Chapter 5
Surveying Equipment

Chapter 5 Surveying Equipment

5.1 General

Surveying equipment is being used under most stressful conditions. The equipment is exposed to extreme weather conditions, used in dusty construction areas and is subject to bumpy transportation. Proper care in the methods by which equipment is used, stored, transported, and adjusted is a major factor in the successful completion of the survey. Lack of good maintenance practices not only causes unjustified replacement costs, but also can seriously jeopardize the efficiency and accuracy of the entire survey.

The crew leader is responsible for training all crew members in the use of equipment for its intended purpose and the maintenance of all surveying instruments, equipment, tools, and supplies. Should there be a need for additional assistance or training to deal with problems that arise during the course of the survey, a supervisor should be notified about it.

5.2 Care and Maintenance of Surveying Equipment and Tools

5.2.1 General

Surveying instruments, which include theodolites, levels, total stations, electronic measuring devices, and GPS receivers, are designed and constructed to provide years of reliable use. The shafts, spindles, pendulums, and electronics of precision instruments, although constructed for rugged field conditions, can be damaged by one careless act, or continued inattention to prescribed procedures for use, care, and adjustment of the instrument.

Each new instrument is furnished with an operator's manual. The manual contains a description of the instrument, specifications of its various components and capabilities, and applications. The manual also contains basic instructions for use of the instrument and describes recommended servicing and adjusting methods. The operator's manual should be kept with the instrument at all times. Each operator should thoroughly study the manual prior to use of the instrument, particularly whenever prescribed field

adjustments are to be made. If the manual is lost, stolen, or damaged beyond use, a replacement copy should be obtained as soon as practicable.

The following general principles of care and servicing should be applied as a routine matter for all survey equipment and supplies:

A. All equipment and tools should be kept as clean and dry as practicable, particularly if they are to be transported or stored for any length of time.

B. Wooden surfaces should be wiped clean of caked mud or moisture prior to returning the equipment to the vehicle. The original painted or varnished surfaces should be repaired as often as needed to keep moisture from entering the wood.

C. Metal surfaces should be cleaned and wiped as dry as practicable. A coat of light oil should be applied to tapes and the metal parts of tools to prevent rusting during storage. Excess oil should be wiped off.

5.2.2 Routine Care of Surveying Instruments

Before making the first set up of the day, visually inspect the instrument for cracks, bumps, and dents. Check the machined surfaces and the polished faces of the lenses and mirrors. Try the clamps and motions for smooth operation (absence of binding or gritty sound).

A. Frequently clean the instrument externally. Any accumulation of dirt and dust can scratch the machined or polished surfaces and cause friction or sticking in the motions.

B. Dirt and dust should be removed only with a clean soft cloth or with a camel hair brush.

C. Non-optical parts may be cleaned with a soft cloth or clean chamois.

D. Clean the external surfaces of lenses with a fine lens brush and, if necessary, use a dry lens tissue. Do not use silicone treated tissues, as they can damage the coated optics. It is permissible to breathe on the lens before wiping it, but liquids, such as oil, benzene, water, etc., should never be used for cleaning purposes. DO NOT loosen or attempt to clean the internal surfaces of any lens.

E. Cover an instrument whenever it is uncased and not being used for any length of time, particularly if there is dust or moisture in the air.

F. After an instrument has been used in damp or extremely cold situations, special precautions must be taken to prevent condensation of moisture inside of the instrument. When working with the instrument in cold weather, it should be left in the carrying case in the vehicle overnight. If stored in a heated room overnight, the instrument must be removed from the carrying case. If the instrument is wet or frost covered, remove it from its case, and leave it at room temperature to dry out.

5.2.3 Transporting

5.2.3.1 Vehicular Transport

The major portion of damage to equipment and tools occurs when they are being placed into or taken out of the survey vehicle. Other damage occurs during transport, when equipment is jostled against other tools or equipment. Compartments (lined with carpeting, when possible) should be provided to keep equipment and supplies separated. This not only keeps the equipment from being damaged, it facilitates finding such items more rapidly. Heavier items should be carried in the lower parts of vehicles and they should never be in direct contact with other tools or equipment below them.

A. The care, organization, and general housekeeping of a vehicle are good indications of the attitude of the entire survey crew. Keep passenger compartments free of unnecessary clutter and equipment. Any equipment or material carried in the passenger compartment should be firmly secured.

B. Transport and store instruments in positions that are consistent with the carrying case design. Many instrument cases indicate the position in which they should be transported. Treat optical targets, prisms, and staffs with the same consideration.

C. Transport the instruments in their carrying cases placed in a compartment cushioned with firm polyfoam or similar material to protect them from jolting or excessive vibrations.

D. Remember, loose equipment, out of place tools, and general clutter not only contribute to damage of the items, they also waste crew time in locating them and are a safety hazard.

5.2.3.2 Casing and Uncasing

Before removing an instrument, study the way it is placed and secured in the case. The instrument must be replaced in the same position when returned to the case.

In removing the instrument from the case, carefully grip it with both hands, but do not grip the vertical circle standard or where pressure will be exerted on tubular or circular level vials.

5.2.3.3 Field Transport of Surveying Instruments

Do not "shoulder" or carry a tripod mounted theodolite or electronic distance measuring equipment (EDM). These instruments should always be removed from the tripod and secured in their carrying cases when moved.

These precautions are necessary because the center spindle (center spigot or standing axis) of a theodolite is hollow and relatively short. When carried horizontally while on the tripod, the alidade's weight is an excessive load for the hollow centerpiece to bear. Instrument damage can result if the above precautions are ignored. Also, the instrument fastener can break, causing the theodolite to fall.

5.2.4 Care During Instrument Setups

Whenever possible, select instrument stations where operation is not dangerous to the instrument operator, the crew, or the instrument. Select stable ground for the tripod feet. Do not set an instrument closely in front of, or behind, a vehicle or equipment which is likely to move. Take a safe route to all setups.

A. At the site, firmly plant the tripod with its legs widespread. Push along the legs, not vertically, downward. On smooth surfaces, use some type of tripod leg restrainer to keep the legs from sliding outward.

B. Always have the tripod firmly set over the point before removing the instrument from its carrying case. Immediately secure the instrument to the tripod with the instrument fastener.

C. Never leave an instrument or its tribrach on the tripod without securing either to the tripod. Moderate pressure on the fastener screw is sufficient. Excessive tightening

causes undue pressure on the foot screws and on the tribrach spring plate. Make sure the tribrach clamp is in the lock position.

5.2.5 Adjustments of Surveying Instruments

5.2.5.1 Field Adjustments

The crew leader should develop a set of test procedures to be used frequently for elimination of gross errors. Such tests should include a check of items such as the levels, optical plummet, and tripod. In the field, adjustments should only be made when the instrument results are poor or require excessive manipulation.

Normally, each instrument should be periodically checked at a facility where the best conditions for testing are possible. Only the adjustments described in the manual for the instrument should be made in the field or shop. Do not "field strip" (dismantle) instruments.

5.2.5.2 Major Adjustments

When an instrument has been damaged or otherwise requires major adjustments, it will need to be sent to an authorized repair shop. The instrument should be accompanied by a written statement indicating the types of repairs needed. In the case of electronic devices, the request should describe conditions under which the instrument does not function properly, i.e., coldness, dampness, etc. If a "loaner" is needed, this should also be indicated.

Wherever possible, the instrument should be "double cased" for shipping, with its case packed inside a cardboard container.

5.2.6 Care of Tools

Improperly maintained tools can be a source of annoyance, as well as being a safety hazard. Each employee is responsible for keeping his or her tools and equipment in good condition. To prevent loss of small equipment and tools, avoid laying them on the ground, on vehicles, or on equipment which might be moved. When not in use, carry them in scabbards and pouches.

A. Repair or replace any driving tool that is burred or fractured on any part of the striking or driving face. Many surveyors have been injured by the "shrapnel" effect from gads

and sledges which had ragged edges. The same is true for "bull points" or other tools which are driven.

B. Crooked or warped handles can cause injury as well as mishitting and damage to the tool. Promptly replace such handles and those that are cracked or broken. Handles should be firmly secured in all cutting and driving tools.

5.3 Angular Measurement Instruments

5.3.1 General

Theodolites and mainly total stations are today's primary angle measuring instruments, particularly on all baseline and control surveys. Angular measurements by a theodolite or a total station are done essentially following the same procedure. The main difference between them is that a total station has battery operated electronic devices to display the measured angles, measure distances and perform on board computation. In general, they are also similarly built with many common features which are necessary to assure accurate and reliable operation.

Due to its low accuracy and inefficiency, the transit is not being used in today's survey work. Only theodolites and total stations will be discussed in this section.

5.3.2 Care of Theodolites and Total Stations

Although the instruments are ruggedly built, careless or rough use and unnecessary exposure to the elements can seriously damage them. If handled reasonably, they will provide consistently good results with a minimum of downtime for repair or adjustment. Some general guidelines for the care of instruments are:

A. Lifting - Instruments should be removed from the case with both hands, gripping the micrometer knob standard and base on the older instruments. Newer instruments are equipped with a carrying handle; the other hand should support the base. One hand should continually support the instrument until the tribrach lock is engaged and the tripod fixing screw secured.

B. Carrying a Tripod - In most cases, the instrument should be removed and re-cased for transportation to a new point. If the point is nearby, the instrument should be carried in the vertical position (tripod legs pointing straight down). An instrument should never be "shouldered" or carried horizontally.

C. Adjusting Collimation - The collimation error of theodolites and total stations is determined by following the procedure outlined in the users manual. If the

collimation error is found to be consistently in excess of ten seconds on the horizontal and twenty seconds on the vertical, the instrument should be adjusted. The collimation adjustment should be made in the field only by a specially trained individual. Otherwise, the instrument should be returned to an authorized repair shop.

5.4 Distance Measurement Instruments

5.4.1 General

Virtually all distance measurements are made today with an electronic instrument such as an EDM or GPS. Tapes are used only when very short distances have to be measured (i.e. on a construction site).

5.4.2 Total Stations and EDM's

Most electronic distance measuring instruments (EDM's) are used in combination with a total station. The EDM is either integrated into a total station or mounted on top of it. Some theodolites have special brackets for mounting an EDM on top of them as well.

Each EDM should be checked on a calibration baseline at least once every year, with results documented and filed at the State Bureau of Weights and Measures in Avenel, NJ. Most EDM's have approximately the same distance measuring accuracy when operated in accordance with the manufacturer's instructions, with the proper reflector systems. Every instrument, whether radio or light beam measuring, has an inherent plus or minus error in every measurement, plus a small error based on parts per million of the distance measured. These errors are generally insignificant in the overall survey, but the surveyor should be aware that they are present and that there is no such thing as an exact measurement.

5.4.2.1 Care of EDM's

A. EDM's are designed, constructed, and tested to withstand normal field conditions. They are, however, precision instruments and should be handled with the same degree of care required for other types of precision survey equipment.

B. Secure EDM's in vehicles in padded compartments with substantial tie downs so movement and jarring are minimized. Cushion with firm polyfoam or similar material. Do not use soft foam rubber. The instruments should be stored and transported in the position indicated on the case.

C. Required maintenance of most EDM's is minimal. However, protection from the elements and routine external cleaning is necessary.

D. NEVER point an EDM directly at the sun. The focused rays of the sun can damage sensitive internal parts.

E. Protect EDM's from excessive heat. Heat can cause erratic readings and deterioration of components. Do not leave instruments in closed vehicles that are parked in the sun. Avoid rapid changes in temperature, particularly from extreme cold to warm, which can cause condensation in the internal parts of the instruments. Condensation can normally be avoided by leaving the instrument in its carrying case for at least 10 minutes and then opening the case to allow any trapped moisture to evaporate. An instrument taken from a warm office or vehicle to an extremely cold operating environment may require some time to adjust itself. The same type of precautions should be taken to let the instrument cool off slowly.

F. Although EDM instruments are water resistant and well shielded, keep them as dry as practicable. The case should be opened and the instrument allowed to dry in a warm dry room when not in use.

G. Frequent partial discharge and charge of batteries could cause the battery to lose its ability to hold power. Periodically, batteries should be discharged completely and then recharged overnight, or for the specified charge time. Effective usage of batteries will also decrease at low temperatures. An EDM in the tracking mode position will discharge the battery quite rapidly, so it is important to be able to charge batteries to their maximum capacity. In general, one should follow the user's manual instructions on how to maintain the batteries for top performance. If the batteries still fail to hold power, they should be re-celled or replaced.

5.4.3 Tapes

Surveyor's tapes are available in various lengths, of different materials, and with many methods of graduations. Although EDM's have replaced tapes for longer measurement, every crew should have both metallic and non-metallic tapes available. Tape reels for metallic or fiberglass tapes save time and help prevent damage to the tape, particularly if used in construction or heavy traffic areas.

5.4.3.1 Care of Tapes

Routine care extends tape life. The following are basic guidelines for the care of tapes:

A. Do not place a tape where it can be stepped on or run over, unless the tape is flat, taut, and fully supported on a smooth surface. Keep the tape straight when in use. When

pulling a slack tape, a loop can develop into a kink and easily break the tape. Avoid pulling a tape around poles or other objects, as a hard pull can stretch or break the tape.

B. Do not wind tapes overly tight on their reels, as it can cause unwanted stresses and lead to stretching of the tape.

C. After the day's work, clean tapes that are soiled. In wet weather, dry before storing. Clean rusty tapes with fine steel wool and cleaning solvent or kerosene. Use soap and water when tape is dirty or muddy. To prevent rust after cleaning, oil lightly and then dry the tape.

D. Avoid storing in damp places.

5.5 Accessories for Angular and Distance Measurement Instruments

5.5.1 Tribrachs

A tribrach is the detachable base of all theodolites, total stations, forced centering targets, and most EDM's. Tribrachs are equipped with a bulls eye bubble for leveling and optical plummets for setting up precisely on a survey mark. The discussion on tribrachs is conducted in a separate section because they are being used with a wide variety of surveying equipment

5.5.1.1 Use of Tribrachs

The ability to "leapfrog" backsight, instrument point and foresight by using interchangeable tribrachs increases the speed, efficiency and accuracy of the traverse survey. Whenever possible, the tribrach should be detached from the instruments and placed on the tripods for either theodolite or EDM setups. This procedure speeds up the setting up process and protects the instrument from accidents. In some cases, the same tribrach can be used to perform angular and/or distance measurements, as well as GPS observations from the same survey point.

5.5.1.2 Care of Tribrachs

Tribrachs are an integral part of the precision equipment and should be handled accordingly. They should be transported in separate compartments or other containers to prevent damage to the base surfaces, bulls eye level, and optical plummet eye piece. Over tightening of the tripod fastener screw can put undue pressure on the leveling plate.

Although the leveling screws are covered, dirt or dust can work into the threads and cause wear. The tribrach should be carefully disassembled, cleaned, and lubricated with light instrument oil whenever the threads appear to be binding. Such repairs should be done in the shop by someone experienced in such work.

5.5.1.3 Adjustments of Tribrachs

An out of adjustment tribrach can cause small random errors and each tribrach should be routinely checked for centering. Careful adjustment with a plumb bob is quite fast and should provide a centering accuracy within 1 millimeter. A more accurate method is to rotate the tribrach 120 degrees over a smooth markable surface. For the first sighting, a soft pencil line is drawn on the tripod head around the tribrach base. The tribrach is carefully leveled and the sighting point marked. The tribrach is then rotated 120 degrees, carefully set in the pencil marks, re-leveled, and a new sighting point marked. Repeat this procedure. If the tribrach is slightly out of adjustment, the three rotational marks should form a triangle. The plummet should be sighted to the center of the triangle and the optical plummet adjusted to that setting. The test should be repeated to verify the adjustment.

5.5.2 Tripods

Tripods provide a fixed base for all types of surveying instruments and sighting equipment.

5.5.2.1 Types of Tripods

In the past, different equipment required different tripods. However, due to standardization by instrument manufacturers, most of today's equipment utilize the same tripod. The same tripod can be used for total station, levels, and GPS. Tripods are made of either metal or wood. Wooden tripods are recommended for precision surveys to minimize errors because of expansion and contraction due to heat and cold.

5.5.2.2 Care of Tripods

A stable tripod is required for precision in measuring angles. A tripod should not have any loose joints or parts which might cause instability. Some suggestions for proper tripod care are:

A. Maintain firm snugness in all metal fittings, but never tighten them to the point where they will unduly compress or injure the wood, strip threads or twist off bolts or screws.

B. Tighten leg hinges only enough for each leg to just sustain its own weight when legs are spread out in their normal working position.

C. Keep metal tripod shoes tight and free of dirt.

D. Keep wooden parts of tripods well painted or varnished to reduce moisture absorption and swelling or drying out and shrinking.

E. Replace top caps on tripods when not in use.

The most damage occurs to tripods when being placed in or taken out of survey vehicles. The life and usefulness of tripods can be significantly extended if compartments are constructed so that the tripods are not riding on or against other equipment.

5.5.3 Sighting Equipment

Surveyors use a wide range of sights for a variety of survey operations. The main purpose of a sight is to provide a reference that is visible to the instrument operator for either referencing from a survey point or establishing a survey point. In this context, sights may be required for line, distance, or a combination of line and distance.

5.5.3.1 Plumb Bob

The plumb bob string with Gammon reel is the old standard short distance sighting method, particularly for establishing temporary points. Steadiness of the holder can be enhanced by the use of braces or any type of framework. Various types of inexpensive string line targets are also available.

5.5.3.2 Range Poles

Range poles are the most common sight used by NJDOT and are made in several cross sectional shapes, of various materials and in different lengths or combinations thereof. Some are solid, some tubular, and others laminated. Most poles are approximately 25 millimeters (1 inch) in diameter. Smaller diameter "lining poles" may be made from small diameter pipe or rod. Electrical conduit suitably tipped and painted makes a good light weight sighting pole.

The use of a bulls eye rod level is an essential option when any type of range pole is "hand held" or guyed.

5.5.3.3 Forced Centering Targets

The tribrach mounted traverse target sets are recommended for all baseline traverse surveys, and other control surveys, when they are available. The tribrach contained optical plummet and target configuration provide the most positive daytime sight available. Several illumination kits, consisting of a light bulb case and battery case, are available for nighttime surveys.

5.5.3.4 EDM Prisms

Each manufacturer of EDM's supplies special prisms and prism holders that are compatible with its equipment. The single lens, tiltable holder with provisions for direct connection on the top of a sectional or telescoping plumbing pole is the most common type used in most survey work. Such prism holders are generally equipped with a sighting target mounted above or below the prism to provide parallel sight between the sighting and measuring beams. The maintenance of parallel sight becomes more significant in the accuracy of measurements as the distance is decreased. The use of the tiltable holder, with properly mounted target, maintains the parallel sight relationship, particularly in rough terrain. The surveyor should understand the necessity for parallel sights and know what the telescope aiming point is for the type of EDM being used. The various EDM's have different methods of transmitting, receiving and computing the light beam. Some light beams may be transmitted and returned to the instrument on the same path, while others travel to one side of the prism and return from the other side in a rectangular pattern. The pattern determines from which part of the prism the beam will be measured and, thus, affects the prism constant relationship between the EDM and prism being used. The position of the prism relative to the vertical axis of the sight also affects the prism constant. It is important that the proper prism constant is used; otherwise a systematic error will be introduced in all the measurements made between a particular EDM and prism. The best way to verify that true measurements will be made is to test the EDM and prism on a baseline of a previously established distance.

A. For longer measurements, cluster holders are available to provide an enhanced light return to the EDM. The clusters are generally arranged in groups of three prisms per holder with facilities to stack up to nine or more prisms on a common sighting plane. The sighting point for such distances is not critical. The surveyor should use his or her best judgment as to where the vertical sighting point should be. Most cluster holders are equipped for mounting on a tribrach by means of a standard tribrach adapter.

5.5.3.5 Care of Sighting Equipment

As with any survey equipment, proper care will extend the useful life of sighting equipment.

A. Range or sighting poles should be kept straight and well painted. Whenever possible, poles should be sheathed or carried in a separate compartment when being transported. Never use range poles for vaulting or spears.

B. Bull's eye rod levels should be checked periodically, or whenever there is any indication that they may be out of adjustment. A quick check against a pre-checked door jamb will indicate if the level is out of adjustment.

C. Forced centering target sets should be treated as any other precision equipment. They should be transported in their carrying case in the proper compartments. They should never be put away wet or dirty. The tribrachs should be kept in the same adjusted condition as theodolite or EDM tribrachs.

D. When not in use, keep prisms in their proper containers with face covers in place. They should be kept clean and moisture free to ensure maximum light return. Clean the reflective surface with a camel hair brush or soft lens tissue.

5.6 Leveling Instruments

5.6.1 Hand Levels

Most surveyors maintain a hand level as part of their personal equipment. Hand levels are useful in level "runs" for quick location of turn and instrument points and to determine differences in elevation when chaining. They are also quite useful for rough elevation checks during grading operations. As with any other level, the level bubble can become out of adjustment and should be checked periodically. A quick check can be made against a good carpenter's level and adjusted similar to a regular level instrument.

5.6.2 Automatic Levels

Although the Department inventory shows dumpy and wye level instruments still in existence, pendulum type automatic levels are the standard leveling instruments used on Department surveys. The principal of operation is essentially the same in all makes. The line of sight is maintained perpendicular to the direction of gravity through a system of prisms, called a compensator. Pendulum levels are fast, accurate and easy to maintain. Proper care and service is required to ensure continuous service and required precision.

Do not disassemble instruments in the field. Only attempt those adjustments set forth in the instrument manual.

5.6.2.1 Care of Levels

Review the previously stated guidelines for the care of instruments. These guidelines are also generally true for the proper care of pendulum levels. Additional guidelines are:

A. Do not spin or bounce pendulum levels, as such movement can damage the compensator.

B. Protect the level from dust. Dust or foreign matter inside the scope can cause the compensator's damping device to hang up.

C. Frequently check the adjustment of the bull's eye bubble. Adjust the bull's eye to the center, not almost to the center. Make certain it is adjusted along the line of sight and transversely as well. Proper adjustment reduces the possibility of compensator hang up.

D. To check for compensator hang up, slightly tap the telescope with a pencil or operate the fine movement screw jerkily to and fro. If the instrument has a push button release, use it. If the compensator is malfunctioning, send the instrument to an approved repair service for servicing. Do not attempt compensator repair in the field.

5.6.3 Leveling Rods

Leveling rods are made of wood, metal, or fiberglass and are graduated in feet or in meters. The foot rod can be read directly to 0.01 feet, whereas, the metric rod is usually read to 0.01 m. More precise reading can be made with add-on accessories such as a vernier or an optical micrometer. Since leveling rod graduations come in a wide variety of patterns, the crew must become familiar with the specific rod used. Digital levels use a special leveling rod that has a bar code, instead of a numerical scale, for reading the elevation.

Leveling rods come in one, two or three sections. The multi-section rods can be extended to their full length in different ways. Some have hinges that accommodate folding of the sections, some have sliding sections that can be locked at the proper length, while others are folded telescopically and can be pulled open. The sole of the rod is a metal plate that will withstand the constant wear and tear of the leveling activities.

For very precise work, a one-section Invar rod is used. Invar rods are precision rods, which have been calibrated and are to be used in control surveys, deformation surveys, precise surveys and resetting or referencing surveys for benchmarks.

5.6.3.1 Care of Leveling Rods

Leveling rods should be maintained and checked as any other precision equipment. Accurate leveling is as dependent on the condition of the rods as on the condition of the levels. Reserve an old rod for rough work, such as measuring sewer inverts, mud levels, etc. The care requirements common to all types of rods are:

A. Protect from moisture, dirt, dust and abrasion.

B. Clean graduated faces with a damp cloth and wipe dry. Touch graduated faces only when necessary and avoid laying the rod where the graduated face will come into contact with other tools, objects, matter, or materials where damage might result.

C. Do not abuse a rod by placing it where it might fall, throwing, dropping, dragging, or using it as a vaulting pole.

D. Keep the metal shoe clean and avoid using it to scrape foreign matter off a bench or other survey points.

E. If possible, leave a wet rod uncovered, unclosed, and extended until it is thoroughly dry.

F. Store rods, either vertically (not leaning) or horizontally with at least three point support, in a dry place and in their protective cases.

G. Periodically check all screws and hardware for snugness and operation.

H. Periodically check accuracy by extending the rod to its full length and checking its scale with an accurate tape. This should be done at the beginning of control level surveys. If the rod indicates a tendency to be "off", it should be checked each time it is extended.

5.6.4 Bull's Eye Rod and Pole Levels

The bull's eye level is used for maintaining both level rods and sighting poles in a vertical position. An out of adjustment bull's eye level can cause accumulative error in level lines. Although the sighting pole is infrequently used for traversing, an out of adjustment bull's eye level used on sighting poles can cause errors in both angle and distance measurements.

5.6.4.1 Adjustment

A simple method for checking for gross error in bull's eye level adjustment is to check it against a previously checked door jamb or other permanent building part.

Other, more elaborate, checking procedures can be developed using plumb lines or other devices.

5.7 Miscellaneous Accessories

5.7.1 Hand Held Radios

Modern survey equipment and techniques have made the hand held radio an essential part of a survey crew's equipment. The statewide mobile radio system may be used to keep the crew in contact with the office and relatively short range hand held radios are used to maintain contact between members of the survey crew. Although units are generally ruggedly constructed, they require special care and maintenance.

Batteries are the primary source of problems with hand held radios. The care and maintenance of batteries is discussed under "Care and Servicing of Other Equipment".

5.7.1.1 Care and Use of Radios

A. Radios should be kept in the carrying case at all times. Avoid laying radios in precarious places where they could be blown off or knocked to the ground.

B. When one radio is being used for most of the transmission, battery life can be extended by switching radios during the day. Transmission causes considerably larger discharge than reception only. Battery life of the receiving radio can be extended by simply pressing the transmission button to acknowledge receipt of a message.

C. All messages should be as short and to the point as possible.

D. It has been found that radio transmission can affect measurements of EDM's. No transmission should take place near the instrument while measurements are being made.

5.7.2 Batteries

Hand held radios and EDM's operate on rechargeable NiCad batteries. Battery failure is the cause of most problems with the operation of radios and such failures can completely

disrupt the crew's effectiveness. Some EDM's are provided with alligator connections for temporary use of the vehicle battery.

A. The need to retain a vehicle at the instrument point can often disrupt the crew's normal procedures. Therefore, the care and maintenance of batteries is an important part of the crew operation and one member of the crew should be assigned that responsibility.

B. NiCad batteries have a tendency to develop false "bottoms" when they are only partially discharged between charging cycles. Periodically, the radio (or instrument) should be left "on" to discharge the battery to almost bottom. Over discharging could cause a reversal in polarity.