following procedures:

1. Position power switch S1 to +24 VDC and the power switch S2 to ON. Power lamp I1 should be on. If it is not, check cables for proper connections.

2. Position display switch S10 to ON and preset the desired UTC hours, minutes, and seconds on the display using switches S5 thru S9. Seconds are set to read zero.

3. Position control switch S3 to OFF.

4. Connect the radio cable to input plug J11.

5. Set switch S11 to WWV SYNC position. TICK lamp will flash on receipt of 1-second time pulses.

6. While listening to the time announcements, turn control switch S3 to EXT during the last (59th) second preceding the preset time. On receipt of the next 1-second pulse, the time system will automatically start.

2.5.6.4 Placing Instrument in the Meridian

There are two general methods for placing the instrument in the local meridian with an accuracy of 1 second of time or better. The most expedient method utilizes the pole star tables in the *Astronomical Almanac* (figure 2.5.6-1) prepared by the U.S. Naval Observatory, Washington, D.C. These tables give data for obtaining the altitude and azimuth of Polaris for all hour-angles and northern latitudes. The azimuth is measured from north, positive to the east and negative to the west. The six tabulated quantities, a_0 , a_1 , a_2 , referring to the correction to altitude, and b_0 , b_1 , b_2 , to the azimuth, are given to a precision of 0.1 arc-minute. The altitude and azimuth are obtained by the following expressions using local sidereal time, latitude, and month of year in the same vertical column of the appropriate pole star table.

$$\text{Altitude} = \text{latitude} - (a_0 + a_1 + a_2)$$

$$\text{Azimuth} = (b_0 + b_1 + b_2) \secant(\text{latitude})$$

The instrument is first accurately leveled and adjusted for collimation. If the pole star cannot be identified by the naked eye, then it will be necessary to search for it with the aid of the instrument. In this case compute the star's altitude from the tables and obtain the zenith distance by subtracting the altitude from 90 degrees. Set the zenith distance in the setting circle and center the setting circle level by elevating or depressing the telescope. Clamp the telescope after centering the level bubble and scan the northern sky by slowly rotating the theodolite until the star is located. Bisect the star, recording the local sidereal time at the instant of bisection and compute the azimuth from the pole star tables. Without moving the telescope, set the computed azimuth on the horizontal circle and then rotate the instrument until the horizontal circle reads zero. The instrument should be in the meridian within 15 arc-seconds. This is verified by again pointing on the pole star, this time measuring the horizontal direction with the theodolite

and comparing the measured and computed values. Repeat, if necessary, to achieve the 15 arc-second requirement.

The following procedure should be used to place the instrument in the meridian when the pole star cannot be utilized. Select from the *APFS* catalog a bright star, preferably 2.0 magnitude or less, that is near upper transit and record the mean time of transit. The tabulated mean place in right ascension is adequate for this purpose. Locate the star in the telescope 1 or 2 minutes prior to the time of local transit. Keep the star bisected with the cross-lines until the instant of transit by rotating the theodolite in azimuth with the slow motion tangent screw. The instrument should be in the meridian within an accuracy of 5 to 10 seconds of time. The final placement of the instrument in the meridian is made as follows: Select two stars, with azimuth factors of 0.5 or greater, one north and one south of the zenith, that will transit 1 to 5 minutes apart. Record the time of transit for each star. Write the following equation for each star:

$$T + Aa - (\alpha - t) = 0,$$

where

T = chronometer correction,

A = azimuth factor,

a = azimuth of collimation axis in seconds of time,

α = right ascension of star

t = chronometer time of transit.

By subtracting one equation from the other, T cancels out and the azimuth $[a]$ may be computed directly. If the computed value of $[a]$ is positive, the telescope pointing north is too far to the west and if negative, too far to the east. Follow the same circle setting and instrument rotation procedures given for the pole star method. Repeat the observations until an azimuth of 1 second of time or less has been obtained.

2.5.6.5 Radio-Chronometer Comparisons

Radio transmissions from the National Bureau of Standards' stations WWV and WWVH are the most often utilized for these comparisons. Time signals are broadcast on standard frequencies of 2.5, 5, 10, 15, 20, and 25 MHz by WWV and 2.5, 5, 10, and 15 MHz by WWVH. These broadcasts are continuous through 24 hours, except for short silent periods. The silent period for WWV begins at 45 minutes 15 seconds after each hour and ends at 49 minutes 15 seconds; that of WWVH begins at 15 minutes and ends at 19 minutes after the hour. Other radio stations that broadcast coordinated standard time, such as CHU in Canada, may be used if conditions warrant.

The Datametrics chronometer comparison is made by tuning the radio receiver to one of the above frequencies, adjusting the volume to the proper level and depressing the PRINT WWV switch S15. Fifteen or twenty usable 1-second time records should be obtained, beginning a few seconds before the 60th 1-second pulse. Upon receipt of the 60th pulse, mark the printed chronometer time by brack-

B56

POLE STAR TABLE, 1981

L.S.T.	0 ^h		1 ^h		2 ^h		3 ^h		4 ^h		5 ^h	
	a_0	b_0	a_0	b_0	a_0	b_0	a_0	b_0	a_0	b_0	a_0	b_0
m												
0	-41.1	+27.2	-46.8	+15.5	-49.1	+2.6	-48.1	-10.4	-43.8	-22.7	-36.4	-33.3
3	41.5	26.6	47.0	14.8	49.2	2.0	48.0	11.0	43.5	23.3	35.9	33.8
6	41.8	26.1	47.1	14.2	49.2	1.3	47.8	11.7	43.1	23.8	35.5	34.3
9	42.2	25.5	47.3	13.6	49.2	0.7	47.7	12.3	42.8	24.4	35.0	34.8
12	42.5	25.0	47.5	12.9	49.2	0.0	47.5	12.9	42.5	25.0	34.6	35.2
15	-42.8	+24.4	-47.7	+12.3	-49.2	-0.7	-47.3	-13.6	-42.2	-25.5	-34.1	-35.7
18	43.1	23.8	47.8	11.7	49.2	1.3	47.1	14.2	41.8	26.1	33.6	36.1
21	43.5	23.3	48.0	11.0	49.2	2.0	47.0	14.8	41.5	26.6	33.2	36.5
24	43.8	22.7	48.1	10.4	49.1	2.6	46.8	15.5	41.1	27.2	32.7	37.0
27	44.0	22.1	48.2	9.8	49.1	3.3	46.5	16.1	40.8	27.7	32.2	37.4
30	-44.3	+21.5	-48.4	+9.1	-49.0	-3.9	-46.3	-16.7	-40.4	-28.3	-31.7	-37.8
33	44.6	20.9	48.5	8.5	49.0	4.6	46.1	17.3	40.0	28.8	31.2	38.2
36	44.9	20.3	48.6	7.8	48.9	5.2	45.9	17.9	39.7	29.3	30.7	38.6
39	45.1	19.7	48.7	7.2	48.9	5.9	45.6	18.5	39.3	29.8	30.2	39.0
42	45.4	19.1	48.8	6.5	48.8	6.5	45.4	19.1	38.9	30.4	29.7	39.4
45	-45.6	+18.5	-48.9	+5.9	-48.7	-7.2	-45.1	-19.7	-38.5	-30.9	-29.2	-39.8
48	45.9	17.9	48.9	5.2	48.6	7.8	44.9	20.3	38.1	31.4	28.6	40.2
51	46.1	17.3	49.0	4.6	48.5	8.5	44.6	20.9	37.7	31.9	28.1	40.6
54	46.3	16.7	49.0	3.9	48.4	9.1	44.3	21.5	37.2	32.4	27.6	40.9
57	46.5	16.1	49.1	3.3	48.2	9.8	44.0	22.1	36.8	32.9	27.0	41.3
60	-46.8	+15.5	-49.1	+2.6	-48.1	-10.4	-43.8	-22.7	-36.4	-33.3	-26.5	-41.6
Lat.	a_1	b_1	a_1	b_1	a_1	b_1	a_1	b_1	a_1	b_1	a_1	b_1
0	-1	-3	0	-2	0	+1	0	+3	-1	-4	-2	-4
10	-1	-3	0	-1	0	+1	0	+2	-1	-3	-2	-4
20	-1	-2	0	-1	0	0	0	+2	-1	-3	-2	-3
30	0	-2	0	-1	0	0	0	+1	-1	-2	-1	-2
40	0	-1	0	0	0	0	0	-1	0	-1	-1	-1
45	0	-1	0	0	0	0	0	0	0	-1	0	+1
50	0	0	0	0	0	0	0	0	0	0	0	0
55	0	+1	0	0	0	0	0	-1	0	-1	0	-1
60	0	+1	0	+1	0	0	0	-1	+1	-2	-1	-2
62	0	+2	0	+1	0	0	0	-2	+1	-2	-1	-2
64	+1	+2	0	+1	0	0	0	-2	-1	-3	-2	-3
66	+1	+3	0	+1	0	-1	0	-2	-1	-3	-2	-4
Month	a_2	b_2	a_2	b_2	a_2	b_2	a_2	b_2	a_2	b_2	a_2	b_2
Jan.	+2	+2	+1	+2	+1	+3	0	+3	-1	-3	-1	-2
Feb.	+1	0	+1	+1	+1	+1	+1	+1	0	-1	0	-1
Mar.	0	0	0	0	0	0	0	0	0	0	0	0
Apr.	-2	0	-1	-1	-1	-1	-1	-1	-1	-1	0	-2
May	-3	+1	-3	0	-3	-1	-2	-1	-2	-2	-1	-2
June	-3	+2	-4	+1	-4	0	-4	-1	-3	-2	-3	-3
July	-3	+4	-4	+3	-4	+2	-5	+1	-5	-1	-4	-2
Aug.	-2	+5	-3	+4	-4	+3	-5	+2	-5	-1	-5	0
Sept.	0	+6	-1	+5	-3	+5	-4	+4	-5	-3	-5	+2
Oct.	+2	+6	0	+6	-1	+6	-3	+5	-4	-5	-5	+3
Nov.	+4	+5	+2	+6	+1	+6	-1	+6	-2	-6	-4	+5
Dec.	+5	+4	+4	+5	+2	+6	+1	+6	-1	-6	-2	+6

Latitude = Corrected observed altitude of *Polaris* + a_0 + a_1 + a_2 Azimuth of *Polaris* = $(b_0 + b_1 + b_2) \sec(\text{latitude})$ Figure 2.5.6-1.—A sample pole star table taken from the *Astronomical Almanac*, published by the U.S. Naval Observatory

eting the seconds and note on the record the UTC time as given by voice announcement.

Figure 2.5.6-2 shows a sample record of a radio-chronometer comparison. The chronometer time, corresponding to the announced radio time, is obtained by simply averaging the fractional part of the seconds. Any recorded extraneous signals, such as static, should be lined through to minimize the chance of inadvertently using them in the averaging process.

2.5.6.6 Directions for Observing Latitude

After the necessary theodolite adjustments have been made and the theodolite placed in the meridian, a radio-

chronometer comparison is made. Ten 1-second print records are sufficient.

The zenith distance for the first star to be observed is set in the setting circle and the telescope tilted until the setting circle level bubble is centered. The telescope is clamped and then the setting circle is reset to locate the star after theodolite reversal. The movable line is positioned at the sixth or fourteenth turn, depending on the position of the eyepiece. As the star approaches the movable line, carefully bisect the star with the fixed vertical line, using the vertical slow motion screw. As the star crosses the movable line, record the time of crossing on the time printer system by depressing the hand held transit switch.

Read the Sterneck level, left and right ends of the bubble as seen from the micrometer eyepiece, and then read the vertical circle. The theodolite is then reversed precisely 180 degrees and the observational sequence repeated on the same star after meridian transit.

These observational procedures are repeated until the required number of stars have been observed.

The position of the movable line must never be changed during the observations on a particular star.

2.5.6.7 Directions for Observing Longitude

Before beginning the observation program, check to see that all electrical connections are functioning properly. Check the micrometer transit circuit for proper operation by turning the tracking wheel through a partial revolution. If the circuit is functioning correctly, a series of time records will be printed by the Datametrics time printer. Make sure synchronization switch S11 is in the DC position for this purpose. Check the theodolite for level and verify that all adjustments are within acceptable limits.

Begin the observation program by making a radio-chronometer comparison. Twenty usable 1-second print records should be obtained.

The zenith distance, or the explement of the zenith distance, depending on the eyepiece position, is set on the setting circle and the telescope is tilted until the setting circle level bubble is centered. The telescope is clamped in position and the zenith setting, opposite to the first setting, is set on the setting circle so that the setting is ready for the reversed position of the theodolite. The movable line should be moved to a position slightly below the fifteenth line for eyepiece west, or slightly above the fifth line for eyepiece east. The star's image will enter the field of view from the apparent bottom for eyepiece west and from the apparent top for eyepiece east. As the star enters the field of view, approximately 1.5 minutes before upper transit for an equatorial star, position the image near the center fixed line using the telescope's vertical slow motion screw. When the star reaches the movable line, begin tracking the star, always bisecting the image, through three complete turns of the micrometer. The hanging level is then read, west end of the bubble first and then the east end. The theodolite is reversed 180 degrees. When the star reaches the movable line it is tracked through the same three turns in reverse order. The hanging level is again read as before. This pro-

Star	day	hr	min	seconds
STAR NO.	DAY	HR.	MIN.	SEC.
0458	119	02	53	10.953
0458	119	02	53	10.407
0458	119	02	53	09.917
0458	119	02	53	09.559
0458	119	02	53	09.001
0458	119	02	53	08.001
0458	119	02	53	07.001
0458	119	02	53	06.001
0458	119	02	53	05.001
0458	119	02	53	04.001
0458	119	02	53	03.001
0458	119	02	53	00.777
0458	119	02	53	00.389
0458	119	02	53	(00.001) ² ₅₃
0458	119	02	52	58.000
0458	119	02	52	57.000
0458	119	02	52	56.001
0458	119	02	52	55.393
0458	119	02	52	55.000
0458	119	02	52	54.001
0458	119	02	52	53.001
0458	119	02	52	52.001
0458	119	02	52	50.999
0458	119	02	52	49.744
0458	119	02	52	49.000
0458	119	02	52	48.000
0458	119	02	52	47.000
0458	119	02	52	46.000
0458	119	02	52	45.000
0458	119	02	52	44.000
0458	119	02	52	43.000
0458	119	02	52	42.000

(WVV) Radio Time 02 53 00.

mean chron. time 02 53 00.000⁵

Figure 2.5.6-2.—Sample record of radio-chronometer comparison

cess is repeated until the required number of star sets have been observed.

At the end of each set of observations, a radio-chronometer comparison should be made and the theodolite leveled, if necessary. Never relevel the theodolite within a set of observations because this could introduce an error in the set longitude.

2.5.7 Field Records

2.5.7.1 General

Two NGS forms, figures 2.5.2-1 and 2.5.7-1, have been developed for astronomic observations, providing both an orderly arrangement for recording the observational data and a rigid structure for the expedient conversion of these data to machine readable form for processing.

Data fields are delineated by heavy lines and each field labeled for specific data entry. As a general rule, alphanumeric data, such as station name and instrument serial number, are entered left justified and those for numeric data are right justified. Left justified means that data entry must begin in the first column of the designated field and right justified means that data entry must end in the last column of the designated field. The use of leading zeros simplifies entry of right justified data. For example, a zenith distance of $6^{\circ} 4' 5''.2$ would be recorded as 006° 04' 05''.2, which fills all columns of the field and automatically provides right justification.

The importance of accurate and legible data records cannot be overemphasized. Sloppy and poorly formed numbers can render the most precise observations useless. All recording should be done in ink, preferably using a fine-line ball point pen. As the observer reads the data, the notekeeper should record this information and then read the recorded values back to the observer for verification. Errors are corrected by lightly striking through the erroneous entry and entering the correct value directly above the one marked through. Even though the recording forms are essentially self-explanatory, the following comments should provide additional clarity.

It will be necessary to abbreviate the station name if it is longer than 25 characters. The accession number and level value fields, which are not usually available to the field party, should be left blank. The space for recording the eccentric measurements should never be left blank. (Enter zeros if there is no eccentricity.) Be sure that correct unit codes are assigned to the temperature and pressure readings. A "C" or an "F" for Centigrade or Fahrenheit and an "I" or an "M" for inches or millimeters. Remarks concerning any unusual conditions should be made at the bottom of the forms.

2.5.8 Computations

2.5.8.1 General

The computational requirements for the astronomic party have been greatly reduced with the advent of high speed computers, improved timing systems, and rapid communications between office and field.

2.5.8.2 Latitude Computations

The only computations required in the field for latitude determinations are those discussed in this chapter.

2.5.8.3 Longitude Computations

In addition to the longitude computations discussed in this chapter, the mean transit times of the stellar observations must be computed and entered on the longitude record and coding form (fig. 2.5.2-1).

The Datametrics chronometer records are first marked for each star as illustrated in figure 2.5.8-1. Note that the "before transit" times are numbered in ascending order and the "after transit" times are numbered in descending order. This numbering sequence should be followed without exception.

Referring to the chronometer times as "breaks," select 21 breaks before transit and 21 corresponding breaks after transit; then compute the mean time of transit and enter this on the longitude form. In practice it is easier to compute separate means of the "before" and "after" transit times and then divide the sum of the two means by 2.

All computations must be independently checked by a different party member.

2.5.9 Data, Records, Reports

2.5.9.1 General

Routine reports that are required of all field parties are discussed in chapter 1.6. General procedures covering data transmittals are discussed in chapter 1.7.

2.5.9.2 Station Descriptions

A recovery description (NOAA form 75-82) is required for each station visited by the astronomic party. The condition of the station and reference marks should be noted, and any other information pertinent to the preservation of the monuments should be recorded.

2.5.9.3 Data

All data relative to the site observations should be forwarded to headquarters as soon as possible. The station name and date of occupation must be written on each record submitted. A rubbing of the station disk should be made on bond paper and submitted with the data.

2.5.9.4 Monthly Report and Journal

The Monthly Report and Journal (NOAA form 76-92) must be completed and received by N/CG161 no later than the 10th of each month. The report should give the number of stations observed and the number of days lost due to travel time, bad weather, illness, and other reasons.

2.5.9.5 Projects Report

An annual project report is submitted at the end of each fiscal year by the astronomic party to N/CG161. See *Special Publication 247* for details. Figure 2.3.11-1 shows an example of a project report cover.

1258	121	00	31	17	.674
1258	121	00	31	16	.846 TD
1258	121	00	31	16	.32830
1258	121	00	31	15	.943 TD
1258	121	00	31	15	.28629
1258	121	00	31	14	.04428
1258	121	00	31	12	.83327
1258	121	00	31	11	.68826
1258	121	00	31	10	.41725
1258	121	00	31	09	.25324
1258	121	00	31	08	.00323
1258	121	00	31	06	.76822
1258	121	00	31	05	.52021
1258	121	00	31	04	.734 TD
1258	121	00	31	04	.40620
1258	121	00	31	03	.952 TD
1258	121	00	31	03	.21119
1258	121	00	31	01	.96518
1258	121	00	31	00	.81717
1258	121	00	30	59	.57516
1258	121	00	30	58	.44315
1258	121	00	30	57	.19514
1258	121	00	30	55	.96213
1258	121	00	30	54	.68412
1258	121	00	30	53	.55111
1258	121	00	30	52	.726 TD
1258	121	00	30	52	.35310
1258	121	00	30	51	.896 TD
1258	121	00	30	51	.1079
1258	121	00	30	49	.9528
1258	121	00	30	48	.7037
1258	121	00	30	47	.4926
1258	121	00	30	46	.3235
1258	121	00	30	45	.1394
1258	121	00	30	43	.9953
1258	121	00	30	42	.6262
1258	121	00	30	41	.4451
1258	121	00	30	40	.748 TD
1258	121	00	30	40	.2410
1258	121	00	30	39	.889 TD
1258	121	00	30	39	.054
1258	121	00	30	37	.923
1258	121	00	30	36	.670
1258	121	00	30	35	.463

MEAN TIME 00 30 57.177

TRACK IN

MEAN TIME	00	32	19.893
	00	30	57.177
ADOPTED	00	31	38.535

TRACK OUT

Figure 2.5.8-1.—Star tracking record

2.6 GRAVITY SURVEYS

NGS performs gravity surveys to aid in the computation of the undulation of the geoid and the deflection of the vertical, to maintain the vertical network, to provide space system support, to satisfy outside requests for point gravity values, and to monitor surface motion due to phenomena such as ground water withdrawal. Discrepancies caused by gravity anomalies can be minimized by using observed or interpolated gravity values.

This chapter gives the party structure, spacing requirements, instruments and equipment, observing procedures, field computations, data, records, and reports. Use of gravity data is discussed in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (revised 1980).

2.6.1 Party Structure

NGS has one gravity survey party consisting of one surveying technician. This technician is responsible for observing gravity along designated leveling lines and performing field computations on the observed data.

2.6.2 Accuracy Requirements

2.6.2.1 Gravity Base Stations

The primary purpose of a gravity base station is to provide an accurate absolute gravity reference on which to base relative regional gravity surveys.

1. **Geographic Position Accuracy.** Scale geographic positions as accurately as possible from available large-scale maps. The position should be scaled to within 180 meters (about 6 seconds) and entered on the "Bench Mark Description" (NOAA Form 76-186). Use published positions if available.

2. **Vertical Accuracy.** If published elevations are not available, scale the elevation from available maps. The elevation should be accurate to 3 meters when scaled from 7½-minute or 15-minute topographic maps.

3. **Gravity Accuracy.** All gravity base surveys must be related to the National Gravity Base Network (NGBN) or to base nets that are adjusted to the NGBN. If these specifications are not met, contact the Gravity Section, N/CG141.

a. **Ties between NGBN stations.** All ties between NGBN stations must be accurate to within ± 0.02 (1 σ) milligal (mgal) with respect to the selected NGBN stations. Make sufficient observations to establish statistically that this accuracy is obtained. NGBN base station descriptions will be supplied to the observing unit for all projects.

b. **Base Networks Established From NGBN.** Gravity base networks must be planned and observed so that all stations are accurate to within ± 0.03 (1 σ) mgal with respect to the originating NGBN bases. A gravity base network must be established before any regional gravity survey is started.

2.6.2.2 Regional Gravity Stations

Regional or anomaly gravity surveys are performed for the purpose of defining the variations of the gravity field in detail over the project area.

1. **Geographic Position accuracy.** Same as section 2.6.2-1.

2. **Vertical Accuracy.** If published elevations are not available, the scaled elevations must be accurate enough to provide a 1 mgal point-anomaly accuracy (usually ± 3 meters of elevation). All elevations must be referred to sea level. Elevations scaled from USGS 7½-minute quadrangles are acceptable.

a. For areas adjacent to the ocean that do not have adequate vertical control, a local datum may be used, provided corrections for marine tides are available.

b. Barometric leveling may be used as a last resort. Permission and instructions must be obtained from the Gravity Section, N/CG141.

3. **Gravity Accuracy.** Regional gravity stations must have an observed gravity value accurate to within ± 0.05 (1 σ) mgal with respect to the originating gravity base net. If these specifications cannot be met, contact the Gravity Section, N/CG141.

2.6.3 Instruments and Equipment

2.6.3.1 Gravity Meter

NGS uses two models of the LaCoste and Romberg gravity meter. For most gravity measurements, NGS uses a pair of Model G meters. These gravity meters read to 0.01 of a unit. For projects which require readings to 0.001 of a unit, NGS uses the Model D meter. A simplified diagram of the basic LaCoste and Romberg gravity meter is shown in figure 2.6.3-1. The gravity response system consists of a weight on the end of a horizontal beam supported by a zero-length spring. The shock-eliminating springs form a floating pivot, thus eliminating any friction in the moving system.

The lever system and measuring screw shown in figure 2.6.3-1 are accurately calibrated over their entire range.

U.S. PATENT NOS —2,293,437—2,377,889

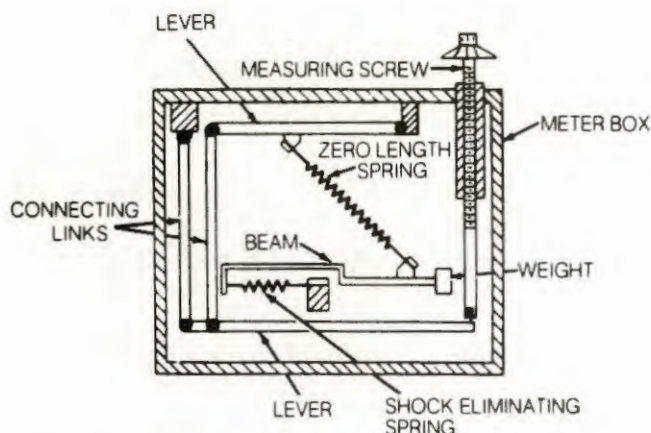


Figure 2.6.3-1.—Simplified diagram of the basic LaCoste and Romberg gravity meter

Calibration factors depend only on the quality of the measuring screw and the lever system, not upon auxiliary springs. For this reason, the calibration factors of LaCoste and Romberg meters do not change perceptibly with time. This eliminates the need for frequent checks of calibration. Figure 2.6.3-2 shows an example of the image that is viewed through the reading microscope. Project instructions will list the area or the leveling lines along which gravity must be observed. The project instructions will also give any changes to the observing procedures listed here.

Figure 2.6.3-2 shows an example of the image that is viewed through the reading microscope.

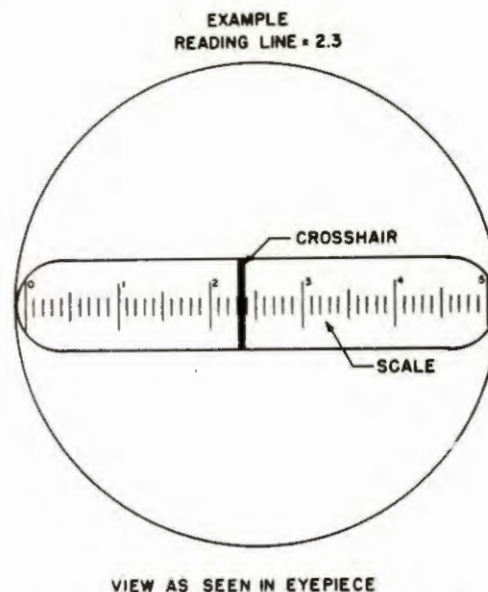


Figure 2.6.3-2.—Image as viewed through the reading microscope of the LaCoste and Romberg gravity meter

2.6.4 Gravimeter Evaluation Procedure

Once a year, in a gravimetrically stable area, perform the following tests on each gravity meter.

2.6.4.1 Determination of Meter Performance

Without changing any of the meter settings perform the following tests:

1. **Displacement sensitivity test.**
 - a. Level meter.
 - b. Unclamp beam.
 - c. Turn on reading lights.
 - d. Observe position of cross hair.
 - e. Turn dial (measuring screw) to locate upper and lower stops (or motion limits of cross hair).
 - f. Position cross hair by means of the measuring screw about one scale division above lower stop.
 - g. For a G meter, turn measuring screw dial clockwise one revolution, which is 10 units on the counter, or approximately 1 milligal. For a D meter, turn measuring screw dial clockwise 10 revolutions, which is 100 units on the counter, or approximately 1 milligal.
 - h. Observe the number of units the cross hair moves in the eyepiece. This number is the displacement sensitivity of the meter.

- i. Record the displacement sensitivity.

This test should be repeated several times for an accurate determination of the sensitivity.

2. **Cross level test.**

- a. Level meter.
- b. Unclamp beam.
- c. Turn on the reading light.
- d. Null the meter using the cross hair.
- e. Move the cross level 1 division off-level in one direction. The long level may need to be recentered.
- f. Record the eyepiece reading.
- g. Move the cross level 1 division off-level in the other direction. The long level may need to be recentered.
- h. Record the eyepiece reading. If the cross level setting is correct, the cross hair should move upscale approximately an equal amount for each tilt.

This test should be repeated several times for an accurate determination.

3. **Galvanometer zero position and sensitivity setting test.**

- a. Level meter.
- b. Unclamp beam.
- c. Turn on reading light.
- d. Null the meter using the cross hair. The galvanometer needle should now be in the center. Record the galvanometer reading.

e. Move the cross hair 1 eyepiece division. Record the galvanometer reading. The galvanometer sensitivity should be about two galvanometer divisions per one eyepiece division.

4. **Magnetic Field Effect Test.**

This test may be conducted in the field of a Helmholtz coil. If a Helmholtz is not available, this test should be made outdoors in an area free of electromagnetic fields.

- a. Orient the meter in the north direction.
- b. Level the meter carefully, null the meter, and record the reading.
- c. Change the azimuth of the meter 45 degrees clockwise.
- d. Repeat B and C eight times, closing on the north direction.

After drift has been removed from the readings, there should not be a difference in the readings at different orientations.

Repeat the test several times. A true magnetic field effect will be systematic.

5. Meter observation standard error test.

a. Observe at least one-half period of the lunar-solar gravitational attraction (about 7 hours). Observations will be made every 15 minutes in the mode in which the meter has been used, i.e., with leveling and unclamping/clamping if the meter is a field meter.

b. Reduce the observations and compute the standard error using program SENS.

The barometric pressure and temperature will be observed at the beginning and end of the test.

6. Internal mechanism standard error test.

a. Observe at least one-half period of the lunar solar gravitational attraction. Observations will be made every 15 minutes without releveing and unclamping/clamping.

b. Reduce the observations and compute the standard error using program SENS.

If the meter shows a sensitivity to its orientation in the Earth's magnetic field (test 4), it may be necessary to return the meter to the manufacturer for degaussing.

Enter results of the above tests in the meter log book.

2.6.4.2 Standardization of Meter Performance

1. *Adjust meter cross level if necessary.* If the results of the cross level test show that the cross level is not centered then:

a. Level the meter so that the cross level is off center approximately one-half of the distance in the direction which gave the lower eyepiece reading in the above experiment.

b. Using the level wrench adjust the cross level so the bubble is in the center position.

c. Repeat the cross level test to check the correctness of the adjustment.

2. Adjust meter sensitivity if necessary.

Sensitivity readings:

field meter (G meter)	10-12 EU/ 10 CU
field meter (D meter)	10-12 EU/100 CU
high sensitivity meter (D meter)	10 EU/ 50 CU

a. If the sensitivity test (section 2.6.4.1) is found to be low:

(1) Tilt gravity meter using the right hand leveling screw, so that the right end of the meter is lowered. (Bubble moves away from the eyepiece stalk.) Adjustments should be made in small increments. Usually about $\frac{1}{4}$ to $\frac{1}{2}$ bubble division is all that will be required.

(2) Adjust the long level by using the level wrench, so the bubble is in the center position.

(3) Repeat the displacement sensitivity test to determine the new sensitivity.

b. If the sensitivity is too high:

(1) Raise the right end of the meter. (Bubble moves toward eyepiece stalk.)

(2) Adjust the long level by using the level wrench, so the bubble is in the center position.

(3) Repeat the displacement sensitivity test to determine the new sensitivity.

The reading line should be checked whenever the long level (displacement sensitivity) has been adjusted.

3. Check reading line location.

a. Level the meter carefully.

b. Set the cross hair on reading line as specified for the meter.

c. Tilt the long level 1 division, keeping the cross level in the level position, first in one direction and then in the other, and record the eyepiece readings. Repeat several times to be sure reading is accurate.

d. Check the cross hair in the eyepiece; if it moves upscale approximately the same for each tilt, then the chosen reading line is correct. If the cross hair moves up scale appreciably more when the meter is tilted to lower the right end (the end with the single leveling screw), the assumed reading line is too high. If the cross hair does not go as high for this tilt, the assumed reading line is too low.

e. Check reading line; if incorrect line was chosen in step b., then the cross hair should be shifted 1 eyepiece division with the dial (either up or down, depending on the results of step d., and the tilting procedure in step c. repeated).

4. Adjust galvanometer if necessary.

a. Check the reading line; if line was redefined in item 3, then it will be necessary to align the galvanometer zero with the new reading line. This is done with a small screw driver through a hole in the top of the gravity meter.

b. Adjust galvanometer sensitivity through a hole in the top of the gravity meter. The galvanometer sensitivity should be 2 galvanometer divisions per eyepiece division.

5. Clean and lubricate leveling screws.

a. Clean leveling screws with a lint-free cloth. Lubricate with thin oil.

b. Turn the measuring screw through its entire length to assure that the screw has an even distribution of lubricants.

6. Clean optics.

Record in the meter log book any adjustments made to the meter. Give both the magnitude and direction of the adjustment along with the date.

2.6.4.3 Computation of Operational Standard Error

1. Determine new meter observation standard error (s.e.)

a. Observe two half periods of the lunar-solar gravitational attraction. Observations will be made every 15 minutes in the mode in which the meter will be used, i.e., with releveing and unclamping/clamping if the meter is a field meter.

b. Compute the drift rate and the standard error for each half period using program SENS.

c. Run an additional set if the difference is greater than 10 percent.

Acceptable s.e.:

field meter, model G	<20 μ gal
field meter, model D	<10 μ gal
high sensitivity D meter	< 5 μ gal

The barometric pressure and temperature will be observed at the beginning and end of each set of observations.

2. Enter the results of above tests and the date in the meter log book.

2.6.4.4 Meter Calibration

1. *Run the meter over the Blue Ridge Calibration Base Line (312 milligal range).*

a. A calibration run consists of beginning at the northeast end of the line (DULLES) and going to the southwest end (SKYLAND) making observations at each mark and returning to the beginning, making observations in reverse order.

b. Barometric pressure and temperature will be observed at the northeast end, at the base of the mountain, at the top of the mountain, and at the southwest end of the line.

c. If the meter is a model D, then a circular error calibration will also be done. A circular error calibration consists of three sets of observations on the milligal Calibration Base Line. The sets are taken at three segments of the measuring screw. (The reset screw is used to change position on the measuring screw).

(1) Set the gravimeter on the bottom station of the milligal range.

(2) Set the gravimeter dial units to 190.00 using the micrometer.

(3) Null the meter approximately, using the reset screw. Wait 20 minutes for spring length to stabilize.

(4) Null the meter precisely, using the micrometer.

(5) Observe and record, up and back, the 10 stations in the milligal range.

(6) Set the gravimeter dial units to 105.00 using the micrometer.

(7) Null the meter approximately, using the reset screw. Wait 20 minutes.

(8) Null the meter precisely, using the micrometer.

(9) Observe and record, up and back, the 10 stations of the milligal range.

(10) Set the gravimeter dial units to 020.00 using the micrometer.

(11) Null the meter approximately, using the reset screw. Wait 20 minutes.

(12) Null the meter precisely, using the micrometer.

(13) Observe and record, up and back, the 10 stations of the milligal range.

2. *Observe barometric pressure and temperature at the beginning and end of the calibration run.*

Enter the date of the calibration run in the meter log book along with any comments, i.e., signal quality, time since last heavy rain, etc.

2.6.4.5 Automation of Test Results

The results of the tests performed in section 2.6.4 shall be entered in the data base "meter performance file."

2.6.5 Observations

2.6.5.1 General

All gravity observations supporting the North American Vertical Datum (NAVD) releveling program must be referenced to NGBN stations or to junction sub-bases that were previously tied directly to NGBN stations.

Project instructions will specify station spacing.

Make every effort to establish the gravity interval between the base stations to an accuracy of ± 0.02 (1 σ) mgal. Take special care to (1) level the instrument, (2) record the height of the bottom of the instrument relative to the top of the bench mark with an accuracy of ± 1 cm, (3) always bring the reading line in from the same direction, and (4) minimize vibration of the instrument when it is transported in a vehicle or carried by hand.

As the observations are collected and analyzed by the Gravity Section, N/CG141, the high-gradient sections will be identified, and additional observations between specified bench marks will be assigned.

Immediately preceding or upon completion of project, an A-B-A-B direct tie (see section 2.6.5.2) is required between NGBN stations that encompass the project range. This tie will be accomplished for meter scale factor determination.

2.6.5.2 Loop Sequence

The basic design of a gravity survey is the loop. This procedure is required in order to remove gravity meter drift computationally; it also provides additional observations to recognize misreadings or tares. All observations will be carried out using two LaCoste and Romberg gravity meters. Project instructions will specify the sequence. The observational loop sequences follows:

1. **Ladder Sequence Loop.** Given base station A with a known gravity value (or a station that has been tied directly to a station with a known gravity value), and stations 1, 2, and 3 to be observed, the sequence A-1-2-3-2-1-A is preferred. This is known as the ladder sequence loop (fig. 2.6.5-1A). The ladder sequence loop is required for direct ties between base stations.

2. **Modified Ladder Sequence Loop.** Difficult field conditions encountered while base ties are being observed may require a modified ladder sequence loop. Given stations A, 1, 2, and 3 as above, the sequence A-1-2-3-1-A is executed, where at least one of the new stations is observed twice during this sequence. This loop method is permissible for all regional surveys (fig. 2.6.5-1B).

3. **Line Sequence Loop.** Often in the observing of regional surveys, it is not possible to return to the starting base. Given bases A and B with known gravity values and stations 1, 2, and 3 to be observed, the line sequence A-1-2-3-2-B may be used (fig. 2.6.5-1C). As with one modified ladder

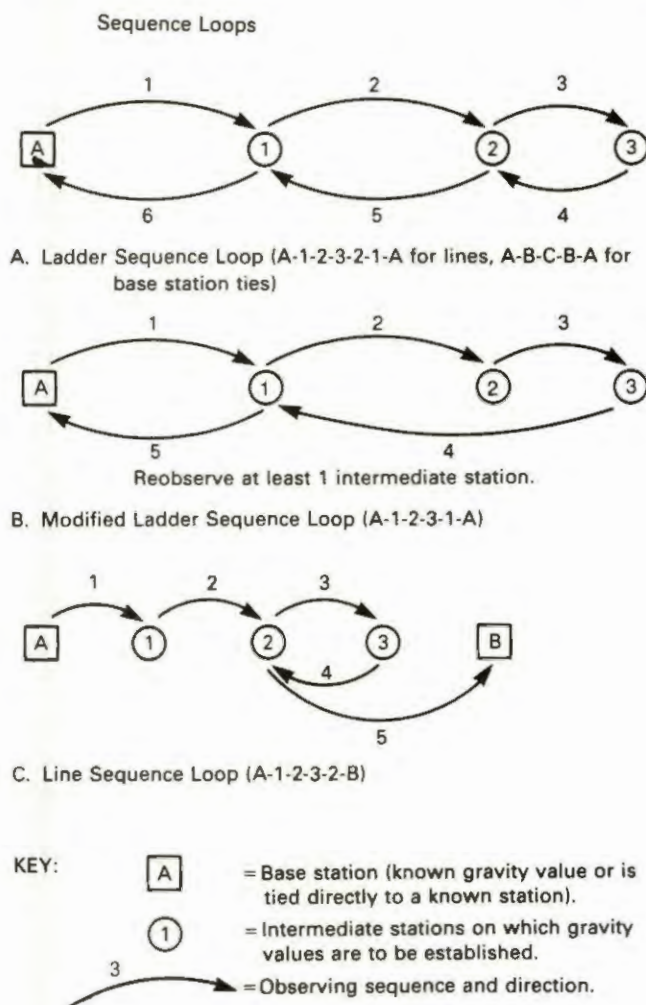


Figure 2.6.5-1.—Sequence of loops

sequence loop, at least one of the new stations must be observed twice.

4. Loop Time and Drift Observations. The observing schedule for a loop must be designed so as to be completed in the shortest possible time (not to exceed 48 hours including layover drift time). Transportation stops of 1 hour or more require that drift observations be made. This is accomplished by observing the gravity meter at the beginning of the stop and again at the same location at the termination of the stop. Geographic positions for drift stations should be recorded to the nearest tenth of a minute. All observations in a loop sequence are performed in accordance with section 2.6.5.3. A base or regional station may be used for drift observations.

5. Loop Closure. If no tares have occurred, and after Earth tide and linear drift corrections are applied, the difference between fore- and back-leg observations at the base station in a loop must not exceed ± 0.03 (1 σ) mgal. If these specifications are not met, contact the Gravity Section, N/CG141. Field check computations must be made for base loops. Section 2.6.6.2 contains instructions for these computations.

6. Time Keeping. Often in the process of observing a loop, two or more time zones are crossed. Keep loop observation times in Coordinated Universal Time (UTC) only. Record time to the nearest minute.

2.6.5.3 Observing Procedures

This section lists the observing and recording procedures for the LaCoste and Romberg gravity meters.

1. **Instrument Setup.** The gravity meter should be allowed to stabilize at its operating temperature for a minimum of 2 hours before use.

a. Disconnect the gravity meters from the vehicle battery and connect them to their individual batteries in the carrying cases.

b. Gently carry the meters in their cases to the bench mark or station.

c. Set tribrach or trivet over the bench mark or station. It must be firmly seated to eliminate any movement while observations are made. If a tribrach is used, level it.

d. Remove the first instrument from its carrying case and set the instrument on the tribrach or trivet.

e. Level the instrument. Do not allow the sun to shine directly on top of the instrument because heat can distort the level-vial assembly. If necessary, use an umbrella to shade the instrument.

f. Measure and record the height of the trivet above (+) or below (–) the station to the nearest centimeter.

2. Observations

a. Unlock the beam. **CAUTION: NEVER DISTURB THE INSTRUMENT OR LEAVE IT UNATTENDED WHILE THE BEAM IS UNLOCKED.**

b. Turn on the reading light.

c. Turn the measuring screw and align (null) the galvanometer needle with the reading mark.

d. Fine tune the gravity meter by turning the measuring screw to bring the left edge of the beam to the right edge of the reading mark. The beam and reading mark are viewed through the instrument's microscope (figure 2.6.3-2). To avoid backlash, always bring the beam to the reading mark from the same direction, either from the left or to the right. If the reading line is passed, back up and begin the approach again.

For a LaCoste and Romberg model “G” meter, a row of five counters may be seen through a window in the top of the meter. The number of counter units is read from the four leftmost counters. The last counter on the right is in tenths of units and corresponds to the tenths of a revolution shown on the dial. The dial has 100 division. Therefore, the meter counter reading can be read to a hundredth and estimated to a thousandth of a counter unit.

e. After aligning the reading mark and the left edge of the beam, record the counter and dial readings. The last two digits should be read from the scale on the dial. Also record the time to the nearest minute when the measurement was taken.

f. Recheck the reading, making certain the instrument is still level.

3. Instrument Teardown

a. Lock the beam in place *before* moving the instrument. Turn off the reading light.

b. Place the gravity meter in its carrying case.

Follow the above procedures for instrument setup, observation, and teardown for each gravity meter observed at a bench mark or station.

2.6.5.4 Recording Procedures

Record all gravity observations on NOAA Form 75-55, Gravity Meter Observations (fig. 2.6.5-2). Observations from two gravity meters may be recorded on one form. If a second meter is being used and the observing time is different from the first meter, then record time and observational data on the next line. *All entries must be completed in the field before transmitting the project data to the office.*

1. **Date.** Enter the Greenwich Civil Date of the first observation recorded.

2. **Chief of Party and Observer.** Enter the names of the chief of party and the observer.

3. **Location.** Enter the general location of the work. The name of the state and the level line number are usually sufficient.

4. **Meter(s).** Record the serial number(s) of the gravity meter(s) being used. Note: Only readings from two meters may be recorded per page.

5. **Station Number.** Assign each station a number. Assign NGBN base: (numbers in the 900 series), junctions and subbases (numbers in the 800 series), and all other marks consecutively from 1. Note: Use a separate line per station per gravity meter.

6. **Bench Mark or Station Name.** Enter the name of the bench mark or station as it is listed in the NGS data base.

7. **G.C. Time.** Enter the Coordinated Universal Time (UTC) of each observation.

8. **Dial Readings.** Enter the dial readings from the gravity meters. M-1 and M-2 are the readings from the gravity meters listed as 1 and 2 in Item 4.

9. **Δh .** Record the height of the **BOTTOM** of the gravity meter above (+) or below (−) the station, to the nearest centimeter.

10. **Elevation.** Record the elevation of the station in meters.

11. **Latitude and Longitude.** Record the approximate latitude and longitude of the station in degrees, minutes, and tenths of minutes.

12. **Remarks.**

2. Earth tide computer printout for survey area
3. Gravimeter conversion tables
4. Calculator

2.6.6.2 Gravity Survey Computation Form

Field computation instructions are referenced to the examples shown in figure 2.6.6-1. Instructions are keyed to column headings on the form. Use a separate page for each instrument.

1. **Header and Trailer Blocks.** Complete the blocks labeled Project, Location, Observer, Instrument Type & Number, Computed By, Checked By, Date, and Page Number.

2. **Station Column.** Enter exact station designation.

3. **Date/Time Columns.** Enter the date based on Coordinated Universal Time (UTC) for the first observation on the sheet and for any date changes during the observing period.

Enter the exact UTC for each observation as recorded on NOAA Form 75-55, Gravity Meter Observations.

4. **$\Delta T/\Sigma T$ Column.** ΣT is the time difference between stations. $\Sigma \Delta T$ is the accumulated sum of ΔT .

5. **Counter/Dial Reading Column.** Enter the counter and dial readings for each station that were recorded on NOAA Form 75-55. (See example that follows.) Record the readings to the nearest thousandth, even though they may have been read only to the nearest hundredth.

6. **Counter/Dial Factor Column.** Obtain the Counter/Dial factor from the calibration table provided with each instrument. (See fig. 2.6.6-2). Each instrument has its own calibration table. The table is used to convert the dial readings to milligals.

Using the counter/dial reading value, proceed to the column in the table headed Counter Reading. Go down the column to the nearest value *less* than the counter reading. Read across to the column headed Value in Milligals and copy the number on the space provided in the form. Proceed across to the column headed Factor for Interval and copy the number in the appropriate place on the gravity survey computation form.

Example:

Counter (35412) & Dial (25) Reading from L & R

G130 = 3541.250

Counter reading on table = 3500.

Value in mgal from table = 3673.34

Factor for interval = 1.05025

Conversion formula:

$(3541.250 - 3500)(1.05025) + 3673.34 = 3716.663 \text{ mgals}$

7. **Corrections Columns.** List the corrections for Earth tide, drift between trips and during trips, and tares in Correction Columns 1 through 4, respectively.

a. **Earth Tide Correction (Column 1).** Using the Earth tide correction given on the computer printout (see fig. 2.6.6-3 for example), locate the date corresponding to the date of observations. Move down to the hour of observation. The correction to be applied is based on the value (EDDEN)

2.6.6 Field Computations

2.6.6.1 General

Gravity field computations are only required for base net surveys, gravity meter checks, and (in some cases for regional surveys) to ascertain accuracy requirements of the survey.

Items required for computation are as follows:

1. Gravity survey computation form (fig. 2.6.6-1).

*Record elevation of bottom of the gravity meter above (+) or below (-) station, to nearest centimeter.

Figure 2.6.5-2.—Example of a completed NOAA Form 75-55, Gravity Meter Observations

Project <u>SLOPE</u>				Location <u>California</u>			Gravity Survey Computation						
Station	GCT		AT (min) EAT (min)	Counter Reading	Counter Mgals	Observed Mgals	Corrections				Correct Mgals	AG (Mgals)	
	Date	(T) Time					1	2	3	4			
San Francisco AA	9-26	1448	57	35	41.250	3673.34 1.05025	3716.663	+0.016		0		3716.679	0
S 1320		1545	13	35	32.840		3707.830	-0.009		+0.001		3707.822	-8.857
U 1320		1558	14	35	34.505		3709.574	-0.014		+0.001		3709.561	+1.739
W 1320		1612	11	35	35.170		3710.277	-0.019		+0.002		3710.260	+0.699
M 1241		1623	12	35	25.920		3700.562	-0.022		+0.002		3700.542	-9.718
Z 210 RESET 55		1635	11	35	06.820	3673.34 1.05025	3680.503	-0.025		+0.002		3680.480	-20.062
J 1241		1648	13	34	99.220	3568.32 1.05025	3672.526	-0.029		+0.002		3672.499	-7.981
F 1241		1659	20	35	45.400	3673.34 1.05025	3721.021	-0.032		+0.003		3720.992	+48.493
C 211 RESET 39		1719	15	35	50.160		3726.021	-0.035		+0.003		3725.989	+4.997
C 211 RESET 39		1752	16	35	50.160		3726.021	-0.039	+0.004	+0.003		3725.989	-
F 1241		1808	14	35	45.420	3673.34 1.05025	3721.042	-0.037	+0.004	+0.003		3721.010	-4.979
J 1241		1822	11	34	99.240	3568.32 1.05025	3672.547	-0.039	+0.004	+0.004		3672.516	-48.492
Z 210 RESET 55		1833	09	35	06.850	3673.34 1.05025	3680.534	-0.039	+0.004	+0.004		3680.503	+7.987
M 1241		1842	17	35	25.950		3700.594	-0.038	+0.004	+0.004		3700.564	+20.061
W 1320		1859	12	35	35.200		3710.309	-0.038	+0.004	+0.004		3710.279	+9.715
U 1320		1911	16	35	34.520		3709.595	-0.036	+0.004	+0.005		3709.567	-0.712
S 1320		1927	41	35	32.870		3707.862	-0.034	+0.004	+0.005		3707.837	-1.730
San Francisco A	9-26	2028	307	35	41.280	3673.34 1.05025	3716.694	+0.025	+0.004	+0.006		3716.679	+8.842
1. Earth Tide			Observer <u>L. M. Johnson</u>			Computed by <u>L. M. Johnson</u>			Date <u>9/27/79</u>		Page No. <u>1</u>		
2. Drift between trips			Inst. Type & No. <u>L & R G 130</u>			Checked by <u>C. W. Wessells</u>			Date <u>9/28/80</u>		No. of page. <u>1</u>		
3. Drift during trips													
4. Tares													

$$\text{Drift correction} = \frac{+0.006}{307} = +0.00002 \text{ mgal/min}$$

Figure 2.6.6-1.—A completed gravity survey computation form

Milligal Values for LaCoste & Romberg, Inc. Model G Gravity Meter #130

Counter Reading*	Value in Milligals	Factor for Interval	Counter Reading*	Value in Milligals	Factor for Interval
000	000	1.04980			
100	104.98	1.04970	3600	3778.37	1.05025
200	209.95	1.04960	3700	3883.39	1.05040
300	314.91	1.04950	3800	3988.43	1.05030
400	419.86	1.04935	3900	4093.46	1.05040
500	524.80	1.04925	4000	4198.50	1.05045
600	629.73	1.04915	4100	4303.55	1.05055
700	734.64	1.04910	4200	4408.60	1.05065
800	839.55	1.04905	4300	4513.67	1.05075
900	944.46	1.04905	4400	4618.74	1.05080
1000	1049.36	1.04905	4500	4723.82	1.05085
1100	1154.26	1.04900	4600	4828.91	1.05090
1200	1259.17	1.04905	4700	4934.00	1.05090
1300	1364.07	1.04905	4800	5039.09	1.05085
1400	1468.97	1.04905	4900	5144.17	1.05085
1500	1573.88	1.04910	5000	5249.26	1.05075
1600	1678.79	1.04915	5100	5354.34	1.05080
1700	1783.70	1.04920	5200	5459.42	1.05085
1800	1888.62	1.04925	5300	5564.50	1.05080
1900	1993.55	1.04940	5400	5669.58	1.05075
2000	2098.49	1.04950	5500	5774.66	1.05060
2100	2203.44	1.04955	5600	5879.72	1.05050
2200	2308.39	1.04965	5700	5984.77	1.05040
2300	2413.36	1.04970	5800	6089.81	1.05025
2400	2518.33	1.04975	5900	6194.84	1.05010
2500	2623.30	1.04975	6000	6299.85	1.05000
2600	2728.28	1.04980	6100	6404.84	1.04985
2700	2833.26	1.04985	6200	6509.83	1.04965
2800	2938.25	1.04995	6300	6614.79	1.04940
2900	3043.24	1.05005	6400	6719.73	1.04915
3000	3148.25	1.05010	6500	6824.65	1.04885
3100	3253.26	1.05015	6600	6929.53	1.04855
3200	3358.27	1.05020	6700	7034.39	1.04820
3300	3463.29	1.05025	6800	7139.21	1.04785
3400	3568.32	1.05025	6900	7243.99	1.04750
3500	3673.34	1.05025	7000	7348.74	

NOTE: Right hand wheel on counter indicates approximately 0.1 milligal.

10-18-66

AWS

Figure 2.6.6-2.—Calibration table provided with LaCoste and Romberg model G gravity meter No. 130

LATITUDE	37.40 (N)	
LONGITUDE	122.25 (W)	
YEAR MON DAY	TIDE (LONGMAN)	TIDE (EDDEN)
1979 9 25	0. -0.00920	-0.01851
	1. -0.03899	-0.04577
	2. -0.06485	-0.06882
	3. -0.07897	-0.08022
	4. -0.07644	-0.07537
	5. -0.05659	-0.05373
	6. -0.02316	-0.01900
	7. 0.01670	0.02183
	8. 0.05431	0.06027
	9. 0.08157	0.08836
	10. 0.09288	0.10058
	11. 0.08638	0.09501
	12. 0.06422	0.07365
	13. 0.03188	0.04178
	14. -0.00321	0.00663
	15. -0.03346	-0.02437
	16. -0.05288	-0.04532
	17. -0.05844	-0.05315
	18. -0.05069	-0.04826
	19. -0.03357	-0.03430
	20. -0.01329	-0.01713
	21. 0.00332	-0.00320
	22. 0.01070	0.00224
	23. 0.00607	-0.00336
1979 9 26	0. -0.00970	-0.01912
	1. -0.03230	-0.04085
	2. -0.05513	-0.06223
	3. -0.07110	-0.07649
	4. -0.07462	-0.07833
	5. -0.06312	-0.06537
	6. -0.03781	-0.03883
	7. -0.00330	-0.00326
	8. 0.03351	0.03461
	9. 0.06523	0.06750
	10. 0.08566	0.08933
	11. 0.09123	0.09647
	12. 0.08160	0.08849
	13. 0.05960	0.06800
	14. 0.03036	0.03991
	15. 0.00008	0.01025
	16. -0.02536	-0.01529
	17. -0.04174	-0.03253
	18. -0.04730	-0.03968
	19. -0.04303	-0.03764
	20. -0.03234	-0.02957
	21. -0.02007	-0.02004
	22. -0.01118	-0.01369

Figure 2.6.6-3.—Earth tide corrections at a specific geographical location

shown across from this time. Upon locating the time, interpolate the correction to be applied corresponding to the number of minutes in observation time, using the correction difference between the hour before and the hour after the observation.

Example:

Date 9-26-79 Time of Observation 1448
 Time Earth Tide Correction (EDDEN)
 1400 +0.0399
 1500 +0.0102

Interpolating to determine the correction at 1448:

$$(1448 - 1400) / 60 \text{ minutes} \times (+0.0102 - 0.0399) = -0.0238 \text{ mgal}$$

$$0.0399 + (-0.0208) = +0.0161 \text{ mgal} = \text{correction.}$$

b. *Static Drift Correction (Column 2).* The drift characteristics of the gravity meter are different when it is under a static mode (i.e., a lengthy stop such as a lunch break or overnight). This drift must be eliminated from the dynamic drift (drift while transporting the instrument or observing). Referring to figure 2.6.6-1 (Column 2 of corrections), the static drift for the layover station C 211 RESET 1939 is +0.004 mgal. This is the difference between the two consecutive readings at station C 211 RESET 1939. Notice that the Earth tide correction is applied before subtracting the two readings.

Example:

From drift reading on C 211 RESET 1939:

Time observed mgals + Earth Tide Corr. = mgal
 1719 3726.021 + (-0.035) = 3725.986
 1752 3726.021 + (-0.039) = 3725.982

$$\text{Static Drift Correction} = \text{Difference} = +0.004 \text{ mgal}$$

The correction is applied in such a manner that the second drift reading is always corrected to agree with the first reading. Consequently, all readings obtained until the next stop in this loop will be corrected by the same amount. Static drift corrections are cumulative.

c. *Dynamic Drift Correction (Column 3).* To compute dynamic drift, the Earth tide and static drift corrections are applied to the starting and ending Observed Mgals readings. The dynamic drift is the difference between these two values.

d. *Tare (Column 4).* This is not normally needed.

Example:

For San Francisco:

Time Observed mgal + Correction 1 + Correction 2 = mgal
 1448 3716.663 + 0.016 + 0 = 3716.679
 2028 3716.694 + (-0.025) + 0.004 = 3716.673

$$3716.679 - 3716.673 = +0.006 \text{ mgal}$$

$$\text{Elapsed time} = 307 \text{ min}$$

$$+0.006 \text{ mgal} \div 307 \text{ minutes} = +0.00002 \text{ mgal/minutes}$$

The drift rate is then multiplied by the $\sum \Delta T$ at each of the stations within the loop.

Example:

Station W 1320 84 minutes (+0.00002) = +0.002 mgal
 Station M 1241 201 minutes (+0.00002) = +0.004 mgal

8. *Corrected Mgals Column.* After all the indicated corrections have been applied to the observed mgals, the corrected mgal value is written in this column.

9. *ΔG Column.* ΔG is the difference between each observation in succession within the loop or line. This computation checks the accuracy of the observations by comparing the ΔG of reobserved stations. If ΔG compares within 0.04 mgal, no reobservations are necessary. If the difference is greater than 0.04 mgal, the stations should be reobserved to identify the error.

2.6.7 Data, Records, and Reports

The following sections list the requirements for data, records, and reports that apply specifically to gravity surveys. Routine reports are discussed in chapter 1.6. Data transmittals are discussed in general in chapter 1.7.

2.6.7.1 Data

Data generated by gravity surveys consist of bench mark recovery descriptions and gravity observations.

1. **Bench Mark Recovery Descriptions.** A recovery description is required for all bench marks that are visited as part of the project. Complete only the following portions of the NOAA Form 76-186, "Bench Mark Description." All entries may be handwritten.

- *10* DRC Code—enter "R"
- *13* Designation
- *14* State Code/County
- *17* Nearest City or Town—Enter name of city or town. Precede name by "IN" if bench mark is in the city or town.
- *18* Distance and Direction From Nearest City or Town
- *22* Other Control—Enter "G" if gravity was observed at bench mark.
- *23* Code/Recovery by Agency—Enter "1/NGS"
- *24* Year station established and name of Chief of Party
- *25* Condition of Mark—Enter appropriate code from back of form
- *28* Stamping—Enter exact stamping on disk
- *30* Descriptive text—Enter either "RECOVERED AS DESCRIBED" or a complete new description.

2. **Gravity Meter Observations.** The gravity meter observations should be submitted to headquarters on a line or project basis.

2.6.7.2 Monthly Report and Journal

The Monthly Report and Journal (NOAA Form 76-92) must be completed and received at the Field Operations

Section, N/CG161, by the 10th of each month. In the "Remarks" section of the report, include the number of old and new stations occupied, the number of new stations occupied, and list all significant comments or suggestions.

2.6.7.3 Project Report

A project report shall be submitted by each project director for each set of instructions issued to the party. Figure 2.3.11-1 shows an example of a project report cover. The following outline lists some of the topics that should be addressed in the report.

- I. Introduction
 - A. Authority—List the title and dates of all project instructions, changes, and supplemental instructions for the season's work. Copies of these instructions should be appended to the report.
 - B. Purpose—As stated in the project instructions.
 - C. Time Period—The time period covered by the report.
- II. Location—Geographic location or the name and number of leveling lines covered.
- III. Conditions Affecting Progress—Equipment failures, climate, annual or sick leave, etc.
- IV. Organization
 - A. Party Personnel
 - B. Liaison
 - C. Equipment Available
- V. Field Work
 - A. Chronology
 - B. Methods
- VI. Discussion of Results
 - A. Deviation from Instructions
 - B. Problems
- VII. Recommendations

2.7 ESTABLISHMENT OF CALIBRATION BASE LINES

NOAA Technical Memorandums NOS NGS-8, Establishment of Calibration Base Lines, and NOS NGS-10, Use of Calibration Base Lines, contain information necessary to establish and use calibration base lines. They also give a brief history and a mathematical discussion of the reduction, analysis, and adjustment of base line data. Requests for the establishment of calibration base lines should be sent to the Chief, National Geodetic Survey, Attn: N/CG1x10. Requests for information or details of base line layout and mark setting should be sent to the Network Maintenance Section, N/CG162.

2.7.1 Party Structure

At present, the National Geodetic Survey has one party establishing calibration base lines. This party consists of two surveying technicians. The party is assisted by the agency requesting the base line.

2.7.2 Monumentation

Specifications and instructions for base line site selection, layout, monumentation, and stamping are contained in *NOAA Technical Memorandum* NOS NGS-8 (pp. 4-12). The requirement for underground marks (pages 8-11 of NOS NGS-8) is suspended. The underground mark is of little use for resetting a surface mark to base line accuracy. Reference marks may be set for recovery purposes only.

The requesting agency is responsible for selecting sites and setting monuments to specifications. Upon arrival at the base line site, contact the Chief, Field Operations Section if the monumentation, terrain conditions, or proximity of radio masts appear to be less than satisfactory for ensuring the reliability of the base line. Any variances from the design procedures which may effect the adequacy and/or accuracy of the base line are to be brought to the attention of the Chief, Field Operations Section immediately. Perform no work if monumentation is substandard.

Base line descriptions are to be submitted on NOAA Form 75-82 or 75-82A, Station Description.

2.7.3 Instruments and Equipment

A list of suggested instruments and equipment for a base line party is given in *NOAA Technical Memorandum* NOS NGS-8 (pp. 14-15).

2.7.4 Observations

Observing procedures are outlined in *NOAA Technical Memorandum* NOS NGS-8 (pp. 16-19, 21). General

observing procedures, applicable to most EDM1, are described in *NOAA Technical Memorandum* NOS NGS-10 (pp. 2-6).

2.7.5 Base Line Verification

The party may be required to remeasure calibration base lines as part of a 5-year verification program. The measurement sequence for the standard base line layout is given in this section. Contact the Field Operations Branch, N/CG161, for the proper sequence for any other layout.

Measurements are to be made from each point of the calibration base line using two instruments (Tellurometer MA100).

1. Use the following sequence and tolerances:
 - a. Measure 0- to 150-meter, 0- to 430-meter, and 0- to 1400-meter line segments with Instrument A.
 - b. Measure 0- to 150-meter, 0- to 430-meter, and 0- to 1400-meter line segments with Instrument B.
 - c. Correct all distances for refraction and reduce to horizontal. Compute the distances 150 to 430 meters, 150 to 1400 meters, and 430 to 1400 meters by subtraction.
 - d. The reduced distances from Instrument A and Instrument B must agree within $1.7 \text{ mm} + 1 \text{ ppm}$ (in mm).
2. Change the heights of all instruments and reflectors by approximately 0.1 meter. Recollimate.
 - a. Measure 1400- to 0-meter, 1400- to 150-meter, and 1400- to 430-meter line segments with Instrument A.
 - b. Measure 1400- to 0-meter, 1400- to 150-meter, and 1400- to 430-meter line segments with Instrument B.
 - c. Follow steps 1c and 1d above.
3. Compute the following:
 - a. The mean distances of segments measured from the 0-meter point.
 - b. The mean distance of segments measured from the 1400-meter point.
 - c. The means of each segment of 3a must agree within $1.5 \text{ mm} + 1 \text{ ppm}$ (in mm) of the means of each segment of 3b.
4. If the above tolerances are not met, sufficient re-observations are to be made to meet these tolerances.

2.7.6 Field Computations

The party reduces observations to a common datum and corrects them for meteorological conditions and geometric configurations. These computations are given in *NOAA Technical Memorandum NOS NGS 10* (pp. 6-14). See section 2.2.6.1 for an example of taped traverse reductions.

2.7.7 Data, Records, and Reports

The base line party should submit data, records, and reports to the Quality Control Section, N/CG164, as outlined in chapter 1.7 and section 2.6.7.

A project report is submitted once a year. (See fig. 2.2.22-3 or 2.3.11-1 for an example of a project report cover.)

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OFFICE OF CHARTING AND GEODETIC SERVICES
ROCKVILLE, MARYLAND 20852

September 18, 1984

ERRATA

Geodetic Operations, NOAA Manual NOS NGS 4, 1984.

Please replace pages 2.1-5/2.1-6 and 2.2-7/2.2-8 with the attached corrected pages.

National Geodetic Survey, N/CG17x2
C&GS/NOS/NOAA
Rockville, Maryland 20852



set marks. Use NOAA Forms 37-4 and 37-4A, Stores Requisition and Continuation Sheet, to order them. Send the forms to:

NOAA Logistics Supply Center, AT/GSM42
National Oceanic and Atmospheric Administration
619 Hardesty Street
Kansas City, Missouri 64124

Send an extra (6th) copy to the Plans and Requirements Staff, N/CG1x10.

Table 2.1.1-1 gives the National stock numbers for each item stocked. Other items available from NLSC are listed in the NOAA Stock Catalog.

Table 2.1.1-1—National stock numbers for frequently used surveying equipment

(Descriptions are given as stated on NLSC inventory listings.
Information in parenthesis further clarifies the items.)

Description	Unit of Issue	Stock Number
Mark Horizontal Rod	Each	6675-00-069-3196
Mark Horizontal Stem	Each	6675-00-069-3205
Mark Azimuth Rod	Each	6675-00-069-0000-X
Mark Azimuth Stem	Each	6675-00-069-0001-X
Mark Reference Rod	Each	6675-00-069-3195
Mark Reference Stem	Each	6675-00-069-3204
Mark Vertical Rod	Each	6675-00-069-3197
Mark Vertical Stem	Each	6675-00-069-3206
Mark Survey (base line w/cross)	Each	6675-00-069-0002-X
Mark Survey (base line w/o Cross)	Each	6675-00-069-0003-X
Mark Blank	Each	6675-00-069-3209
Rod, Intermediate (stainless steel)	Each (std. length)	5945-00-999-0008-X
Studs, for SS Rod	Each	5945-00-999-0010-X
Cap, Stainless St (datum cap)	Each	5945-00-999-0013-X
Pipe, PVC 1" Bell	Each (10-ft length)	5945-00-999-0002-X
Coupling PVC (1")	Each	5945-00-999-0004-X
Fitting, PVC (1" to 3/4")	Each	5945-00-999-0005-X
Female Adapter	Each	5945-00-999-0000-X
Cement, For PVC	Quart	5945-00-999-0006-X
Petrolatum Filler	16-gal drum	5945-00-999-0011-X
Grease	16-gal drum	9150-00-530-7369
Ring	Each	5945-00-999-0001-X
Pipe PVC, 5"	Each (10-ft length)	5945-00-999-0003-X
Aluminum Logo Cap	Each	5945-00-999-0012-X
Sign Witness Post	Each	9905-00-689-8327
Sign Post	Each	CFN-9905-00-689-8327

2.1.1.9 Use of NGS Disks

National Geodetic Survey disks are to be used by NGS field units and by outside organizations or private individuals performing maintenance or contract work for NGS. They are not to be used by organizations outside NOS for marking their own control points.

2.1.2 Mark Maintenance

2.1.2.1 Purpose, Scope, and Organization

1. **General.** This section is a guideline for mark maintenance field practices. It establishes objectives for the maintenance

program and explains the proper steps for completing each phase of a project. It does not try to instruct personnel in the procedures necessary for measuring distances and directions but does reinforce some subjects already detailed in *Special Publication 247*. It has been so written that qualified engineers can use it and achieve satisfactory results in performing mark maintenance.

2. **Regions.** The mark maintenance program divides the 48 contiguous states into 14 regions. Hawaii has no mark maintenance program and Alaska has a field office that coordinates work done by the Highway Department.

3. **Requirements.** Field work consists of precise vertical and horizontal observations and measurements made in order to maintain the geodetic accuracy of marks established by high precision surveying techniques. All NGS maintenance personnel are highly skilled surveyors capable of independent and responsible analysis of maintenance problems.

4. **Responsibilities.** Field work is coordinated by the Network Maintenance Section, N/CG162. Periodically, the Instrumentation and Equipment Section, N/CG163, repairs, maintains, and calibrates the instruments and equipment used by the mark maintenance engineers (chapter 1.8).

5. **Data Transmittals.** Mark maintenance data should be sent monthly to the Quality Control Section, N/CG164. See section 1.7.4 and figure 1.7.4-1. In addition, the following procedures apply to submitting mark maintenance data:

a. All data should be transmitted on the modified version of NOAA Form 61-29 shown in figure 1.7.4-3.

b. A single Letter Transmitting Data may contain data from several States, but each State must be listed on separate sheets because each State's work is accessioned separately.

c. Within each State the data must be further separated by type (either horizontal or vertical). Both horizontal and vertical data can be submitted as part of the same transmittal but must be listed on separate sheets because horizontal and vertical data are accessioned separately by State.

2.1.2.2 Horizontal, Vertical, and Astronomic Azimuth Observations and Expected Accuracy

The geometry necessary to move a mark or to establish a new azimuth mark is discussed in sections 2.1.2.9 and 2.1.2.10. This section will provide guidance on the number and quality of direction observations necessary to move a mark or to re-establish an azimuth. It will also cover the accuracy expected in work of this type.

1. **Direction Observations.** The number of direction observations required is governed by either the geometry of the existing main scheme network, the order and class of the replaced station, the nearness of other monumented horizontal control, and the distance the mark is to be moved. Unless otherwise noted, the procedures outlined are designed to relate the new station to the old station within 1 part in 50,000. In no case should the procedures employed fail to meet the requirements for third-order, class II surveys as specified in *Classification, Standards of Accuracy, and*

General Specifications of Geodetic Control Surveys. Since checks on mark maintenance work are often by nonstandard methods, it is imperative that the specifications for observations be followed closely.

The following standards apply for setups where the primary lines are shorter than 400 meters. If only the azimuth mark and reference marks are observed in a set of directions, three positions of the circle are required. If additional azimuth points, such as intersection stations, old or new horizontal stations, new azimuth marks, etc., are observed in the same set, four positions of the circle are required. If a mark is moved more than 400 meters, the direction observations and triangle closures will conform to specifications for the order of the mark being moved. When moving marks more than 400 meters, NGS Headquarters should be contacted for recommendations.

Rejection limits between positions of the circle for horizontal directions remain the same as specified in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys*. Rejections will be made immediately in the field and reobservations will be taken to make certain the proper number of observations are made.

When old reference marks are reobserved, check the old angle by the following criteria:

$$[(30/S_1)^2 + (30/S_2)^2]^{1/2} = \text{minutes of difference between new and old angle (rounded up to next minute),}$$

where

S_1 = Distance to RM 1 in meters

S_2 = Distance to RM 2 in meters

Example:

Distance to RM 1 = 15.6 meters

Distance to RM 2 = 21.7 meters

$$[(30/15.6)^2 + (30/21.7)^2]^{1/2} = 3' \text{ allowed between old and new observations to the RM's.}$$

2. Observation of Astronomic Azimuth. When it is necessary to observe an astronomic azimuth for orientation, eight positions of the circle will be observed using at least a 1-second instrument. The mark station will be the most distant visible horizontal point from the observing station. Preference will be given to "in the ground" marks. If there are two stations nearly equidistant from the observing station, both stations will be included in the observations with the star. The rejection limit for positions of the circle is 5 seconds from the mean. After rejections, a minimum of six positions must remain or the azimuth should be completely reobserved. If possible, the azimuth should be computed before destroying the occupied or mark station.

A correction for the inclination of the standing axis (instrument not level) must be made. The higher the latitude, the more critical this becomes. The inclination correction at 48° latitude is about twice as much as it is at 30° latitude for equal amounts of inclination (mislevel). Therefore, bubble readings must also be taken after each pointing on Polaris. If the vertical angle to the mark sta-

tion is greater than ± 2 degrees, bubble readings must also be taken after each pointing on it. Sufficient time must be allowed between each pointing and bubble reading, to ensure that the bubble has completely stabilized. When the level vial is progressively numbered from the vertical circle end to the other end, compute the corrections as follows:

Correction = $d/4 [(W)-(E)] \tan h$, where

d = Bubble value in seconds of arc per level vial graduation.

W = Arithmetic difference of the direct and reverse readings of the west end of the bubble.

E = Arithmetical difference of the direct and reverse readings of the east end of the bubble.

h = Vertical angle of Polaris or station (positive angle if Polaris or station is above the horizontal, negative angle if below horizontal).

Example:

$$d = 7."567$$

$$W = 19.5$$

$$E = 18.9$$

$$h = 35^\circ 41' 56''$$

Bubble readings

$$W \quad E$$

$$05.6 \quad 24.8$$

$$25.1 \quad 05.9$$

$$W = 19.5 \quad E = 18.9$$

$$(W)-(E) = +0.6$$

$$(7."567/4) (0.6) (0.718543) = 0."82$$

Even when bubble readings are taken for the inclination correction, the instrument should be kept close to level in case there is any error in the bubble value or in the uniformity of the graduations of the level vial. Bubble readings should be estimated to the nearest 0.1 graduation.

Pointings on Polaris can be made simultaneously with the 1-minute radio signal or by using a reliable timepiece and computing a drift rate for it. When using a timepiece, three sets of radio vs. timepiece comparisons should be made for each set of observations (eight positions in this case), one each at the beginning, middle, and end. At least three, and preferably five, 1-minute signals should be noted. The timepiece should be read and recorded to at least the nearest 0.5 second and preferably to the nearest 0.25 second for the comparison. During the observations, it should be read and recorded to the nearest 0.5 second for pointings on Polaris.

3. Vertical Observations. Differences in elevation must be determined between stations where distances are measured. If vertical angles are observed, they should be observed reciprocally when the vertical angle exceeds 1 or if both marks will be occupied for other reasons. Zenith distance observations will be made during daylight hours and corrected for the heights of instruments and lights (t-o). The sum of the corrected reciprocal zenith distances should equal $180^\circ \pm 1'$. For long lines, curvature of the Earth must be considered in the closure. The number of seconds of curvature and refraction for reciprocal observations is approximately equal to the distance in meters between the stations multiplied by 0.0277. Elevations computed from different points should agree within 10 cm per km. Zenith distances will consist of a minimum of three observations

out in the field at the station site instead of writing descriptions in the "Observation of Horizontal Directions" volume. The completed forms are original field records and should be submitted with project data for archiving.

NOAA Form 75-82 follows the format of program "HZTDES." It has partially coded text that allows observers to fill in the blanks. Much of the station identification data relating to the reporting or establishing agencies, mark and disk types, setting classification, condition, and transportation are coded. These codes are given in NOAA Form 75-82 and in *Input Formats and Specifications of the National Geodetic Survey Data Base* (ch. 3, annex I). The "notes" listed in *Special Publication 247* are no longer used:

Space is provided for a statement of general location, a "To Reach" statement (a concise description of the route to the station), measurements to reference objects and other marks at the station site, and a sketch. Partially coded text is provided for a detailed description of the station, azimuth mark, reference marks, and other marks at the station site. *Input Formats and Specifications of the National Geodetic Survey Data Base* (ch. 3, annex I) contains examples of the text for each paragraph of the description.

The contents of a recovery description depend on whether conditions at the station site or along the route traveled to reach it have changed and on the completeness and accuracy of the previous descriptions. A clear statement should be made of any discrepancies between the published descriptions and what exists at the station site. Any change made to the station by the party should be mentioned.

The descriptions and recovery descriptions should provide a word picture of all pertinent information relative to the station. It should explain in detail any changes that have occurred since that last recovery description, stating the reasons if known. The following are a few examples of omissions that have occurred:

a. A number 2 station was established with no mention being made of the original station or whether a search had been made for its underground mark. Also, no explanation was given for establishing the number 2 station.

b. A number 2 station was set into the same drill hole as the original station, but no mention was made of this fact, or of the original station.

c. Some recovery descriptions have indicated discrepancies in directions and distances to reference marks with no mention made of the value of the differences. When these differences were noted, no attempt was made to explain them or state that the new values had been confirmed.

d. Descriptions and recovery descriptions were written that did not contain the names, addresses, and phone numbers of the lease holder (if any) and owners of the property on which stations are located.

e. Some monuments contain magnets or ferrous metal. This was not indicated on the *12*/*13* M codes in the Station Identification Record fields of the description.

2.2.5.2 Automated Descriptions.

Field units with computer terminals shall enter station descriptions and recovery descriptions into the computer

system, in addition to submitting NOAA Form 75-82 or 75-82A. These units must use the latest programs for compiling the descriptions. (All other units submit NOAA Form 75-82 and 75-82A to the Field Records Analysis Section of NGS for incorporation into the data base.) The descriptions shall be carefully proofread and edited. The final computer listings are generated from files and used for the publication of project station descriptions.

NOAA Forms 75-82 and 75-82A replace NOAA Forms 76-39, 76-81, 76-96, and 76-165.

When an occupied parent station has positioned azimuth marks, one "Station Description" booklet (NOAA Form 75-82) will be used for both the station and its azimuth marks. The following data for each positioned azimuth mark should be filled out on a separate "Station Description-Short Form" (NOAA Form 75-82A) and attached with tape to the "Station Description" booklet on the parent station's pages for *90* codes:

- The header station description codes *10* through *30* where applicable,
- A location paragraph (i.e., airline distances and directions to nearby towns), and
- A route "to reach" those azimuth marks where "to reach" is different or cannot be extracted from the parent station description.

The automated description for the parent station will include complete writeups for its reference marks and for its azimuth marks that are not positioned. If the azimuth marks are positioned, the "to reach" and the local measurements for the azimuth marks can be omitted from the parent station description, since these data will be included on the automated description for the azimuth marks.

A complete, separate and automated description for each azimuth mark will include the following:

- The header station description codes *10* thru *30*,
- A location paragraph,
- A route to-reach paragraph,
- A mark writeup paragraph describing the mark and local measurements made with respect to permanent objects in the immediate area, and
- Name of person describing the azimuth mark.

2.2.5 Instruments and Equipment

Although much of the information in *Special Publication 247* is still relevant, modern instruments and technology will be discussed here.

2.2.5.1 Theodolites

1. **General.** NGS no longer uses the Parkhurst theodolite described in *Special Publication 247*. At present, NGS field parties use the Wild T3 theodolite. This instrument is available in two different micrometer configurations. The old model is equipped with a half-scale (so called 2-minute) micrometer and the new model with a full-scale (so called 1-minute) micrometer. (Actually both micrometers rotate through a full 2-minutes.) This section describes both the

half-scale and the full-scale micrometer drums for the Wild T3 and two acceptable second-order theodolites.

2. Wild T3 Theodolites. The half-scale model T3 is identical to the instrument described in *Special Publication 247* (pp. 28-30, 141). On this model, two readings must be summed to determine the additive minutes and seconds. The full-scale model reads directly the additive minutes and seconds. Figure 2.2.5-1 shows Wild T3 readings for half-scale and full-scale micrometer drums.

3. One-Second Theodolites. Other theodolites used by NGS units are the Wild T2 and the Kern DKM2. These instruments should be read only to the nearest second. Figure 2.2.5-2 shows examples of 1-second theodolite circle readings.

4. Maintenance and Field Adjustments. All theodolites used in the field will be returned to the Instrumentation and Equipment Section every 18 months for maintenance. Therefore, only minor adjustments are required in the field. The effect of many maladjustments are compensated for by proper observing procedures. It is better to leave an instrument slightly out of adjustment than to continually adjust it in a vain attempt to make it perfect. The following are some routine tests and adjustments which should be made in the field.

a. **Focusing.** The instrument must be correctly focused before observations are begun. Parallax and incorrect focus are not compensated for by the observing procedure. Instructions for focusing the telescope and reading microscope are contained in section 2.2.7.6, subsection 2.

b. **Plate Level.** By following the setup procedure outlined in section 2.2.7.1, subsection 2, observations will be unaffected by a level vial out of adjustment. Level vials more than 2 divisions out should be adjusted as follows:

(1) The instrument should be set up on a stable stand and shaded from the sun and wind.

(2) Rotate the instrument so the plate level is parallel to any two foot screws. Center the bubble accurately by turning these screws equally in opposite directions. The bubble will move in the same direction that the left thumb moves while turning the screws.

(3) Rotate the instrument 90° and center the bubble using only the third screw.

(4) Rotate the instrument back to the first position and recenter the bubble if necessary.

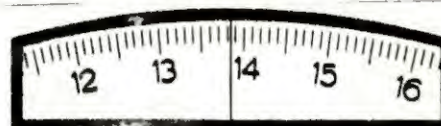
(5) Rotate the instrument 180°. If off-center, bring the bubble halfway back to center using the capstan screws recessed in the right standard. Completely center the bubble with the footscrews.

(6) Rotate the instrument 90° and center the bubble using the third footscrew.

(7) Rotate the instrument through 360°. The bubble should remain within one division of center throughout. If not, steps (5) and (6) must be repeated.

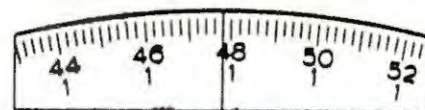
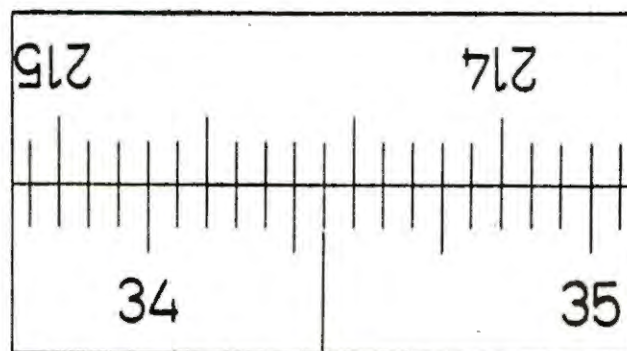
c. **Reticle Verticality.** A skewed reticle is compensated for by using the intersection of the reticle for sighting. The reticle used in modern theodolites consist of lines etched on a glass diaphragm. The horizontal lines are etched pre-

cisely perpendicular to the vertical lines in the manufacturing process. Do not adjust a skewed reticle unless collimation must be adjusted.



(a)

circle reading	123°	34'	
first drum reading			13.8 u
second drum reading			13.9 u
(u represents units)	123°	34'	27.7"



(b)

circle reading	34°	24'	
first drum reading			1' 47.8"
second drum reading			1' 47.8"
	34°	25'	47.8"

Figure 2.2.5-1—Examples of Wild T3 circle readings. (a) vertical circle, half-scale micrometer; (b) horizontal circle, full-scale micrometer. Depending on setting of selector knob, horizontal and vertical circles appear separately in micrometer telescope.

To test for verticality of the vertical hair, carefully level the theodolite and point on a well-defined object such as a