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DIVISION OF STRUCTURES AND ENGINEERING SERVICES

TRANSPORTATION LABORATORY

RESEARCH REPORT

Development Of Borehole TV Operational Techniques

FINAL REPORT

CA-DOT-TL-2149-1-76-43

JULY 1976

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES & ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

July 1976

TL No. 642149

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have reviewed and now submit for your information this final research report titled:

DEVELOPMENT OF BOREHOLE TV OPERATIONAL TECHNIQUES
A FINAL REPORT

Study made by . . . . Geotechnical Branch

Under the Supervision of . . . . R. A. Forsyth

Principal Investigator . . . . M. L. McCauley

Co-Principal Investigators. . . . . D. D. Smith
R. L. Bendixen

Report Prepared by . . . . R. L. Bendixen

Very truly yours,

George A Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment
RLB:bjs

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Mr. David Route, Geotechnical Branch, U. S. Bureau of Reclamation, Denver, Colorado, for providing innumerable suggestions on operating procedures and equipment design.

Special thanks is extended to Mr. Leroy Peters, California Transportation Laboratory for repairing and updating the electronic and video components of the borehole television system.

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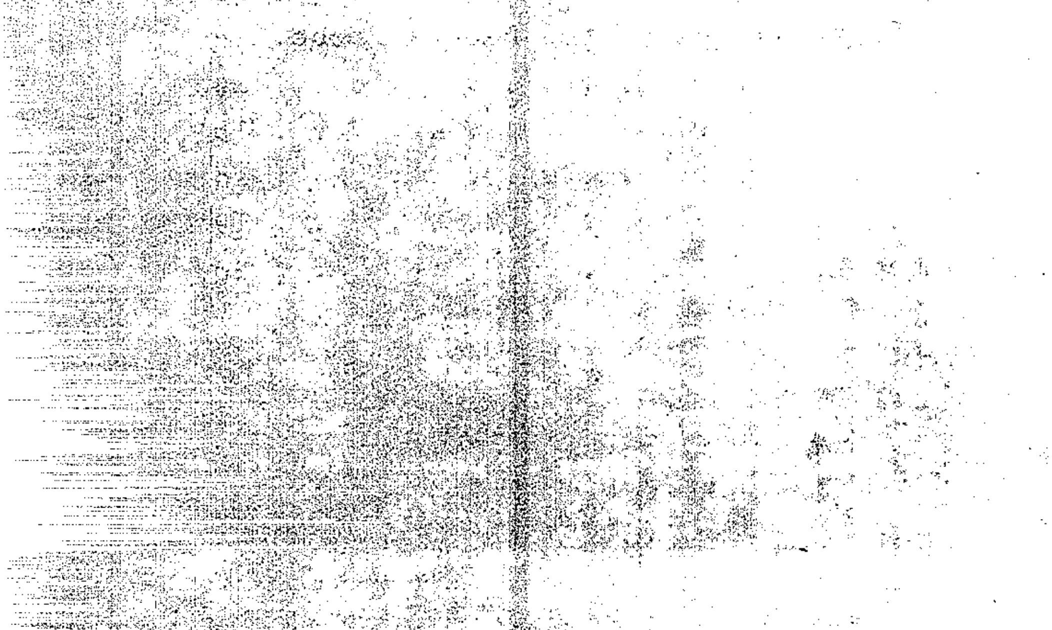


INTRODUCTION

The California Department of Transportation makes regular use of borehole data to determine the nature and condition of subsurface materials for the foundation design of highways and related structures. Although drilling and sampling provides essential information, it is an expensive procedure. Also, under adverse conditions, sample retrieval is minimal.

A borehole television system, if properly utilized, can supplement the expensive and time consuming sampling operation during a multi-hole investigation. It can be used to investigate regions of poor sample recovery and to determine the reasons for drill fluid loss. Cross-hole correlation can be made, reducing the amount of sampling required, and the attitudes of various planar structural features such as joints, fractures, and shear zones may be inspected and measured in situ. Horizontal boreholes and utility conduits can also be inspected for maintenance operations.

The objective of this study was to investigate and develop improved operational techniques for the optimum retrieval of subsurface data using a commercially developed, closed-circuit borehole television system. The study was performed by the Engineering Geology Section of the Transportation Laboratory. Results of the study will enhance the expertise and services available to all Transportation Districts and other State agencies.

Work on this project consisted of three phases:

1. An examination and evaluation of commercially available borehole or conduit investigative systems which incorporate a closed-circuit television. Included, were modifications and operational techniques used by the U. S. Bureau of Reclamation and U. S. Bureau of Mines with their Eastman Borehole Television cameras.

2. The construction of simulated boreholes which are used as instructional aids for the interpretation of textural characteristics and the measuring of planar features. They also provide controlled conditions to check the accuracy and capabilities of the instrument.

3. The development of a comprehensive operational manual which includes a maintenance and trouble-shooting guide for the various video, audio, and mechnaical components.

OBSERVATIONS AND CONCLUSIONS

Simulated Boreholes

Observations - Simulated boreholes fabricated from cut sections of PVC pipe offer an excellent opportunity to measure attitudes of random planar features and to determine the thickness of successive bedding planes. Textural features of materials applied to the pipe walls were difficult to interpret because the adhesives were absorbed by the fine-grained soil and flowed around the coarse sand and gravel. Glare, caused by reflections from the adhesives, could not be sufficiently minimized to allow the identification of fine-grained material or subtle textural changes. Different adhesives and textural materials were tried with poor results.

Blown-up photographs of different natural materials were viewed with excellent results. Coarse-grained material, fractures, and veins were easily identified. Soil and finer gained sands were grainy but textural and tonal differences could be identified. Measurements of some planar features were possible.

The cast concrete block resulted in the most effective simulation as it more closely resembled natural conditions, including rock appearance, reflectivity, tool marks on the walls, and relative size of features. Better viewing was possible when the walls were moist.

While using the above simulated boreholes, the operator develops a feeling for the probe orientation during the measuring sequence.

Conclusions - Simulated boreholes provide an excellent training aid in developing operational expertise. This familiarity with the equipment is essential for efficient and accurate field operations.

Instructional Aids

Observations - A video tape accompanied by annotated instructions show and describe the sequence and procedures required while orienting north and measuring strike and dip of simulated planar features. The observer had time between steps to make required measurements on the monitor screen and follow the progress with photographs in the accompanying instructions.

Conclusions - A video tape used in conjunction with annotated instructions is an excellent technique to train operators the measuring sequences for planar features.

Radial Probe

Observations - The orientation and attitude of planar features within a simulated borehole were measured with a hand held Brunton compass and compared against repeated measurements made with the radial probe.

Conclusions - Simulated boreholes offer controlled conditions to test the repeatability and accuracy of the measuring components within the radial probe. The following accuracy ranges were determined for the radial probe:

North Orientation	±2°
Strike	±4°
Dip	±1°
Mirror Rotation	2°
Inclination	±3°

Note: Accuracy of successive determination are dependent upon previous measurements.

Illuminating Systems

Observations - Existing illumination on the radial probe is insufficient for quality pictures and detailed observations in holes greater than 5" diameter. When used underwater, the amount of turbidity and diffusion reduces the useful range of the lights. The dual upper lights offer little benefit other than shadow control.

Internal illumination in the axial probe is totally inadequate and unreliable.

Conclusions - External illumination is essential for the optimum and efficient use of the borehole television system. A different lighting harness, with interchangeable lights, should be fabricated for both the axial and radial probes, the skid frames, and for either large or small diameter holes.

Both probes should be fitted with appropriate through-the-wall electrical fittings to power the lights, thus eliminating an auxillary down hole power cord.

Lights should be the low voltage (12-24 V) quartz halogen type, fitted with a light shield to protect the T.V. camera. The intensity may be regulated by a variable rheostat at the control panel. Power may be tapped from existing terminals within the control unit. Direct current (DC) should be used for the lights to avoid the electronic interference produced by alternating current (AC).

Operational Notes

Observations - Field and laboratory operations, resulted in frequent break downs which required substantial repair and modifications to the entire borehole television system.

Conclusions - Rigid adherence to the switching on-switching off procedure is mandatory.

Electronics within the television system are in poor condition and are unreliable. Much internal maintenance requires an electronics repairman experienced with television circuits.

The inclinometer seldom operates and is unreliable at best.

Operators who have had experience observing the simulated bore-holes have a better feeling for the investigative procedures under field conditions

IMPLEMENTATION

The knowledge and experience gained by the Transportation Laboratory on the operations, accuracy, and capabilities of the Eastman Borehole Television Camera will be incorporated into the existing exploration program for foundation and maintenance field investigations.

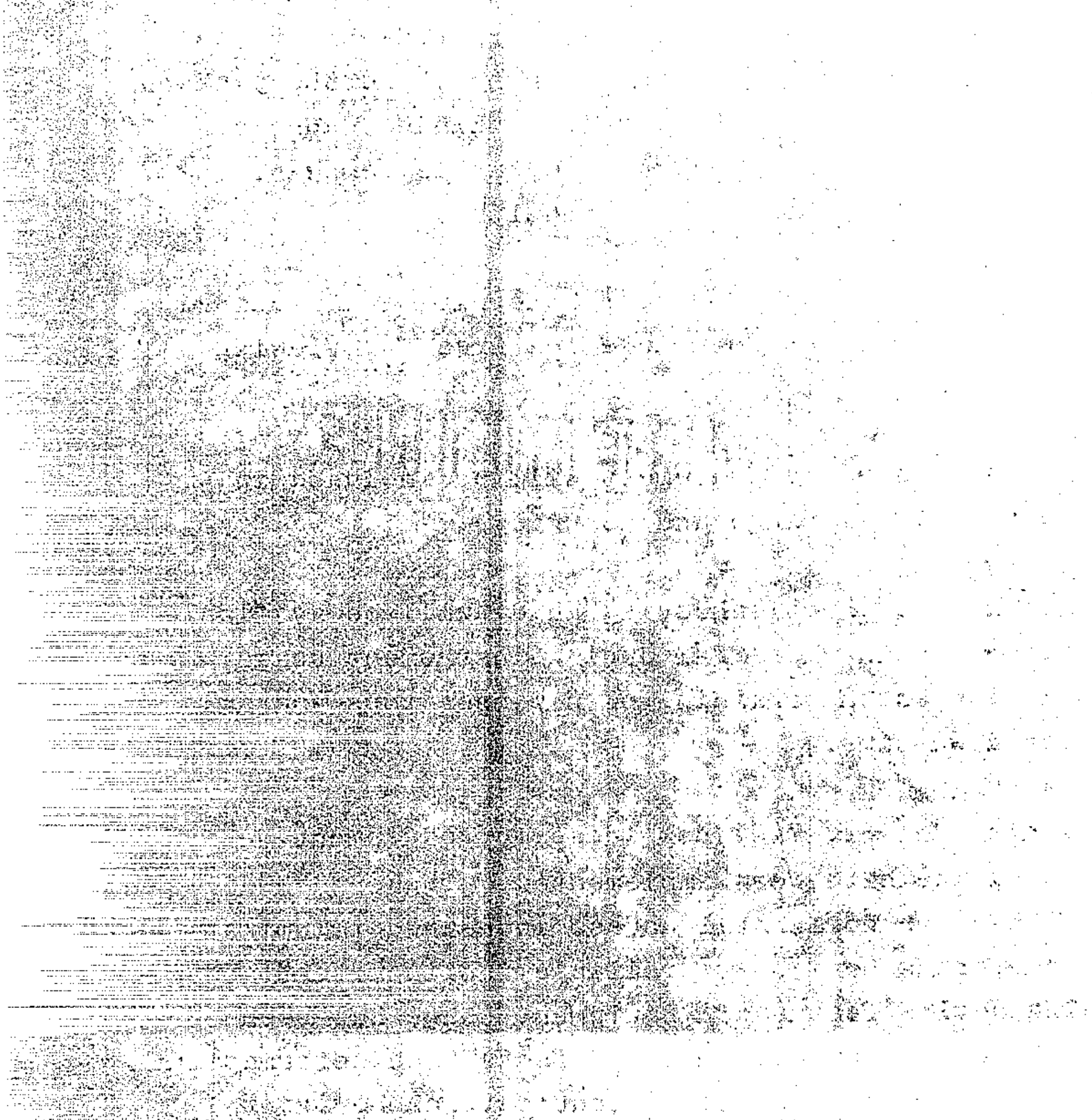
Expanded services to the Districts will be available by using increased illumination from external lighting packages. Holes up to 2 feet in diameter can now be investigated, and the picture quality has been increased in smaller holes. Expanded use of existing equipment makes the system more versatile, emphasizing its capabilities for use in horizontal conduits.

Users may receive a written log for each hole plus an annotated video tape record of pertinent down-hole features for viewing in their office.

When measurements are taken, a statement will be included in the report evaluating their range and accuracy.

An operations manual and troubleshooting guide will be available to the operator for instant referral during instrument usage. This will also assist in the training of new operators and reduce instrument down-time.

As a result of this project, many new ideas for equipment design, modification, and usage have been implemented. These include: skid frames and draglines for horizontal holes, increased illumination packages, hole centering devices, a reliable inclinometer, and improved lowering device features. Equipment usage has been expanded to check for blockage, breaks, offsets, and deformation in drainage culverts, sewers, utility conduits, and horizontal drains. In addition to the applied engineering functions, investigations of vertical holes include checking well screens and casings, locating perched water tables above the standing water level in uncased wells, and confirming contract obligations.



Background

Early in the project various commercial borehole and conduit investigative systems were reviewed to glean ideas regarding equipment modifications, field operation procedures, and customer requirements. Although these systems used either closed-circuit television or still photograph records, they were designed to investigate culvert or casing walls, not to measure the planar features important to engineering geologists. Suggestions were obtained from advertising brochures and systems owners regarding auxillary illumination, construction of horizontal skid frames, and techniques for investigating utility conduits.

A two day visit was made to the U. S. Bureau of Reclamation and U. S. Bureau of Mines in Denver, Colorado, in June 1974, to examine, photograph, and evaluate modifications and operational techniques they have incorporated into their Eastman Borehole Television Camera systems.

Internal modifications include a new inclinometer using an inclined, rotating accelerometer whose DC output voltage is calibrated in degrees of tilt. Internal illumination has been increased with some success. Newly designed or modified external equipment includes an auxillary illumination harness using an array of 110 V quartz halogen bulbs, various skid frames, borehole collar adaptors, conduit deflection indicators, and a powered lowering device for use with deep holes. A computer program is available from the Bureau of Reclamation for the reduction, analysis, and plotting of attitudes of planar features.

These organizations have a budget for new equipment and spare parts such as videcon tubes, television monitors, video tape recorders, and special vehicles to transport the borehole camera system. They are well equipped to investigate a variety of subsurface boreholes or conduits and to use their equipment extensively throughout the nation.

The Tennessee Valley Authority (TVA) in Knoxville, Tennessee, and the Corps of Engineers in Vicksburg, Mississippi, both have the Eastman Borehole Television Camera systems. They report problems with maintenance and reliability; primarily with the operation of the inclinometer.

Sperry Rand Corporation in Huntsville, Alabama, has recently completed a prototype Borehole Television Inspection System. This system was designed for the engineering geologist to observe and measure subsurface features. It incorporates the latest electronic and television components and is designed for easy operation and maintenance. The system was not available for inspection.

Simulated Boreholes

A series of simulated boreholes were developed to perform various training and testing functions; all had some degree of success.

Several simulators were designed using lengths of 4" diameter PVC pipe, ripped longitudinally for interior access and mounted vertically. The control cable was passed through a ceiling mounted pulley which allowed the radial probe to be raised or lowered through the simulator.

Planar Features

When a round borehole intersects an inclined plane, the planar feature appears as an ellipse on the walls of the borehole. The first design used ellipses of differing orientation, drawn on the inside of the pipe with black ink. This was only partially successful as the ellipses were not symmetrical and the semi-major and semi-minor axes were distorted.

This design was modified by cutting the pipe at different angles with a random orientation. Before gluing the pieces back together, the relative strike and dip of each plane was measured and recorded. Parallel cuts were used to measure thickness.

The white PVC pipe was highly reflective, producing glare on the monitor screen. Subsequent application of photographic non-glare spray to the interior of the pipe greatly reduced this problem.

This modified design worked very well for measuring attitudes of planar features and determining their thickness.

Textural Features

Combinations of silt, sand, and gravel were glued to the insides of the split PVC pipe, simulating various inclined layers of interbedded sediments. This system was not successful because the bonding agents were absorbed by the finer grained material and flowed around the coarser grained sand and gravel. The high reflectivity of the adhesive caused too much glare on the monitor screen which prevented the identification of subtle textural changes. The use of non-glare photographic spray and different bonding agents did not help.

Close-up photographs were taken of planar features (joints and veins) in outcrops of fresh granite, decomposed granite, sandstone, slate, and soil. Photos were enlarged and printed with a mat finish on a 9 x 9 inch format. Two prints were made, one with the negative upside down, thus producing mirror images of the same feature. Planar features were matched and the prints glued inside the PVC pipe.

Views of the granites, sandstone, and slate were excellent and allowed detailed evaluation of a variety of textural, tonal, and structural features. Soil photos were very fine grained and lacked planar features; however, tonal and textural features could be identified even though the television quality was poor.

The most successful simulated borehole was made by casting large rocks within 2 foot square concrete blocks, and subsequently coring a 4 inch diameter hole through both blocks using a trailer mounted Acker pavement drill. After one block was set on top of the other, with the boreholes in close alignment, the radial probe was raised and lowered through the blocks. Voids, veins, joints, spauled sections, and rock types were all visible and readily identifiable. Several veins were ideally situated to practice measuring the attitudes and thickness of planar features under natural conditions.

A video tape of this simulated borehole has been recorded showing the different steps to measure attitudes of planar features. Sufficient time is spent on each view to allow the "operator trainee" to make his measurements. Audio instructions describe procedures and alternate solutions, and point out problem areas. An instruction book with photographs, accompanies the video tape.

This simulator is very successful in providing the opportunity to interpret textural features and to practice mechanical operations of the entire borehole television system at the laboratory. The blocks are quite heavy and must be moved by forklift; however, once set up they are always accessible.

Testing the Measuring Capabilities of the Radial Probe

After repeated observations of the same planar feature in the simulated borehole, a range of measured values were obtained. This research project was then expanded to include a determination of the capability and repeatability of measuring systems within the radial probe. The actual measuring operation was reviewed and steps which would affect or influence final results were analyzed, including: mirror activation distance, north orientation, strike, dip, and inclination.

The mirror rotation dial controls the servo-motor which rotates the inclined mirror; this is the basis for all measurements. There is approximately 2 degrees of play in the dial before the servo-motor is activated, which, if not recognized, will introduce an error at each separate dial rotation. This error can be minimized by always rotating the mirror in the same direction during measuring operations.

Proper north alignment is indicated by the appearance of a small light located just above the black partial radius line on the inclined mirror. The light is supplied by the main illumination bulb when holes in both the compass card and inclined mirror are aligned. Too much illumination causes a broad flare making the north determination difficult and grossly inaccurate. Generally north can be determined to within ±2 degrees, as checked by a Brunton compass.

Direction of strike is normal to the semi-major axis of the ellipse figure formed on the borehole wall. Ellipses formed by a high angle dip have a sharply defined semi-major axis, approaching a point. Likewise, if the dip angle is low, the ellipse figure approaches a circle and the semi-major axis is difficult to identify.

Accuracy of strike can be measured to within ±4 degrees for planes dipping greater than 10 degrees, while accuracy of ±5 to 8 degrees is common for planes dipping less than 10 degrees. These values are also affected by the accuracy of the north determination.

Angle of dip is measured with a protractor on the monitor screen as the mirror is directed toward the semi-minor axis of the ellipse. Accuracy to within ± 1 degree is possible, however, the dip must be measured relative to the bottom of the probe. True angle of dip must be corrected for borehole inclination.

Inclination is measured as the maximum deflection of an internal pendulum and monitored on a meter calibrated from 0-90 degrees. The scale is non-linear with 1 degree divisions from 0°-40° and 2° divisions between 40°-90°. Repeated observations at various degrees of tilt suggest that the inclinometer is more accurate when the probe is near vertical than when approaching horizontal. The inclinometer checks to within ± 3 degrees.

Operations Manual

An operational manual has been compiled to assist the field operator and to ensure a proper operational sequence. Hopefully, compliance with this manual will reduce equipment breakdown and facilitate instrument repairs.

It describes the various components, assembly, positioning, and basic operating procedures. The maintenance section provides photographs and descriptions of the maintenance and assembly sequence for all components, and potential problems of which to be aware.

A detailed discussion follows describing the sequence and procedures for setting north and measuring inclination, strike, and dip.

An appendix includes a troubleshooting guide for both electrical and mechanical equipment, a fuse correlation guide, and manuals for all electronic components used with the system. Also included are: general hints for field operations and borehole preparation, equipment check lists, and sample borehole logs.

This manual is presented in a looseleaf binder with mylar sheet protectors. Room is available for comments and additions. The manual will be kept with the borehole television equipment and used as a guide during field operations.

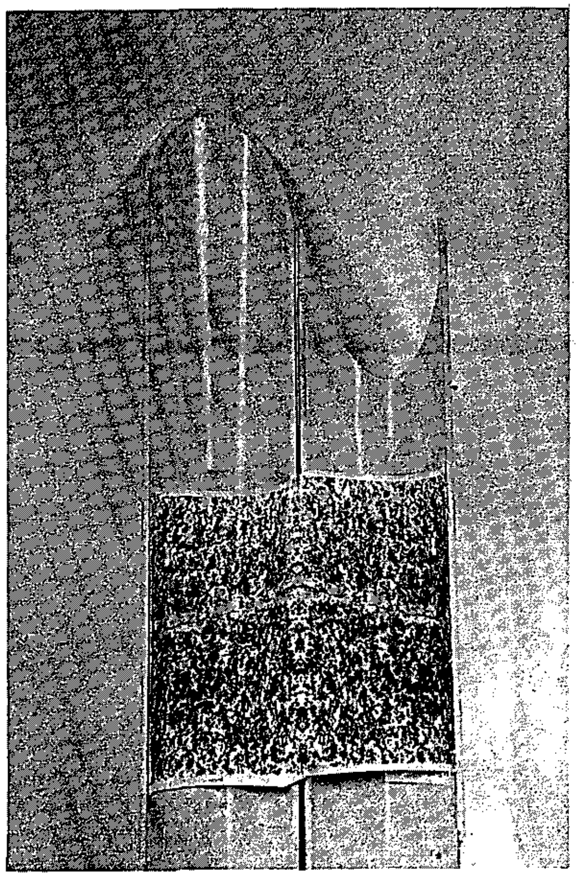


Figure 1 Simulated borehole. Note the random orientation of various planar features, and the ellipse figures for steep and shallow dipping beds

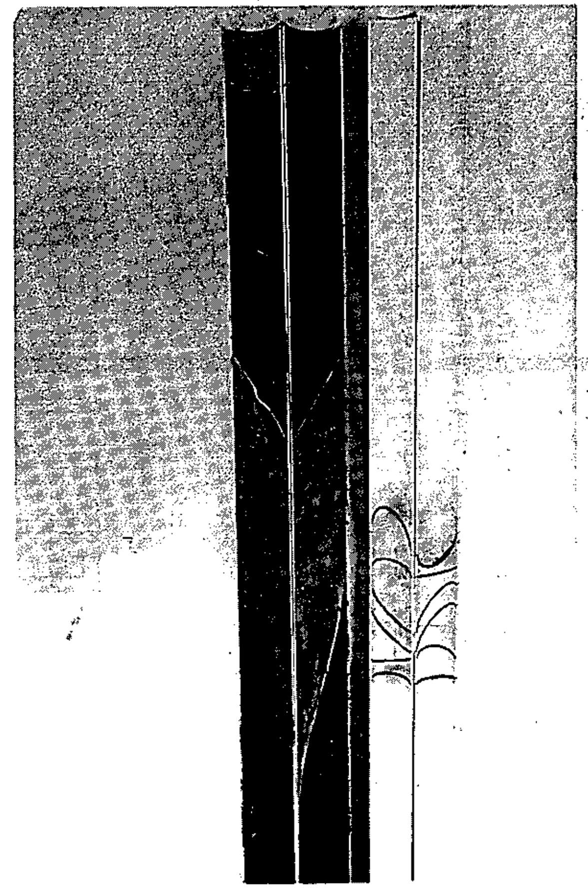


Figure 2 Simulated borehole. Different textural material applied to the borehole walls; and mirror image photographs

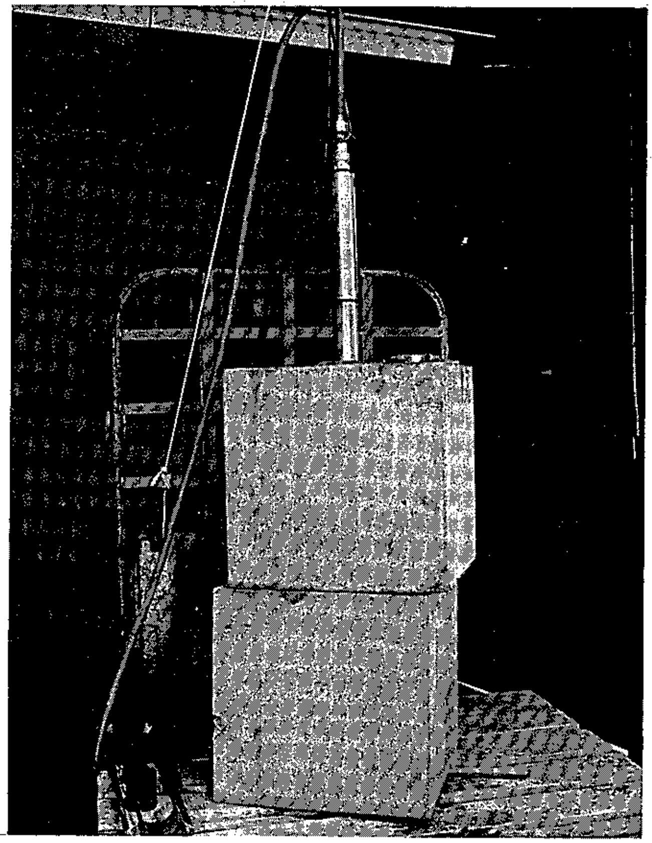


Figure 3 Radial probe in position over "cast concrete" simulated borehole

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APPENDIX I

EASTMAN BOREHOLE TELEVISION CAMERA

OPERATIONS MANUAL

DESCRIPTION OF EQUIPMENT

External Equipment

- I. Generator
- II. Control Cable
- III. Lowering Device
- IV. Borehole Probe
  - a. Axial
  - b. Radial
- V. Dummy Probe
- VI. Overshot Retriever
- VII. Horizontal Skid Frame

Internal Equipment

- I. Power Unit
- II. Control Unit
  - a. Illumination
  - b. Depth Counter
  - c. Mirror Rotation
  - d. Inclinometer
  - e. Moisture Indicator
- III. Intercom
- IV. Video Tape Recorder
- V. Video Television Monitor

Systems Operations

- I. Pre-Turn On
- II. Turn On
- III. Standby
- IV. Turn-Off

Methods for Measuring Planar Features

- I. Discussion
- II. Vertical Borehole
- III. Inclined Borehole
- IV. Horizontal Borehole
- V. Notes on Procedures

Equipment Maintenance and Assembly Television Mini-Camera

I. Removal of Camera from Probe
II. Removal of Camera from Its Housing
III. Changing Vidicon Tube
IV. Mechanical Focus Adjustment

Control Cable Connections

Axial Probe

I. Camera
II. Axial Probe
III. Control Unit

Radial Probe

I. Central Section
   a. Disassembly and Access to Panorama Window
   b. Changing the Large Bulb
   c. Interchanging the Magnetic Compass with the Weighted Compass Card
   d. Reassembly of Central Probe
II. Inner Probe Section
   a. Moisture Detection System
   b. Servo-Motor
   c. Wire Bundle and Slip Ring Contact
   d. Removal of Inner Probe from Upper Housing
   e. Small Dual Lights
   f. Reassembly of Inner Probe
III. Lower End Section
   a. Access to Dessicant Canaster

Field Techniques

I. Hole Preparations
   a. Boreholes
   b. Conduits
II. Video Tape Recorder and Television Monitor

Component Layout-Borehole T.V. System

Equipment Check List

Fuse Correlation Guide

Borehole Television Log

Magnetic Declination Correction Tables

Operating Instructions

- Videocorder AV-3650
- Videocorder AV-3600
- Videomonitor PVM-900

EXTERNAL EQUIPMENT DESCRIPTION

I. Generator

The portable power plant must be large enough to provide sufficient power, constant voltage, and minimal fluxuation of frequency. A 4 kw unit is recommended as a standard.

Locate the power plant at least 50 feet away from the borehole, preferably on the opposite side of the vehicle for noise control. The extension cord should be of at least 12/3 wire with twist lock connectors. The generator frame should be grounded.

The following equipment should be available at the site:

Gasoline in a safety can.
Engine oil.
Fire extinguisher.
Rags.

II. Control Cable

The coaxial control cable weighs 1/3 lb per foot and should not be bent to a radius less than 15 inches. Three cable lengths are available; 1300 feet, 450 feet, and 250 feet, complete with connector heads, adaptors, and storage reels (Figure 4). For convenience the shortest length possible should be used.

The electrical impedance of the cable is dependent upon its length and is matched to the television's electronics by a cable length selector switch located inside the control unit.

Preparatory to investigating a borehole, unwind a sufficient length of cable from the reel equal to the hole's depth plus an extra working length. For shallow holes the cable may be streached out on the ground surface. Deeper holes, in excess of 100 feet, should have the cable looped into a series of large overlapping figure eights. Before use, the entire loop must be flopped over.

If the cable becomes streached or worn by use, it may be switched end for end, and rewound onto its reel.

Keep the protective caps on the cable heads when it is not in use.

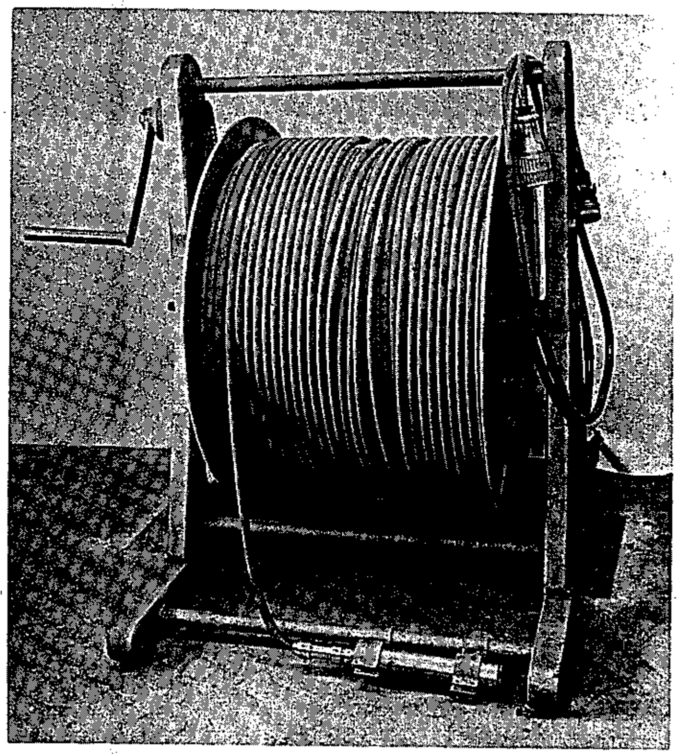


Figure 4 1300 Foot Control Cable and Reel

III. Lowering Device

The lowering device is used both for a controlled instrument lowering system and for an automatic depth counter. It is also linked to the control unit with an intercom system.

Position the lowering device over the borehole collar with the small tension pulley directed towards the cable supply. Adjust the leg height for stability (Figure 5).

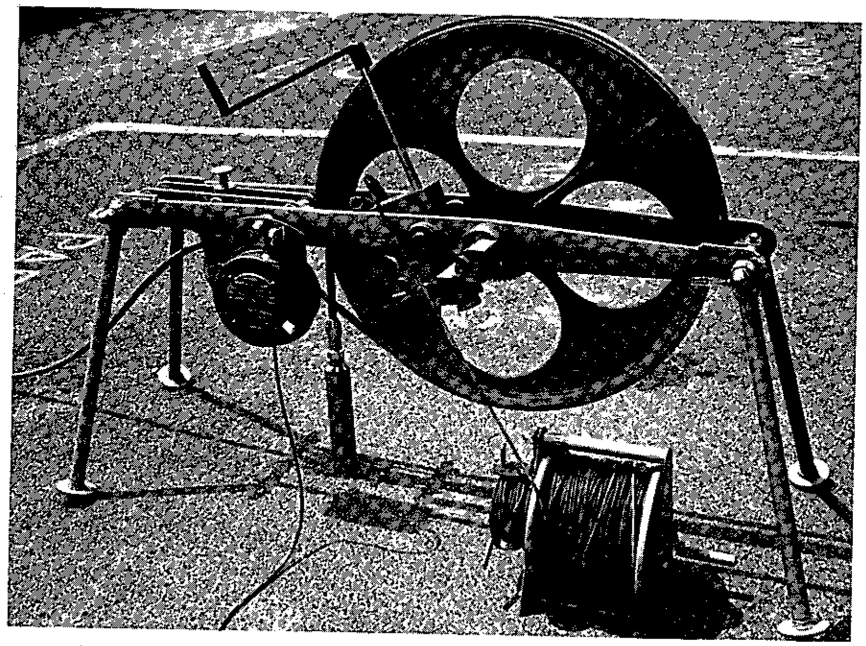


Figure 5 Lowering Device showing control cable, intercom and depth counter cable. Spool-like knob beneath crank handle is for cable tension adjustment.

Before attaching the probe, thread the control cable around the pulleys and secure the top strap to the frame. Position the tension pulley, insert its axle, and secure the metal side plate with four bolts (Figures 6, 7, 8).

Adjust the cable tension knob towards tight. Engage the worm gear drive to prevent the large counter wheel from free wheeling.

Connect the depth counter reel.
Connect the communications reel.

Connect the probe to the cable head, insert it into the borehole, and adjust the external focus.

The camera must be protected from bright sunlight at all times!

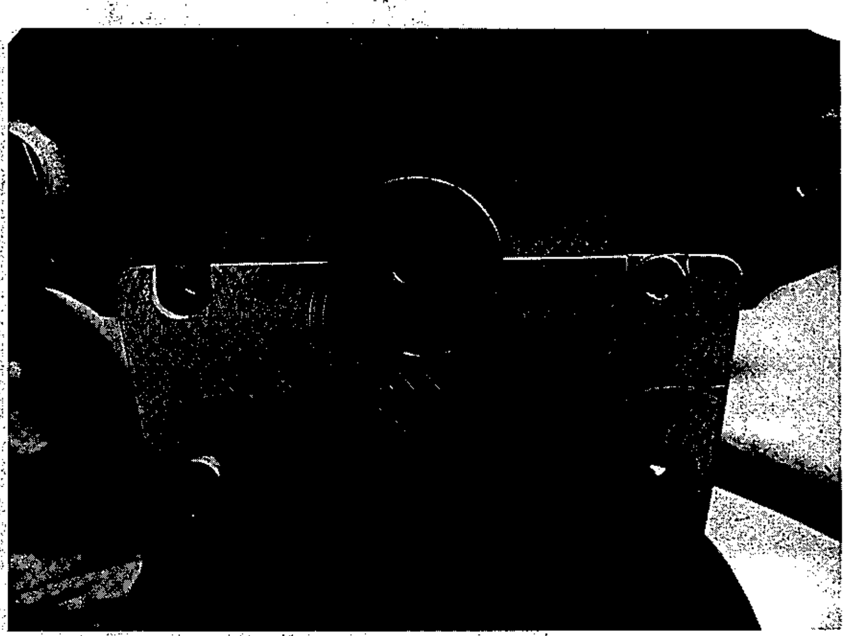


Figure 6 Knurled nut holding the axel for the tension pulley

Insert the probe into the borehole.
Adjust the probe elevation so the viewing window is at zero elevation, generally located at the top of the collar.

Set the depth counters to zero on the lowering device and on the control unit.

Set the depth indicator switch to DOWN (Figure 9).

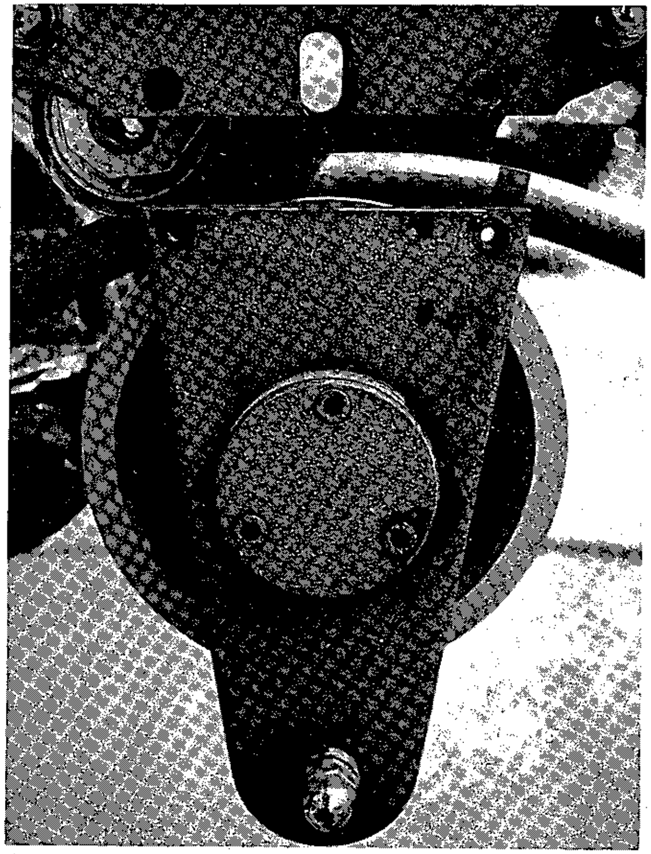


Figure 7 The control cable and tension pulley before being secured in place.

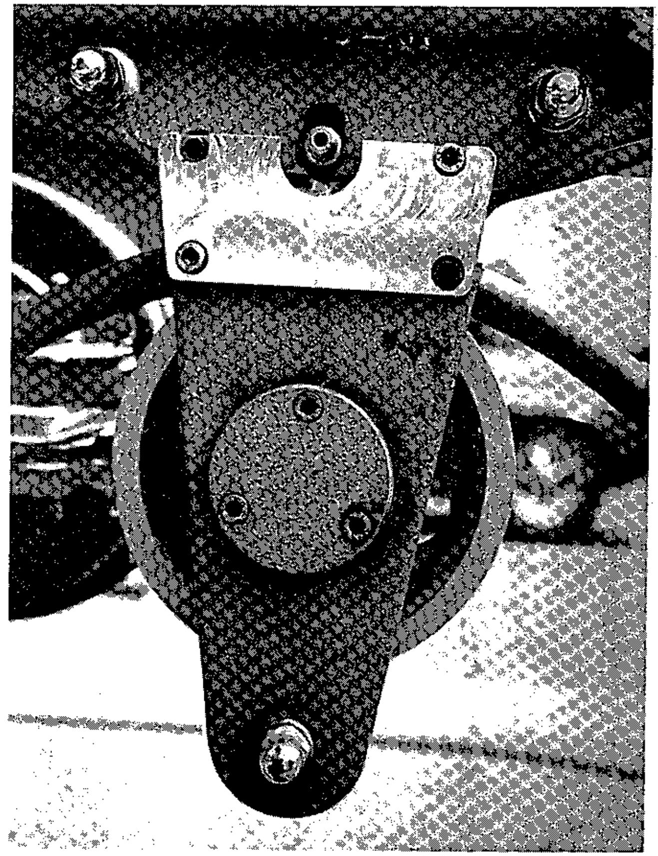


Figure 8 The axel for the tension pulley and the metal side plate in position.

Check that the control cable does not rub or chaff against the borehole collar. Inclined holes may require additional roller surfaces for proper cable alignment.

Lowering speed should be approximately 60-90 ft/hr or 1-1/2 ft/min for simple scanning of a borehole.
One rotation of the large wheel equals 9 feet of cable.
Crank with an even, smooth motion avoiding jerks.

When removing the probe from shallow holes, it is easier to hold the cable, disengage the worm drive gear, and walk the cable out of the hole.

During windy weather, drape a rag over the external speaker to minimize noise transmitted to the observation cab.

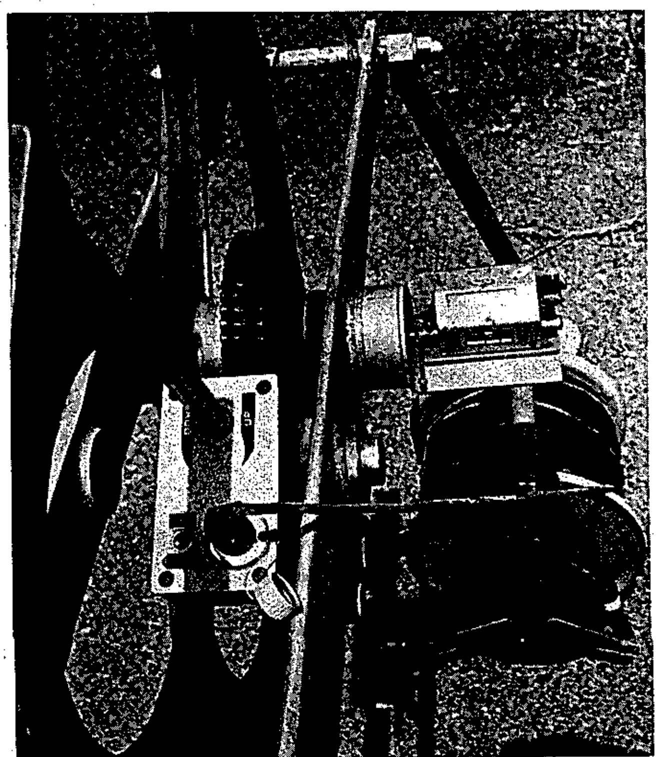


Figure 9 Worm gear drive, mechanical depth counter, direction switch and cable reel for electrical depth counter to control unit. The worm gear drive is disengaged by a lever located beneath the worm gear.

IV. Borehole Probe

Two different probe assemblies are available and interchangeable with the television camera equipment. The axial probe has a bottom mounted lens which provides a in-line view of the borehole and a portion of the sidewall. The radial probe has a side mounted panorama window and scans the sidewall using a rotating mirror.

a. Axial Probe

The axial probe (Figure 10) is ideal for reconnasiance surveys of boreholes, wells, sewers, and pipelines because of its small size, light weight, and general portability. The entire sidewall of the hole is visible as the axial probe advances, thus, no small but important feature will be missed. During the survey a log should be maintained, noting features that should be inspected in greater detail when using the radial probe.

The conventinal lighting system provided with the axial probe is inadequate. External mounted, auxillary lighting using quartz halogen bulbs are recommended (Figure 11).

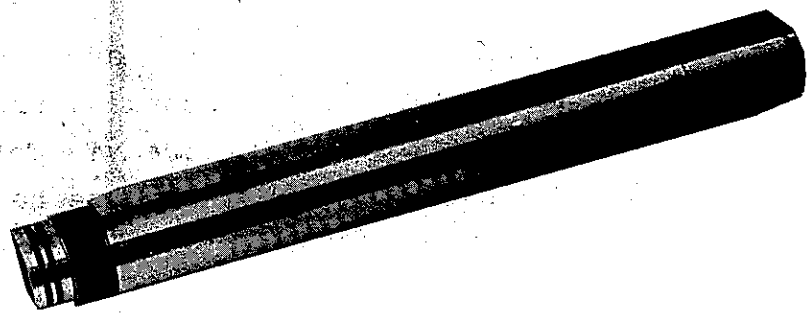


Figure 10 Axial view borehole probe.

The mechanical focus must be adjusted before the camera is inserted into the axial probe as no external focus is available.

The standard lens system is used in 4-8" diameter holes. Larger holes require the telephoto lens system, which includes a spring-loaded light shield.

External lighting must be adjusted to illuminate the portion of the hole being investigated, at the same time being shielded from the camera lens.

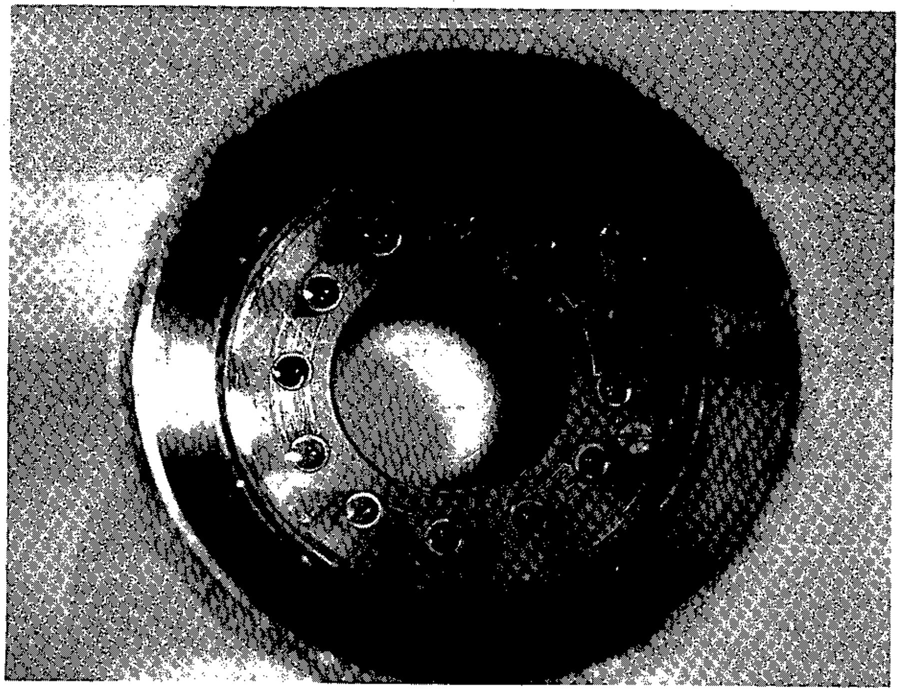


Figure 11 Close-up showing the front of the axial probe. Note the 12 mini lights and the center space for the TV camera lens.

b. Radial Probe

The radial probe contains the camera, lights, and various directional and tilt measuring devices (Figure 12). It is designed to provide a partial sidewall view of the borehole, reflected off an inclined, rotating mirror to the fixed-mounted camera. Because the camera is fixed and the mirror rotates, the picture viewed on the TV monitor revolves about the center of the screen. This is a design feature to which the operator and interpretor must adapt. The bottom of the probe is always indicated by a black partial radius line scribed on the mirror and viewed on the monitor. North direction may be determined. The scale and area of the viewed surface depends upon the hole diameter, how close the probe is to the side being viewed, and the screen size of the viewing monitor.

As the probe is being lowered, the camera-mirror can scan the walls, which in effect, provides a continual spiral view of the borehole walls. If the probe is lowered too fast and the scan rate is too slow, portions of the wall will be missed. This is the advantage of first logging the hole with the axial probe, and consulting that log while viewing with the radial probe.

Internal lighting provided with the radial probe is just adequate in 6 inch holes above the water. Larger holes or underwater, externally mounted, auxillary quartz halogen lights should be used.

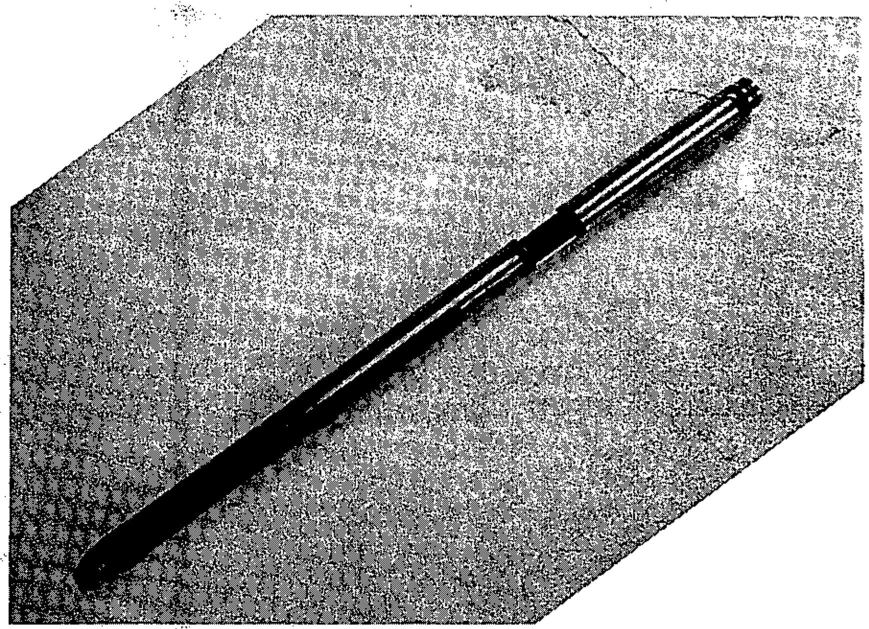


Figure 12 Radial view probe. Notice panorama window, inclined mirror, and internal lights.

During a field investigation be aware of the following conditions and problems:

Dry deseccant
Lubricate and secure all O-rings and fittings

Clean windows inside and out.
Avoid sudden shock.
Transport horizontally in shock mounted box.
Keep panorama window covered and camera protected from direct sunlight or strong artifical light.
While in operation check the following:

- external focus - secure plug
- scale of picture
- mirror rotation
- compass operation
- illumination
- inclinometer

Record depth to top of ellipse of planar features while recording:

- Don't scan too fast.
- Don't lower probe too fast.

Reorient north before each attitude measurement.
If one of three support bars is blocking the field of view, have the lowering operator twist the cable by hand.
Occasionally check that the mechanical and electrical depth correspond. A correction factor may be required for the electrical counter.
Beaware that scan direction and minor dial rotation coincide.
Manipulate the dial so they both rotate in the same direction.
Provide auxillary external lighting for larger diameter holes.
Turn off lights and allow them to cool before probe enters water.

Mechanical Focus Procedure (Radial Probe)

Conditions: Power on
Camera operating
Lowering device positioned over hole

Secure target to sidewall of hole.
Insert probe into collar of hole.

Lower probe so window is below collar and focus access screw is still accessible.
Remove focus access screw (Do not drop into hole).
Center probe in hole
Place rags around collar and upper probe to block out light.
Mechanically focus camera with screwdriver.
Check scale and its variation by moving probe to either side of the hole.
Record "scale check" on video tape.
Lubricate and reinstall access screw.

Target:

Draw a series of crosses, boxes, and circles on a clean sheet of 8-1/2 x 11" paper using a wide, black felt pen.
Target design should include a vertical and horizontal scale in inches or tenths.

V. Dummy Probe

An investigation is occasionally required of a small diameter hole or one that is suspected of sloughing or caving. Under these circumstances a dummy probe which is the same size, shape, and weight as the radial probe is used to test the hole.

The dummy probe is connected to a small diameter wire cable by a special cable head (Figure 13). It is raised and lowered by a tripod mounted reel and winch system mounted directly above the borehole collar.

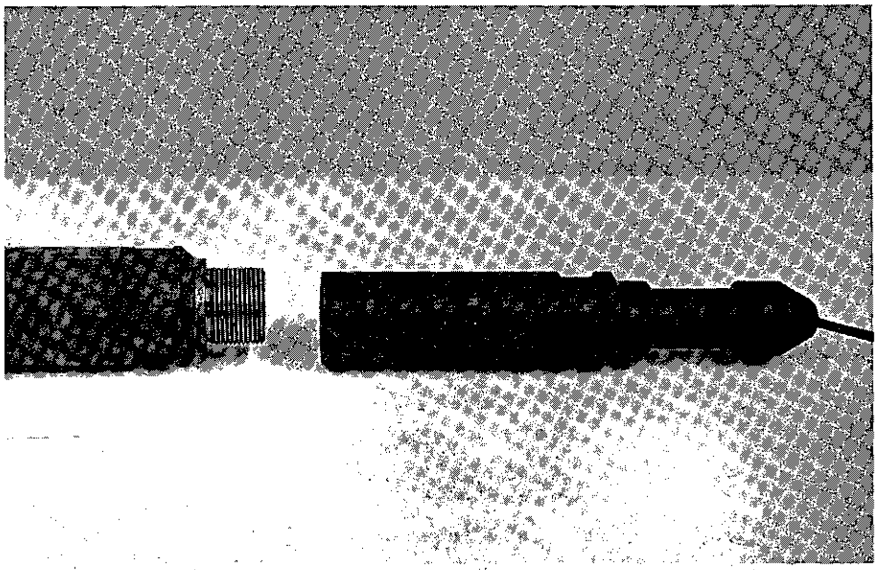


Figure 13 Top of dummy radial probe showing wire cable and special cable head.

VI. Overshot Retriever

If either the radial or axial probe should become stuck in a borehole, first try to determine why or how it is being held. Hauling on the control cable using continual pressure, hard jerks, or even a twisting motion could free the probe. If all other attempts fail to dislodge the probe, an overshot assembly should be used.

The overshot assembly is attached to the base of the dummy radial probe. Remove the weighted end piece from the dummy probe, replacing it with the overshot guide sleeve. Slide the jaw assembly into the guide sleeve and secure to the base of the dummy probe with two bolts (Figure 14).

The overshot probe can be raised and lowered using either the standard wire cable and winch or drill rod and special adaptor.

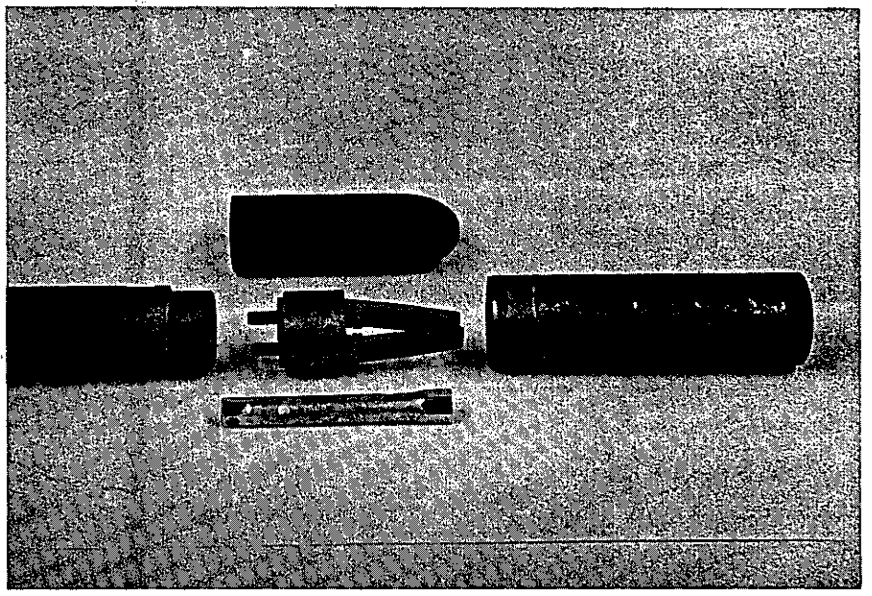


Figure 14 Overshot assembly aligned with base of dummy radial probe. Probe base has been removed.

Preparatory to retrieval, turn off the power to the entire borehole TV system. Pull the control cable loose from the stuck probe. At least 600 lbs tensile pull is required for separation. Remove the control cable from the hole. Lower the overshot assembly into the hole and attempt to engage the probe with the spring loaded jaws. If the recovered probe has been underwater it must be opened up, flused with alcohol, and thoroughly dried.

VII. Horizontal Skid Frame

The borehole television probe is often mounted on a metal skid frame during the investigation of concrete or metal culverts, sewers, or pipelines. It prevents excessive wear to the probe housing, keeps the probe from rolling longitudinally in the culvert, and provides a mount for external lights. Both the axial and radial probes may be used with a skid frame and are attached by hose clamps (Figure 15).

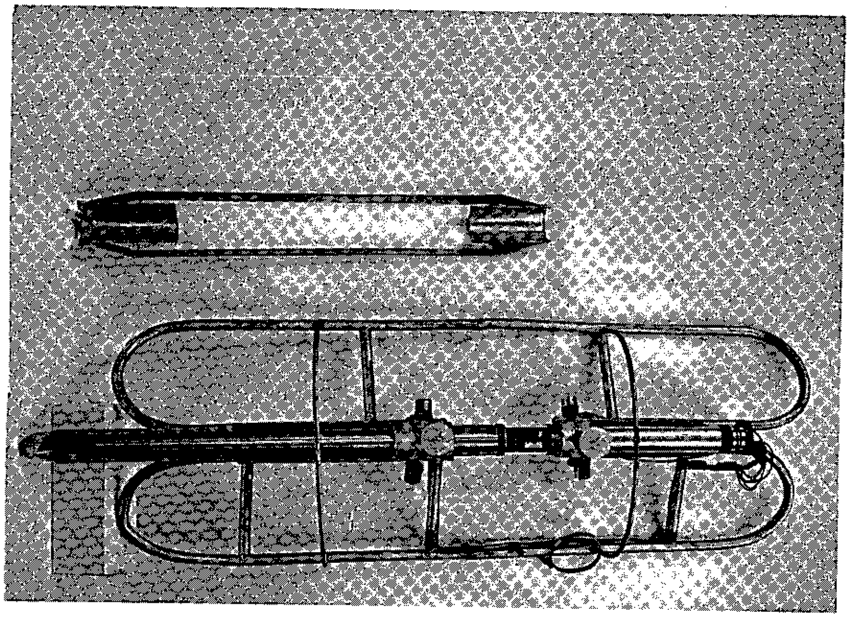


Figure 15 Horizontal skid frame with the radial probe

The probe may be pulled through the culvert by a previously installed cable or pushed by sectional rods. The haul cable should be conected to the skid frame by a swivel. An adaptor is available to connect rods to the rear of the probe. During the investigation the probe's location is determined by depth markings on the control cable or on the haul cable.

An external light source should be used in holes with a diameter greater than 6 inches. The light may be mounted on the skid frame or on the probe housing, but must be shielded from the camera lens.

I. Power Unit

The power unit converts external 110 V 60 Hz power to 220 V 60 Hz power which operates the control unit and television camera. The unit is turned on by the main switch. Output voltage is monitored on the face-mounted voltmeter. Input voltage is checked by pressing the black button below the voltmeter. Output voltage is adjusted by the screw-dial located right of the voltmeter (Figure16). Frequency is checked with a frequency meter connected to terminals beneath the voltage regulator adjustment control.

The power unit is fused to prevent overload by too much or too little external power. This occurs frequently if the power generator is not large enough. Remember to carry extra fuses!

This unit generates heat. Keep the surrounding area clear to allow ample ventilation.

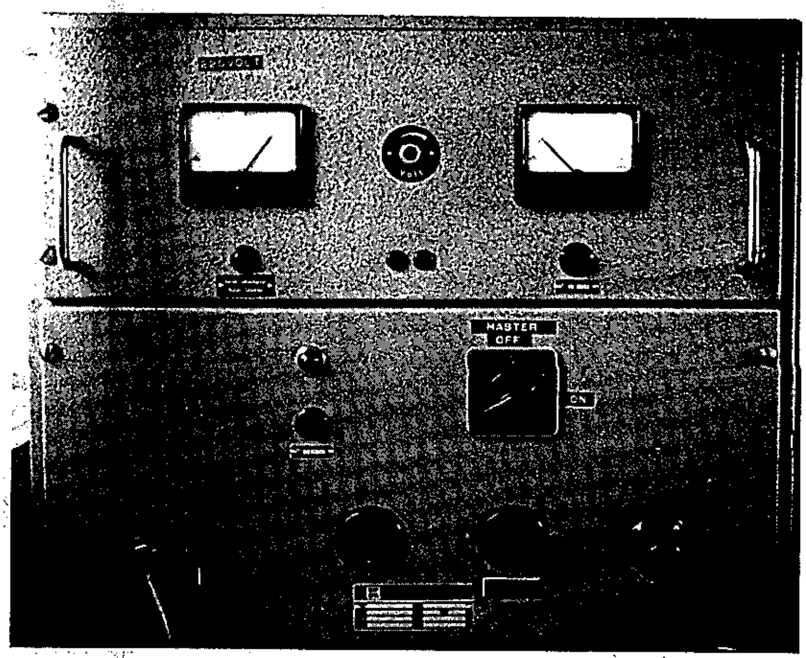


Figure 16 Power Unit. The three lower right plugs are for 220 volt output.

II. Control Unit

The control unit distributes power, signal, and switching for most components within the borehole television system. The front panel (Figure 17) consists of the main switch, accessory switches and meters, fuses, and the television camera controls.

On the back are recepticals for power, control cable, television signal, depth counter and communications (Figure 18). Inside, accessible through the right side panel, are the selector switches for using the axial or radial probe and various cable lengths (Figure 19). The right door panel contains much of the electronics controlling the television system.

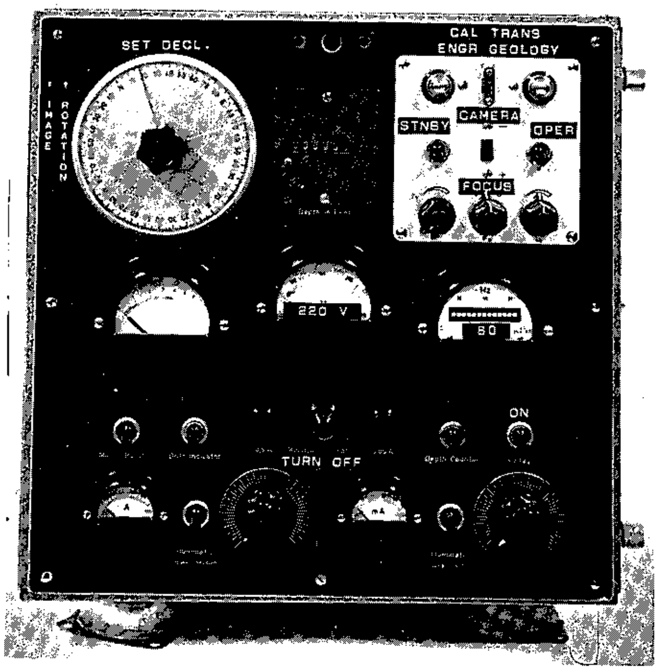


Figure 17 Front panel of the control unit

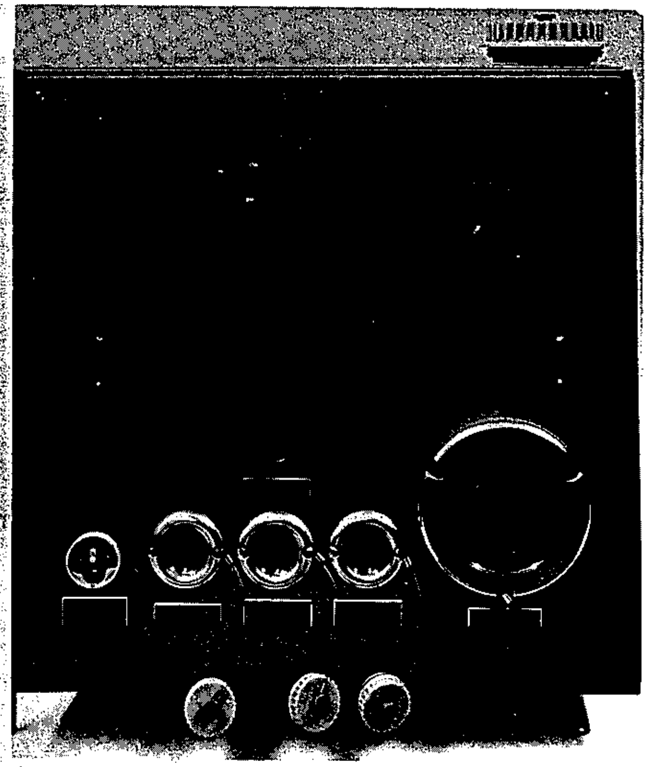


Figure 18 Back panel of the control unit.

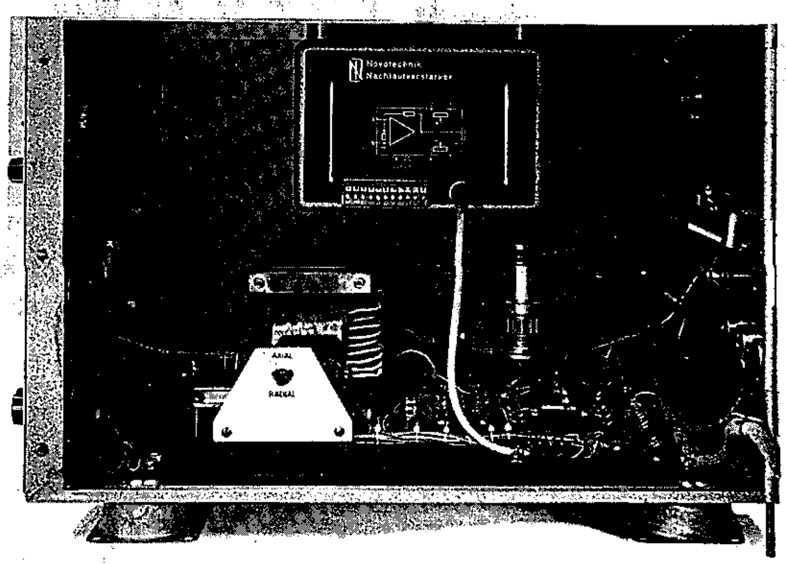


Figure 19 Inside the control unit. Notice the axial/radial switch and cable length selector.

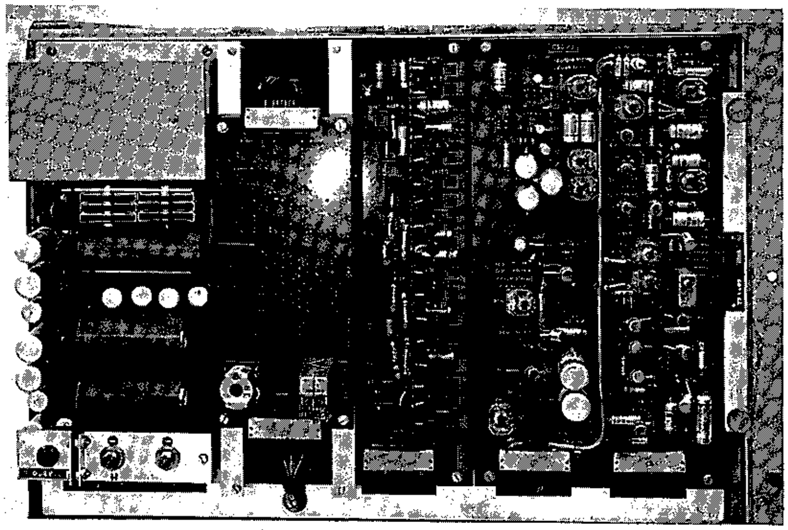


Figure 20 Inside the control unit's right access panel. These are controls and adjustments for the TV camera.

a. Illumination

Both borehole probes are provided with internal illumination systems. Twelve mini bulbs encircle the face of the axial probe and are controlled by the Lower Illumination Switch and rheostat. The radial probe uses one large main bulb, Lower Illumination, and two mini bulbs, Upper Illumination. Power to the lights should not be increased beyond their limits as indicated by the red line on their respective meters. If the bulbs burn out it is a time consuming process to change them.

The illumination system is designed to operate in or out of water, however its efficiency decreases rapidly with increasing turbidity. As the probe approaches the water level the lights should be turned off and allowed to cool before submerging. Once underwater the lights can be turned on.

Auxillary lighting, externally mounted to the probe, is available. This 110 volt, 500-1500 watt system using quartz halogen bulbs is required in larger diameter boreholes. Other illumination packages are available using lower voltage, smaller sized bulbs.

b. Depth Counter

Two independent depth counting systems are incorporated in the lowering device. Both indicate how much cable has passed over the large friction wheel. A false probe depth may be indicated if the borehole is not vertical or if the cable has slipped on the pulleys.

A mechanical counter is attached directly to the axel of the large friction wheel. When the wheel turns in either direction, the counter is activated and displayed at the lowering device.

An electrical counting system is displayed at the control unit and is activated by turning the lowering crank. This system only works when the worm gear drive is engaged. The direction switch must correspond to the cranking direction.

Occassionally the depth indicated on the two systems does not match. This is usually caused by the outside operator forgetting to trip the counter's direction switch. Coordinate the counters by disengaging the worm gear drive and manually adjusting the probe's depth until the mechanical counter matches the electrical counter. Engage the worm gear drive before continuing.

Both counters are accurate to about 0.1 foot. One revolution of the main friction wheel of the lowering device is nine feet. Null both counters when the window is at the surface zero point, usually the collar of the borehole. Check that the counter has returned to zero when the probe is pulled back to the surface.

c. Mirror (Image) Rotation

The inclined mirror in the radial probe is rotated by a servo-motor and controlled by the mirror rotation dial located on the control unit. Behind the mirror dial is a moveable bezel graduated as a compass. The camera is fixed-mounted and views the borehole sidewall through the inclined mirror. This causes the image displayed on the monitor to revolve around the center of the screen. Bottom of the probe is defined by a black partial radius which is scribed on the mirror and revolves with the picture.

The system is turned on by the mirror rotation switch. Scan direction is activated by the mirror rotation dial.

Procedures to orient north measure attitudes are discussed in the section "Measuring Planar Features".

d. Inclinometer (Drift Indicator)

The attitude of a planar feature is measured relative to the axis of the intersecting borehole; therefore the direction (azimuth) and inclination of the borehole must also be measured.

The system consists of a pendulum and variable rheostat mounted longitudinally in the probe, and rotated by the servo-motor. As the radial probe is tilted the pendulum is offset and the variable DC voltage is monitored at the control unit as degrees of tilt or inclination.

The operation of this system is described in detail in the section entitled "Measuring Planar Features".

e. Moisture Indicator

A red moisture indicator warning light and buzzer is located below the volt meter on the control unit. The moisture sensor is located in the base of the radial probe, just above the disiccant package. If moisture enters the probe and is detected, the warning light and buzzer will activate immediately. Turn the power to the control unit off. Hopefully, this will prevent the television camera and other electrical systems from shorting out. Return the probe to the surface and check for interior moisture. If wet inside, flush thoroughly with alcohol and allow to dry. Change or reactivate the desiccant package. Check the probe for leakage.

III. Intercom

An intercom provides direct communications between the lowering device operator and the control operator. Often they are separated by a substantial distance.

The television picture of the borehole is often recorded on videotape. Extraneous outside noise from the operator's intercom can be eliminated if the speaker is bypassed and connected to one side of a dual channel earphone. The other side is used to monitor the comments recorded on videotape.

IV. Video Tape Recorder

A borehole investigation should be recorded on videotape. The present system incorporates a Sony 3650 Videotape recorder which is capable of audio and video dubbing, slow and stop motion playback, and can record from a television camera, a television monitor, or another videotape recorder.

Prior to investigating a borehole the following should be recorded on videotape, preferably during the focusing/scale determination operation which is also recorded:

Job Title	Hole Number	Crew Members
Location	Run Number	Others Present
Date	Time	

Generally the axial probe is used first to perform a reconnaisance survey of the borehole. This can be done quite rapidly, and the entire sequence should be recorded on videotape. Scanning the entire hole with the radial probe is time consuming so only important areas should be recorded. The control operator should continually describe his interpretation of what is being viewed and frequently state the depth of the probe.

Dual channel earphones are used to monitor the intercom and must be used to monitor the audio portion of the video tape, since the videotape recorder is not equipped with a speaker. The microphone should have an OFF/ON switch which helps minimize extraneous noise.

Figure 21 Back panel of the Sony 3650 videotape recorder.

V. Video Television Monitor

Two nine inch television monitors (Sony PVM-900) (Figure22) are connected to provide direct monitoring of camera and videotape playback. A third monitor is available as a spare, or may be placed outside, near the lowering device, so the lowering operator can better judge the lowering speed and help position the probe for an attitude determination. If interested public are at the site they could watch the operation outside without bothering the investigators.

The picture scale is variable depending on the diameter of the borehole, the distance the probe is from the wall, and the monitor screen size. This scale range should be determined during the focusing operation and recorded on videotape.

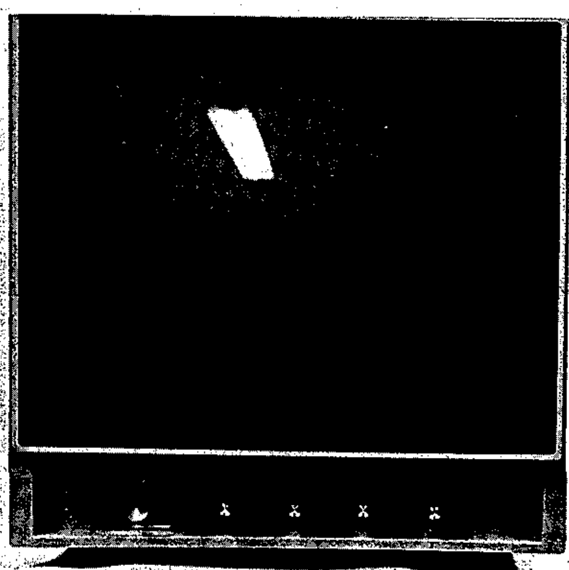


Figure 22 Front of the television monitor

SYSTEMS OPERATIONS

Conditions:
Equipment is assembled
Electrical and mechanical connections are secure
Power source is available. 110V, 60 Hz, 3000 Watts

Activity	Action	Results
I. Pre Turn On		
A. Power Unit		
1. Main switch	OFF(0)	
B. Control Unit		
1. Switches	OFF	
2. Illumination rheostats	CCW (full)	
3. Cable length selector	Proper length position	Position depends upon length of cable used.
C. Camera Control		
1. Switches	OFF	
2. Polarity	+	
3. Sp (Contrast)	Mid point	
4. Fo (Focus)	Mid point	
5. Ik (Beam Current)	CCW (full)	
II. Turn On		
A. Power Unit		
1. Main switch	ON (0 to 1) Wait 2 minutes	Red light - on Relay clicks on
2. Volt meter		220V ±3V
3. Amps meter		
4. Frequency meter		60 Hz ±2Hz
Problems:		Check
1. Unit fails to turn on		Fuses (3) see fuse chart Electrical connections
2. Voltage not 220V		Adjust voltage regulator
3. Frequency not 60 Hz		Adjust power source
B. Monitor(s)		
1. Main switch	ON	Green light - on
2. Brightness	CW	Raster just visible
Problems:		
1. Image is not clear	75Ω ON 75Ω OFF	Last monitor in line Mid line monitor

C. Control Unit

1. Power	ON	
2. Voltage meter		220V ±3V
3. Frequency meter		60 Hz ±2Hz
4. Accessories	ON	

Problems:

1. Voltage not at 220V		Adjust voltage regulator at Power Unit.
2. Frequency not at 60 Hz		Adjust power source
3. Frequency not steady		New power source

D. Camera Control

1. Standby switch	ON Wait 2 minutes	Neon light - on Monitor screen brightens
2. Camera switch	ON	Neon light - on
3. Ik *	CW (slow)	Picture appears and is scanned throughout screen
4. Sp	As required	CW - Increase CCW - Decrease
5. Fo	As required	

Problems:

1. * Too much Ik (Beam Current) causes internal electronic noise and will overload the vidicon tube - Keep as low as possible!

E. Camera

1. Mechanical focus	As required	
2. Waterproof plug	Install	Clean & lubricate

F. Monitor and Camera

1. Fo	As required
2. Ik	
3. Sp	
4. Brightness	
5. Contrast	
6. Vertical Hold	
7. Horizontal Hold	

Problems:

1. 75 ohm switch behind monitor will be "OFF" for all interior monitors. Last monitor in line will have 75 ohm switch "ON".

III. Standby

A. Power Unit

1. Main switch	ON	See Section II

B. Control Unit

1. Main switch	ON	See Section II

C. Camera Control

1. Standby switch	ON	Camera electronics remain "warmed up".
2. Camera switch *	OFF	Vidicon tube is off.

Warning:

1. * The vidicon tube has a limited life. Leave camera on "Standby" when on intermittant use during day.

IV. Switching Off

A. Camera Control *

1. All switches	OFF	Neon lights - off
2. Dials	Null	

B. Control Unit

1. Illumination rheostats	CCW (full)	Probe lights dimmed
2. Accessory switches	OFF	
3. Main switch	OFF	

C. Power Unit

1. Main switch	OFF (1 to 0)	Red light - off

Warning:

1. * If the camera is out of the borehole, the panorama window should be covered. Bright sunlight can overload and burn out the vidicon tube - even if the camera is turned off!

Protect the camera from bright lights!

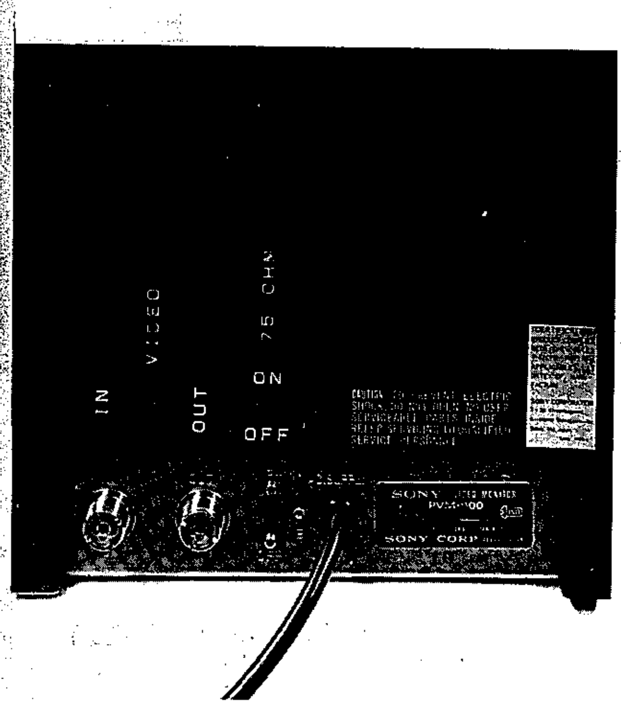


Figure 23 Rear of television monitor.

METHODS FOR MEASURING PLANAR FEATURES

I. Discussion

An inclined planar structure appears as an ellipse on the wall of an intersecting borehole. The true attitude of the structure can be determined directly in a vertical borehole; however, when intersected by an inclined borehole the structure's apparent attitude must first be related to the vertical.

The major and minor axis of the ellipse is related to the dip and strike direction of the intersected planar feature. Depth of the feature is commonly measured from the borehole collar to "appex up" Apex up is the major axis of the ellipse nearest the collar, irregardless of the borehole orientation.

A magnetic compass orients the north direction in holes inclined downward at any angle between vertical and 30° from the vertical (figure 24). In holes approaching horizontal a weighted compass card is used to define an imaginary line along the back, or arch, of the hole, from which all measurements originate. Holes inclined from vertical to 30° off the vertical, must be oriented by a taut wire installed in the borehole at a known azimuth.

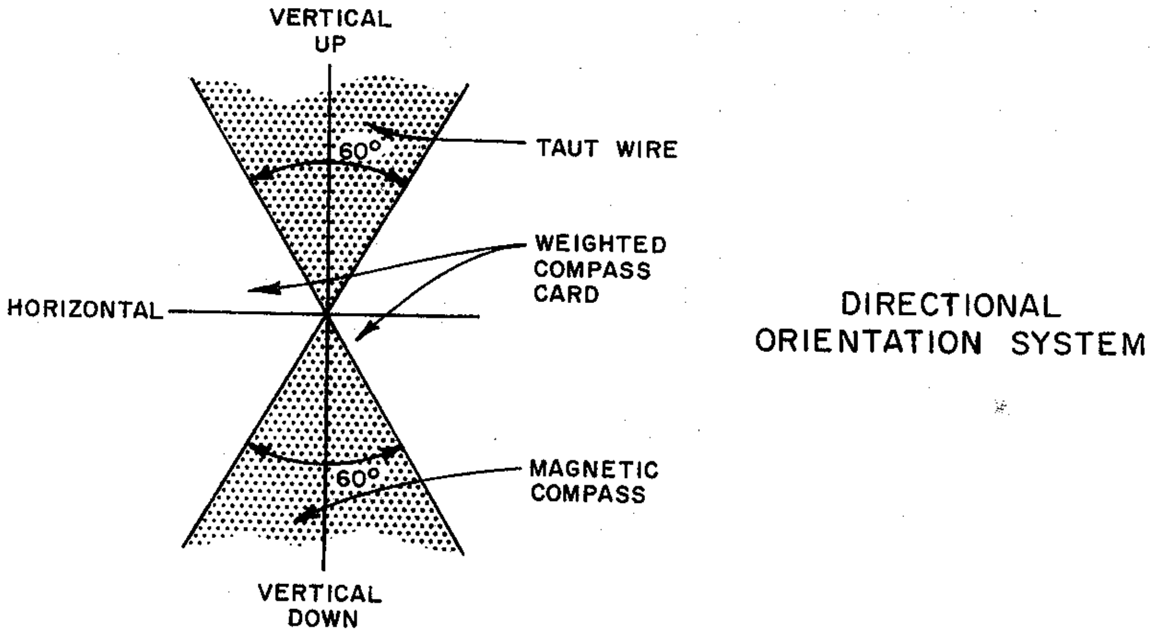


Figure 24 Zones which require different orienting systems for the radial probe.

II. Vertical Borehole

Direct measurements of the true dip, strike, and depth of planar features are possible in a vertical borehole.

The procedure is to rotate the mirror to magnetic north, indicated by the small light flare near the center of the monitor screen, in line with the black partial radius line. North is more accurately determined if the size and intensity of the light flare is reduced by lowering the intensity of the main light bulb.

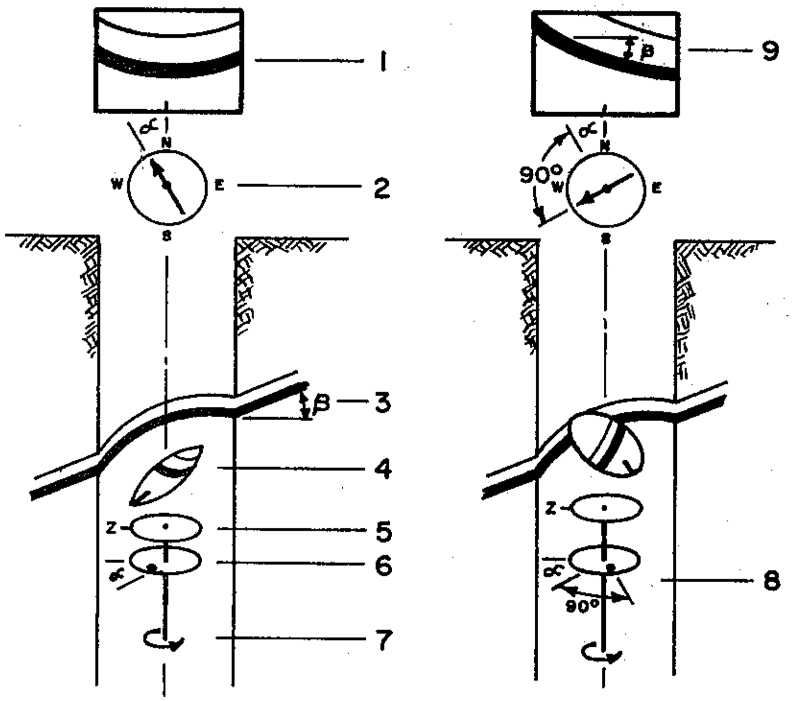
Adjust the graduated compass bezel so north or 00° coincides with the primary pointer on the mirror rotation dial.

Rotate the axis of the mirror, indciated by the partial radius line, to the major axis of the ellipse. This is the direction of dip and is read directly from the compass bezel.

Rotate the mirror 90° in either direction to the minor axis of the ellipse. This is the strike of the planar feature and is read directly from the compass bezel.

While aligned with the minor axis of the ellipse, the dip angle of the planar feature is measured directly, using a protractor set on the monitor screen. The base of the protractor must be normal to the partial radius line!

Depth of the planar feature is measured from the borehole collar to the apex of the ellipse (major axis). Prevent confusion by always measuring to apex up.



Towards Major Axis
Dip Direction

Toward Minor Axis
Strike Direction
and Dip Angle.

Figure 25 Projection of Image

1. Television monitor
2. Mirror control dial
4. Inclined mirror
5. Partial radius line
6. Compass card
7. Compass lamp
9. α Dip direction
10. β Dip angle

Procedure: Orient mirror to north.

Rotate mirror to major axis. Measure α, direction of dip.

Rotate mirror to minor axis (α+90°) which is direction of strike. Measure angle of dip, β.

III. Inclined Borehole

Attitudes in an inclined borehole are measured in the same manner as for the vertical hole; however, the inclination and azimuth of the borehole must also be measured.

Measure and record the apparent attitude and depth of the planar feature (see vertical borehole).

Rotate the mirror to magnetic north and adjust the compass bezel.

Rotate the mirror until the maximum deflection is obtained on the inclinometer.

Borehole azimuth is read directly from the compass bezel. Borehole inclination is read directly from the drift meter.

The true dip, strike, and depth of the planar feature can now be determined with the use of descriptive geometry.

IV. Horizontal Borehole

A weighted compass card replaces the magnetic compass card for holes whose inclination range from horizontal through 30° from the vertical. Since a downhole magnetic direction is not now available, it must be assumed that the hole's azimuth does not change from what it is at the collar.

Rotate the mirror to the arch of the hole, as indicated by the light flare on the monitor screen.

Adjust the graduated bezel so north (00°) coincides with the primary pointer on the mirror rotation dial (arch of hole).

Rotate the axis of the mirror, indicated by the black partial radius line, to the major axis of the ellipse. The dip direction is read from the graduated bezel.

Rotate the mirror 90° to the minor axis or direction of strike. Read strike direction directly from the graduated bezel. While in this position measure the angle of dip using a protractor on the monitor screen.

Rotate the mirror to the point of maximum deflection of the drift meter. Record this as the hole's inclination.

The aximuth of the hole is measured at the collar using a hand held compass.

REMEMBER: In a non-vertical borehole the attitudes of all planar features are measured relative to the inclination and azimuth of the borehole. All data must be reduced to the vertical for proper analysis.

V. Notes on Procedures

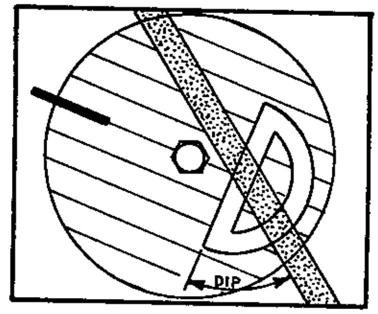
1. All compass bearings are magnetic and must be corrected to true north by applying the local magnetic declination.

2. The apparent thickness of a planar feature can be determined by lowering the probe past it and noting the distance on the control cable. Small features can be measured on the monitor screen using the scale made during the focusing operation. True Thickness = (Cosine Dip) x (Apparent Thickness).

3. Rotating the mirror causes the image to revolve around the monitor screen. The short black partial radius line denotes the bottom of the probe, or the downhole end. The compass flare will be located between the center of the screen and this line.

4. The partial radius line will probably not be at the bottom of the screen when you are measuring a dip angle. Be sure that the base of the protractor is normal to the direction of this line. A clear plastic guide is provided for this measurement.

Figure 26 Sketch showing orientation and use of partial radius line, alignment guide, and protractor while measuring the dip angle of a planar feature.



5. Occasionally the mirror and the mirror control dial do not rotate in the same direction. The operator must be aware of this malfunction and check that they always rotate in the same direction while obtaining a measurement.

6. A small amount of play occurs in the mirror control dial before the servo-motor is activated. This will add an error to a measurement; minimize this error by always rotating the mirror control dial in the same direction during a measurement operation.

EQUIPMENT MAINTENANCE AND ASSEMBLY TELEVISION MINI-CAMERA

I. <u>Removal of Camera from Probe</u>

The camera mounting systems are the same for both the axial and radial probes (Figure 27).

Disconnect the probe from the axial control cable. Unscrew the notched retainer ring from camera base using the special spanner wrench. Grasp the camera base and pull straight out.

To install the camera, align offset terminals on the camera face with recepticals inside the probe. Push camera into probe, seating firmly. Before replacing retainer ring, check that the focusing screw is accessible through the probe's external access hole (radial probe only).

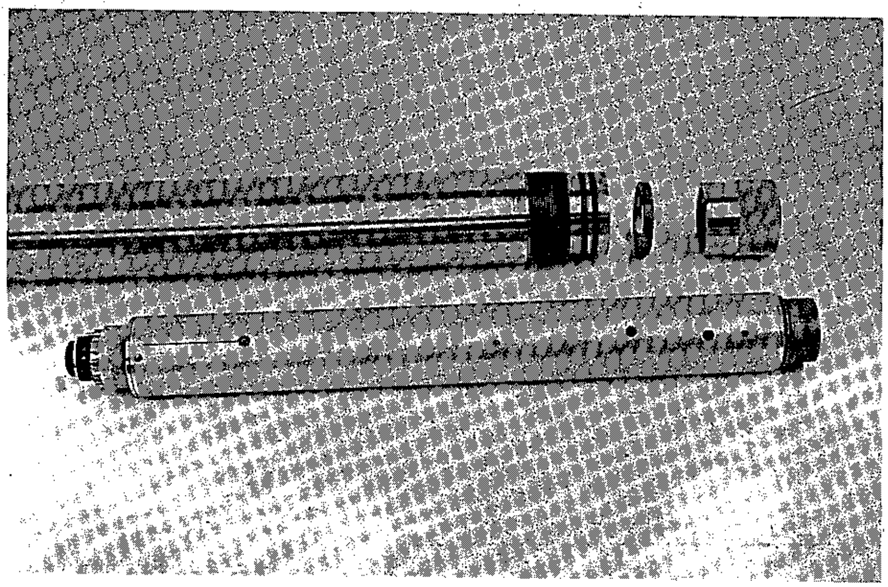


Figure 27 Television Mini-Camera outside the probe. Note the retainer ring and spanner wrench.

II. <u>Removal of Camera from Its Housing</u>

Remove eight retaining screws on aluminum housing. Hold front of camera. Unscrew aluminum sleeve and slide back.

During assembly, check that focusing screw is accessible through the aluminum housing.

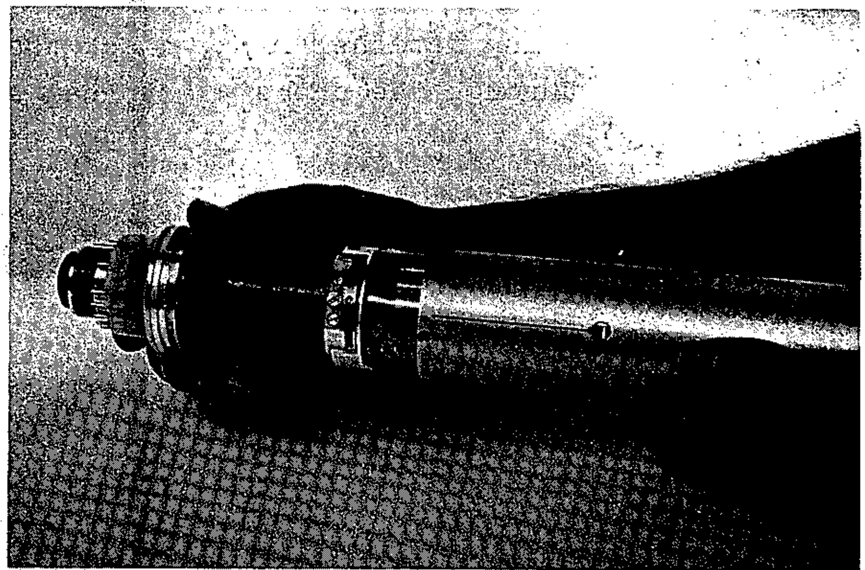


Figure 28 Removing the camera from its housing.
Note the focus adjustment screw.

III. Changing Vidicon Tube

Unscrew entire lens system from camera. Remove clear plastic shield from around the forward printed circuit boards. Fold back the two forward printed circuit boards. Gently pry the seven-pin socket from the base of the vidicon tube (Figure). Push vidicon tube forward and remove.

Clean face of replacement tube with lens tissue. Insert tube as far as possible into camera and seat firmly. Check that the metal clip on the camera frame contacts the metal collar ring on the front of the vidicon tube. Replace the seven-pin socket. Replace the lens assembly. Check that the iris diaphragm on the lens assembly is set full open and secure.

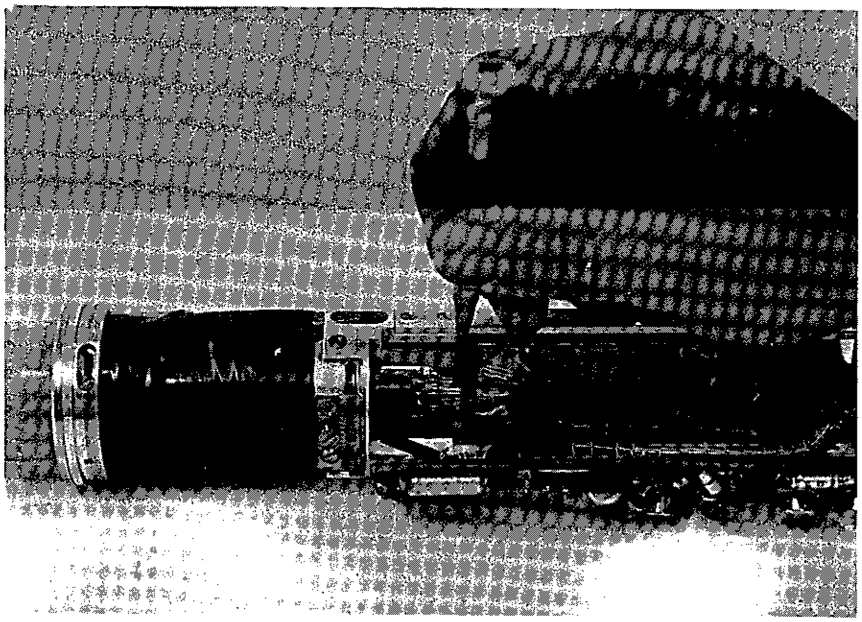


Figure 29 Removing the seven-pin socket from the base of the vidicon tube. Note the two printed circuit panels are laid back.

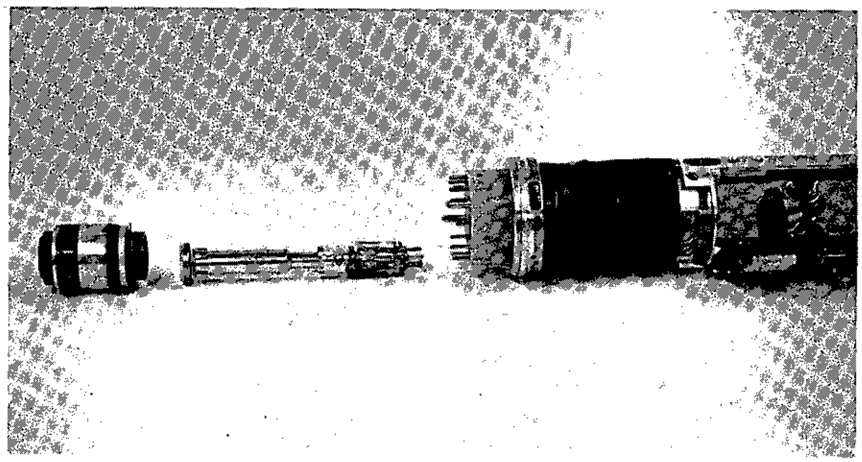


Figure 30 The lens system, vidicon tube, and camera in assembly sequence.

IV. Mechanical Focus Adjustment

Camera is connected to control cable. Video system is operating.

Point the camera at the target located at a reasonable working distance. Adjust the focus adjust screw while observing the change on the monitor screen.

Always lubricate the focus adjustment access plug before replacing it into the radial probe. The axial probe has no external focus adjustment. It must be focused before insertion into the probe casing.

CONTROL CABLE CONNECTIONS

Connect the upper end to the control unit. Use the 5 foot adaptor cable if necessary.

On the downhole end, slide the screw head back on the cable using a twisting motion to expose the O-rings (Figure31). Wipe the O-rings clean and lubricate with silicon jelly. Lubricate the two O-rings on the upper end of the probe casing. Insert the cable head into the keyed camera base. Slide the screw head forward and screw onto the probe. Tighten snugly with wrenches.

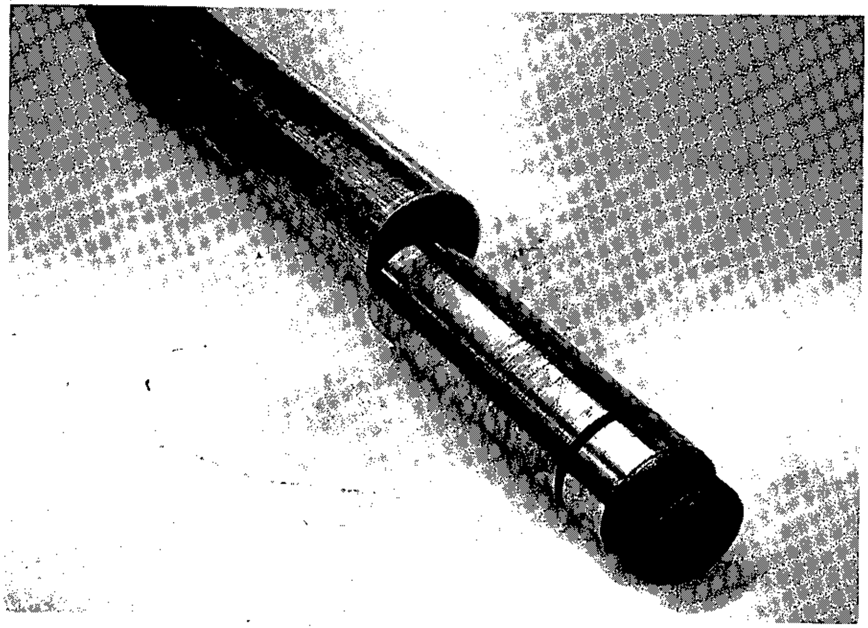


Figure 31 Control cable with screw head back on connector to expose O-ring seals.

AXIAL PROBE

Conditions: Camera assembly is outside of axial probe.

I. Camera

Screw the wide angle lense system into the camera. Check that the spring loaded light shield is in place and functions properly. Check that aperature is fully opened. Set mechanical focus at 15 inches.

II. Axial Probe

Insert camera assembly into axial probe. Carefully align the offset electrical connections before seating the camera to the probe.

Install slotted retainer ring at base of camera. Tighten with spanner wrench.

Lubricate O-rings on control cable head and upper end of probe. Match the control cable plug with the slotted camera socket. Screw cable head onto the probe housing.

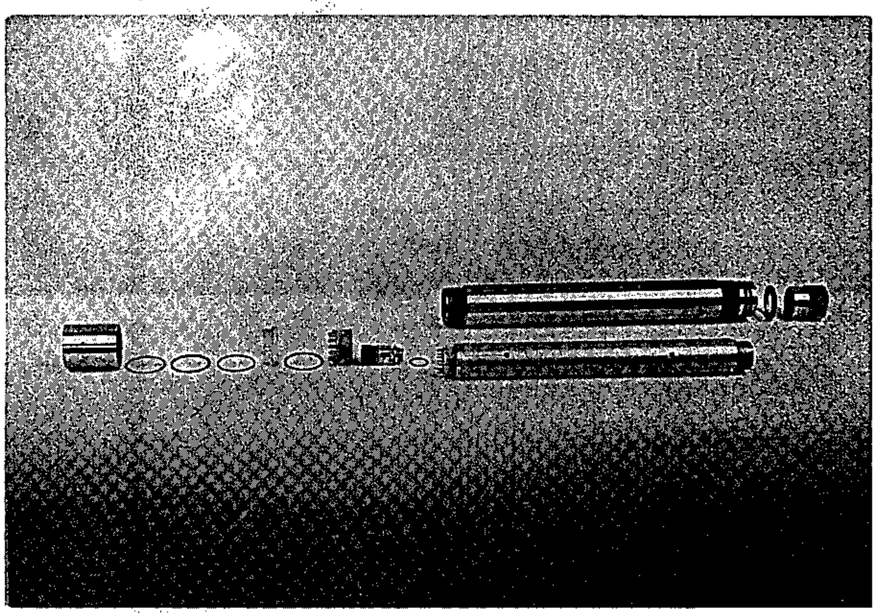


Figure 32 Exploded view of the axial probe and television camera.

The mini-light bulbs are accessible by removing the end sleeve and observation window. Remove three screws from the plastic light bulb retainer ring. Unscrew bulbs as required. Lubricate the O-rings when replacing the end sleeve.

III. Control Unit

The Radial/Axial selector is switched to Axial. The selector is accessible through the right panel door (Figure 20). Lights are controlled by the Lower Illumination Switch and rheostat.

RADIAL PROBE

I. Central Section

Access to: Large light bulb
Magnetic compass and weighted compass card
Panorama window

a. Disassembly and Access to Panorama Window

Remove entire lower housing unit. Use a pipe wrench on the lower sleeve and an open end wrench on the notched adaptor below the panorama window. Pull housing straight off.

Unscrew notched adaptor and remove. Prevent damage and chafe to the two O-rings below the window.

Rotate and slide off the brass retainer rings, rubber washers, and the window.

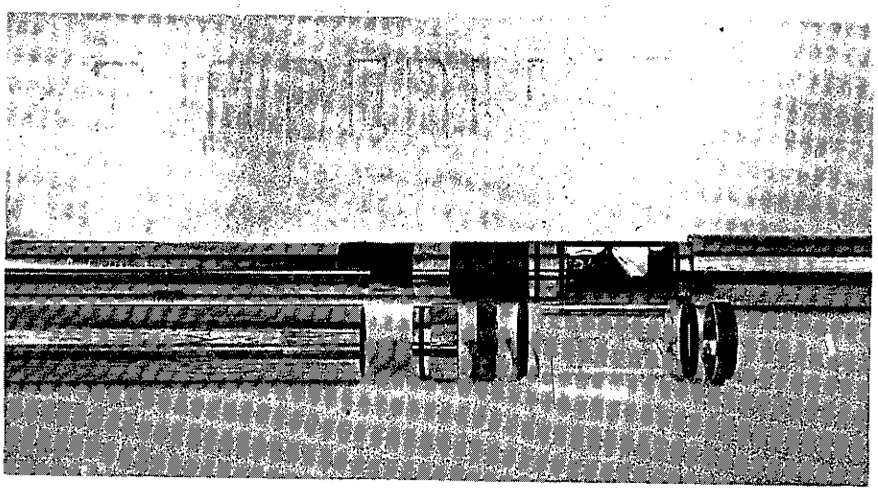


Figure 33 Exploded view of the central section of the Radial Probe.

b. Changing the Large Light Bulb

Press bulb down from the top and turn to the left. Tilt the housing and allow the bulb to drop out.

Reinstall bulb in reverse order. Clean finger prints off bulb. Check for proper operation.

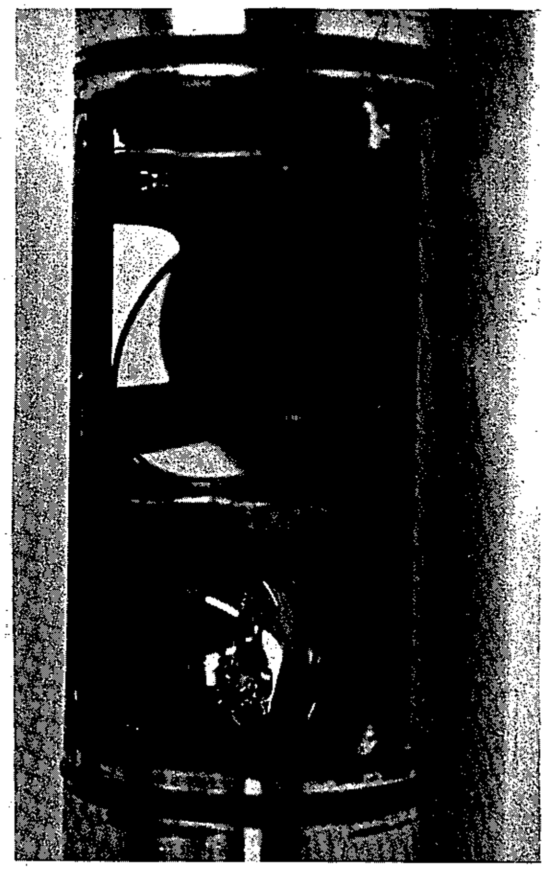


Figure 34 Close-up of central section of radial probe. Note the main light bulb and inclined mirror. The black line is visible on the monitor screen and indicates the bottom of the probe. The north flare is seen through the small hole in the center of the mirror, above the black line.

c. Interchanging the Magnetic Compass with the Weighted Compass Card

The compass unit is located between the large light and the inclined mirror. Pull the compass out of the socket and exchange it for the alternate system. It can only be installed one way. Check system for proper operation before reassembly.

Figure 35 Close-up view of compass unit being installed into its housing.

d. Reassembly of Central Probe

Wash panorama window with liquid detergent and water to remove all silicon lubricant. Slide upper window housing into place. Lightly lubricate the top before seating against base of camera housing. Slide upper rubber washer into place. Lightly lubricate before dasing into upper window housing.

Wipe ALL lubricant off the three bar supports. Remove all lubricant from the lower two O-rings on the probe; it will smear the insides of the window during installation.

Moisten lower two O-rings with water. Slide panorama window on STRAIGHT and seat against upper rubber washer.

Lubricate the upper of the two O-rings and around the base of the window. Slide on the lower rubber washer, lubricate, and seat against the window. Slide lower window housing over rubber washer.

Lubricate lower O-ring. Screw notched stainless steel adaptor into place and firmly seat against lower window housing. DO NOT over tighten as excess pressure may break the window.

Lubricate O-ring on adaptor sleeve. Insert and screw lower probe into lower probe housing. Tighten with wrenches.

II. Inner Probe Section

Access to: Moisture Detector
Servo-Motor
Inclinometer
Small Dual Lights

a. Moisture Detection System

Remove lower probe housing. It is not necessary to remove the lower end section unless access to desiccant is desired.

Remove moisture detection cylinder. Unscrew two flat head screws from octagonal ring nut. Ease the moisture detection cylinder out, being careful not to break the connecting wire bundle (Figure 36). Remove the two screws retaining the black connector plug (Figure 37). Disconnect the plug.

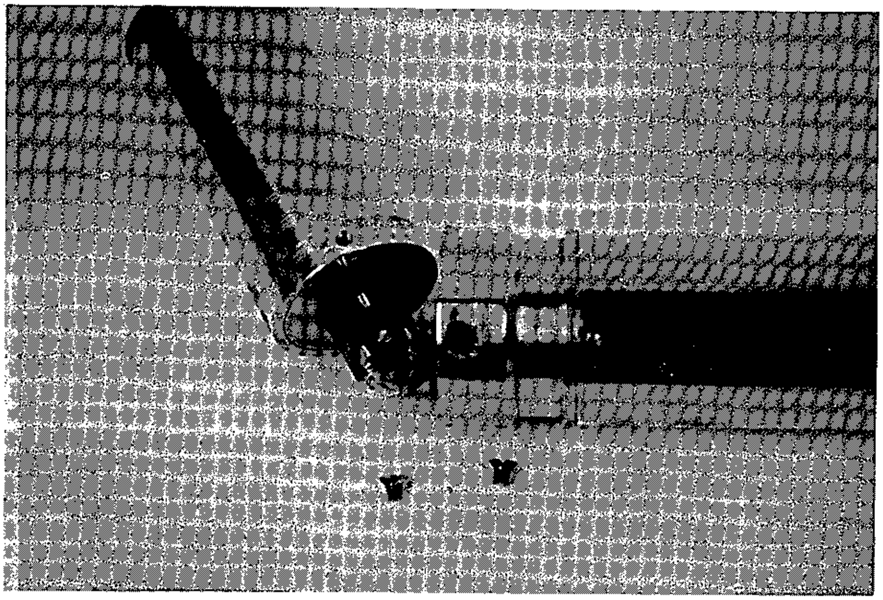


Figure 36 The lower portion of the inner probe section. Note the partially disconnected moisture detection cylinder, the connector plug, and the octagonal ring nut.

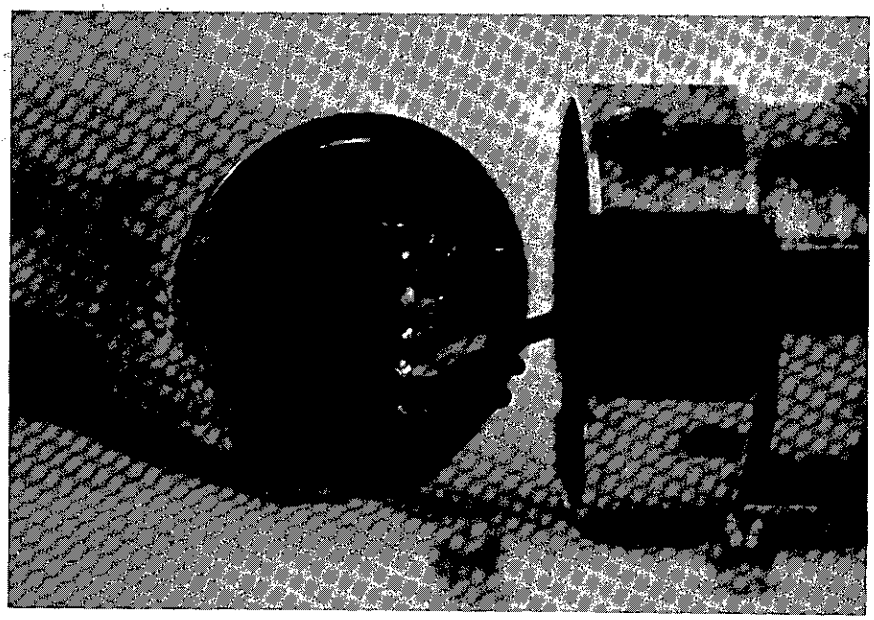


Figure 37 Black connector plug between moisture detection cylinder and lower probe.

b. Servo-Motor

Remove small set screw at top of octagon ring nut. Unscrew ring nut (Figure 38). Be careful that the red wire bundle is not pinched or broken while unscrewing the ring nut. Remove three flat head retainer screws located below the square hole on the lower central portion of the inner probe. Press the servo-motor out of its coupling with a screw sriver (Figure 39). Slide servo-motor down until the black metal cap at base of motor is entirely exposed. Carefully pry the black metal cap off, thereby disconnecting the motor (Figure 39). Slide the servo-motor out of the housing if desired (Figure 40).

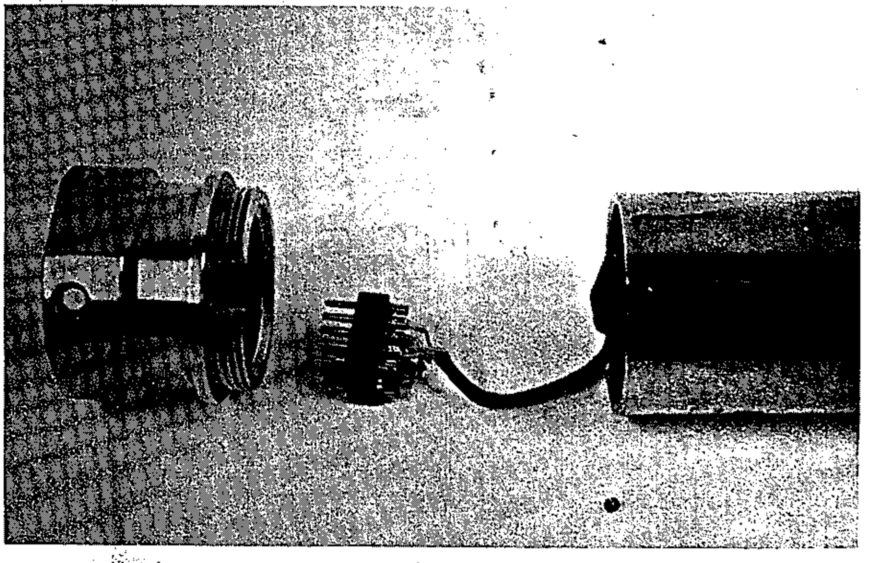


Figure 38 Octagonal ring nut, small set screw, wire bundle, and connector to moisture detection cylinder.

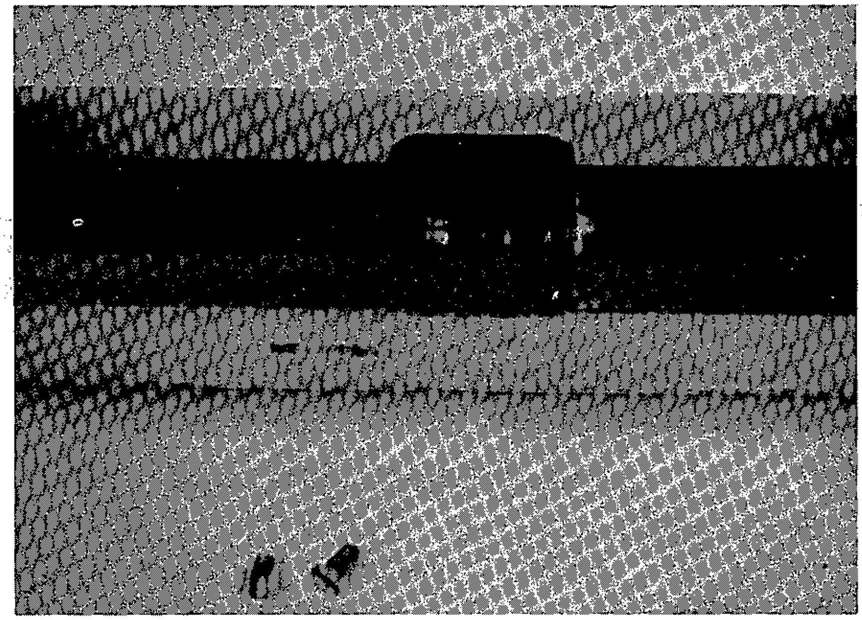


Figure 39 Square hole on the central portion of the inner probe. Note retainer screws (removed), and brass servo-motor connector.

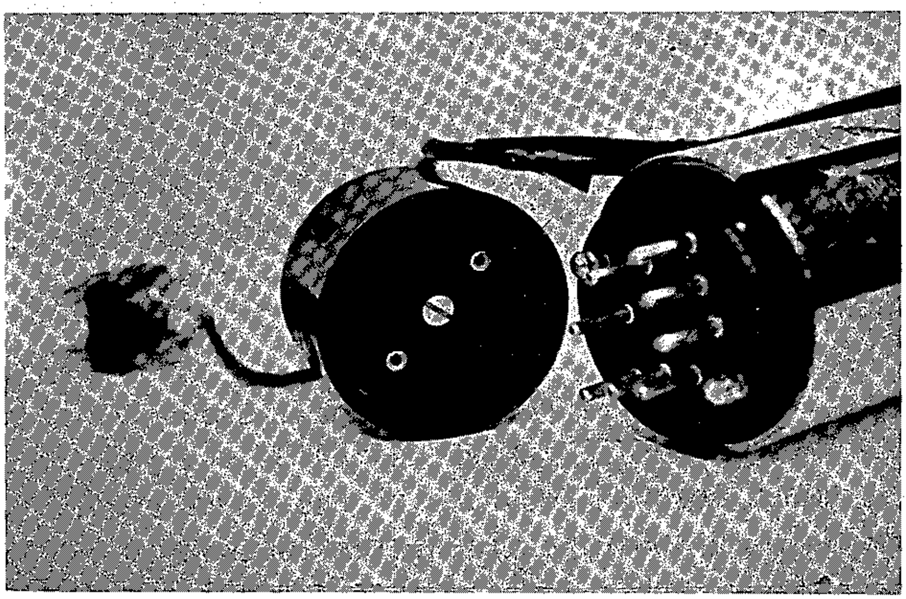


Figure 40 Black metal cap and wiring bundle removed from lower end of servo-motor.

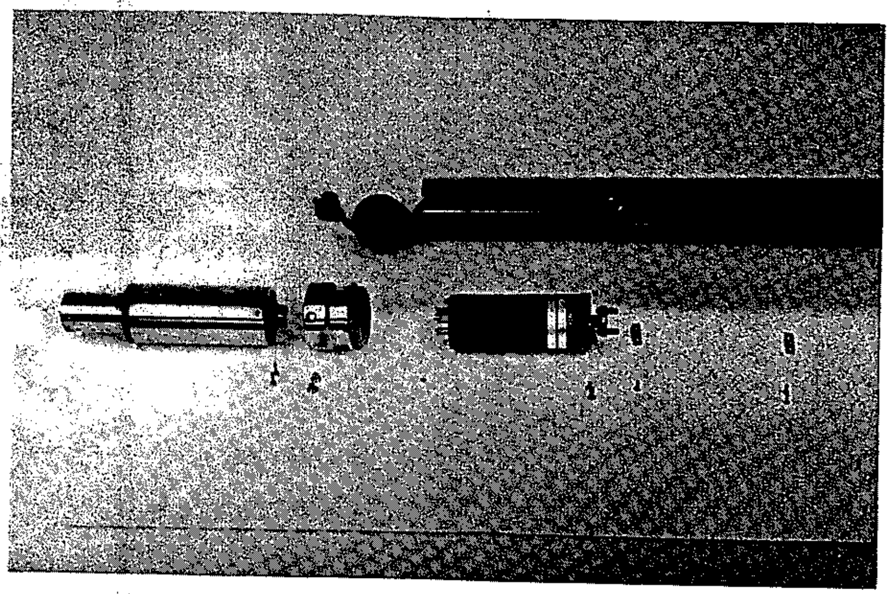


Figure 41 Assembly sequence for the lower portion of the inner probe. Note the moisture detection cylinder, octagonal ring nut, small set screw, power and control connectors for moisture detector and servo-motor, servo-motor, and wire bundle retainer clips.

c. Wire Bundle and Slip Ring Contact

Remove the two wire retainer clips from the side groove. Remove tape protecting slip ring contacts.

Remove the red slip ring bracket and its two retaining screws (Figure 42). Normally the six wires to the slip ring contact bracket WOULD NOT be removed. If the wires are to be removed, be sure to mark their positions for reassembly.

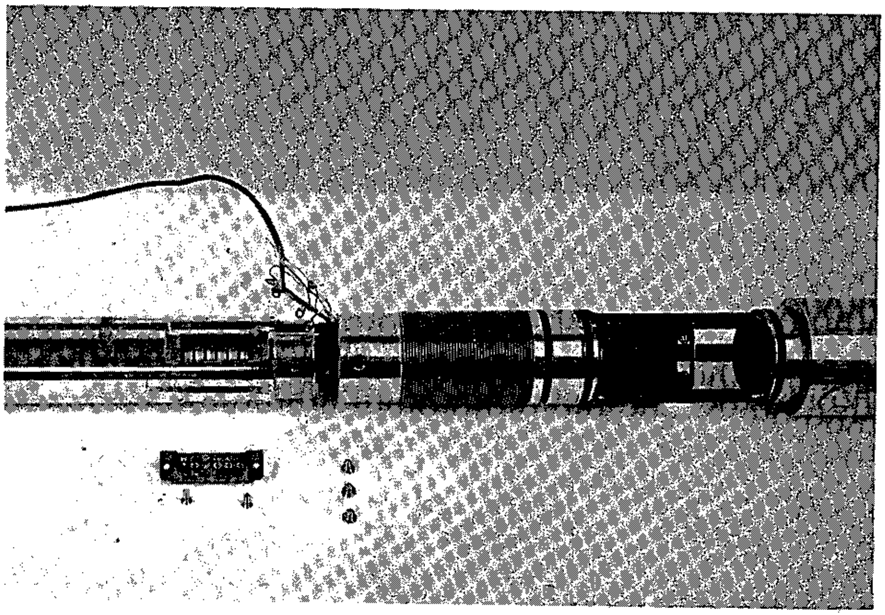


Figure 42 The inner probe being removed from the upper housing. Note the slip rings, contact bracket, wiring bundle, and retainer screws.

d. Removal of Inner Probe from Upper Housing

Remove three flat head screws located above slip ring contact. Check that the wire bundle is CAREFULLY laid back and is out of the way. Ease the inner section out of the upper housing (Figure 43). DO NOT twist, the wire bundle may break! Pull STRAIGHT out or the mirror/light assembly may bind or be bent.

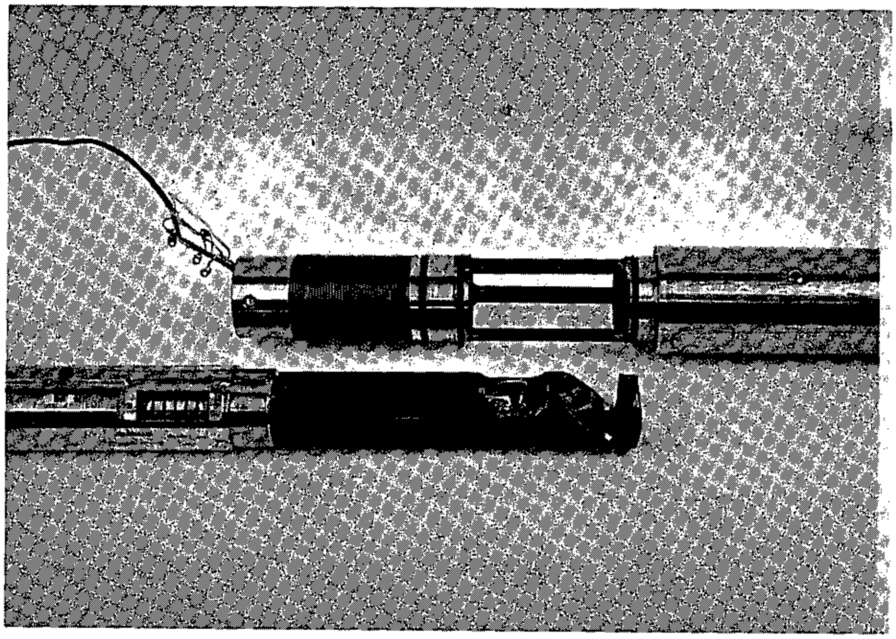


Figure 43 The inner probe removed from the upper housing. Note the main light bulb, inclined mirror, and small dual lights. The inclinometer is located in the black cylinder between the main light and the slip ring contacts.

e. Small Dual Lights

Remove the upper and side light shields, held in place with small screws (Figure 44). Unsolder and replace defective light bulbs. Reassemble in reverse order.

Note: Threads on the small brass screws are easily stripped. Apply a small dab of rubber cement to each screw before use.

The curved sides of the light mounting bracket must be tight against the plastic mirror mount. If loose, the unit will bind on one of the vertical support bars during rotation.

When replacing the mirror check that the two wires to the dual lights do not block the compass light hole. Bend them out of the way; retain with tape if necessary

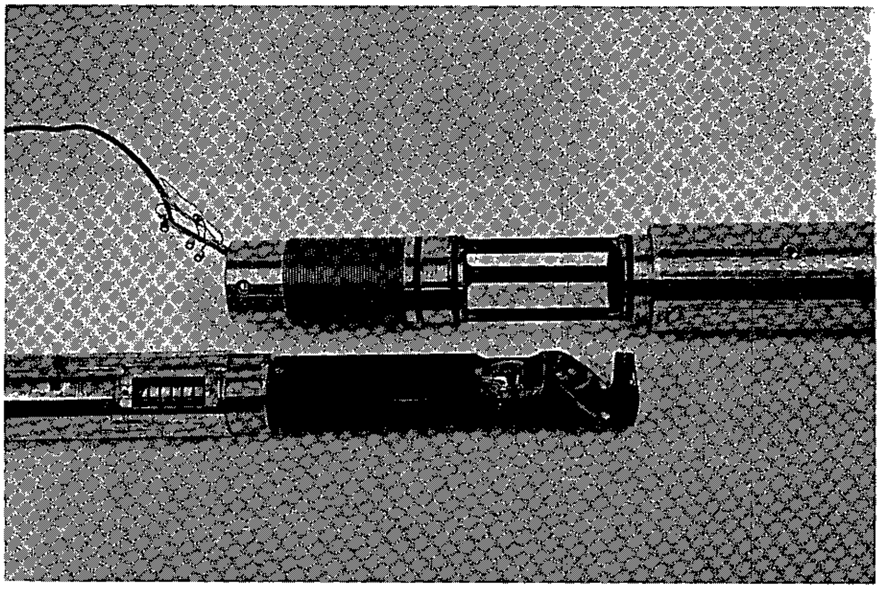


Figure 44 Close-up of small dual lights. Note inclined mirror, side and upper light shields, and the dual lights.

f. Reassembly of the Inner Probe

Reassemble in reverse order. As each component is replaced, check that it functions properly. If the mirror unit binds during rotation, it must be removed from its housing, bent slightly, and reinstalled.

III. Lower End Section

a. Access to Dessicant Canaster

Unscrew and remove the probe's end section using wrenches. Remove retainer clip with needle nose pliers. Remove dessicant canaster.

Dry canaster in oven at 250° for 12 hours. The desiccant is silica gel which is bright blue when dry and pink to red when wet.

Clean the lower end section and lubricate the O-ring. Install the desiccant canaster and retainer clip. Screw lower end section into central probe housing. Tighten snugly with wrenches.

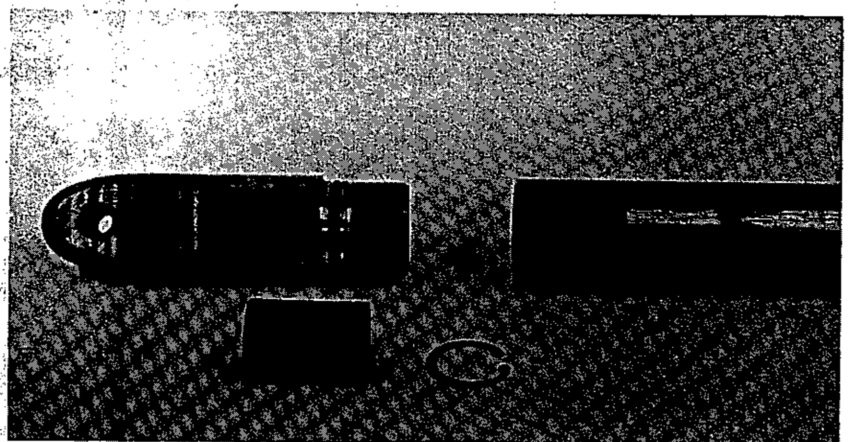


Figure 45 Lower end section showing desiccant canaster and retainer clip.

I. Hole Preparation

a. Boreholes

To properly view structural and textural features the borehole walls must be clean. If below the water level the fluid must be optically transparent with a minimum of turbidity.

Drilling mud can usually be removed by extensive flushing with clear water. If wall support is required, a drilling fluid similar to "Revert" should be used. This high density material becomes transparent shortly after use. Other flocculent agents, such as "Calgon", help increase precipitation of suspended particles. Care must be exercised not to use an environmentally deleterious material.

In softer unconsolidated material and soil, drill cuttings are often smeared on the borehole walls, especially when drilling with augers. Deeper holes can be reamed using a large amount of fluid. Shallower holes can be scrubbed with a large diameter brush.

When air is used during drilling, holes can generally be blown clean. When moist material or small amounts of ground water is encountered, the drill cuttings often ball up on the borehole walls.

Drill holes in rock are better viewed if the walls can be moistened with water. A limited amount of fluid should be used to keep the water level to a minimum.

Holes suspected of being collapsed or containing rock protrusions should first be viewed with the axial probe or even tested with the dummy probe.

Inclined holes should be viewed using a skid frame or small diameter centering devices. If the radial probe lies along the side of the borehole, that portion of the wall cannot be investigated because of insufficient light and close focus.

b. Conduits

Sewers, utility conduits, wells, or drain culverts can all be inspected for obstructions, grade, alignment, collapse, offset, or deteriation using a combination of the axial or radial probes with high intensity external illumination.

Generally, depending upon the conduit diameter, the probe would be attached to a skid frame. The skid frame supports the illumination system, prevents the probe from rolling, and attaches to the advancement system.

Most multi-conductor utility conduits already have a pull wire in place. This wire is attached either to the skid frame or a heavier haul line. Depth of entry is noted on the control cable. "E" size drill rod can be used to push the skid frame after attaching to a special fitting on the probe.

Lightweight haul lines can be run through a culvert by attaching it to a one gallon empty plastic bottle and flushing the bottle through the culvert with water. Also, the line may be attached to the straight handle of a partially open umbrella. The umbrella is forced through the culvert with air or water.

II. Video Tape Recorder and Television Monitor

While checking the probe's mechanical focus record on video tape and verbally:

Job name	Date
Job number	Crew
Location	Others present
Hole number	Scale
Run number	

Construct a scale along the edge and top of monitor masking tape and grease pencil. Also a portable scale of clear plastic.

Record the entire investigation using the axial probe, also complete a borehole log. Record only pertinent features while using the radial probe.

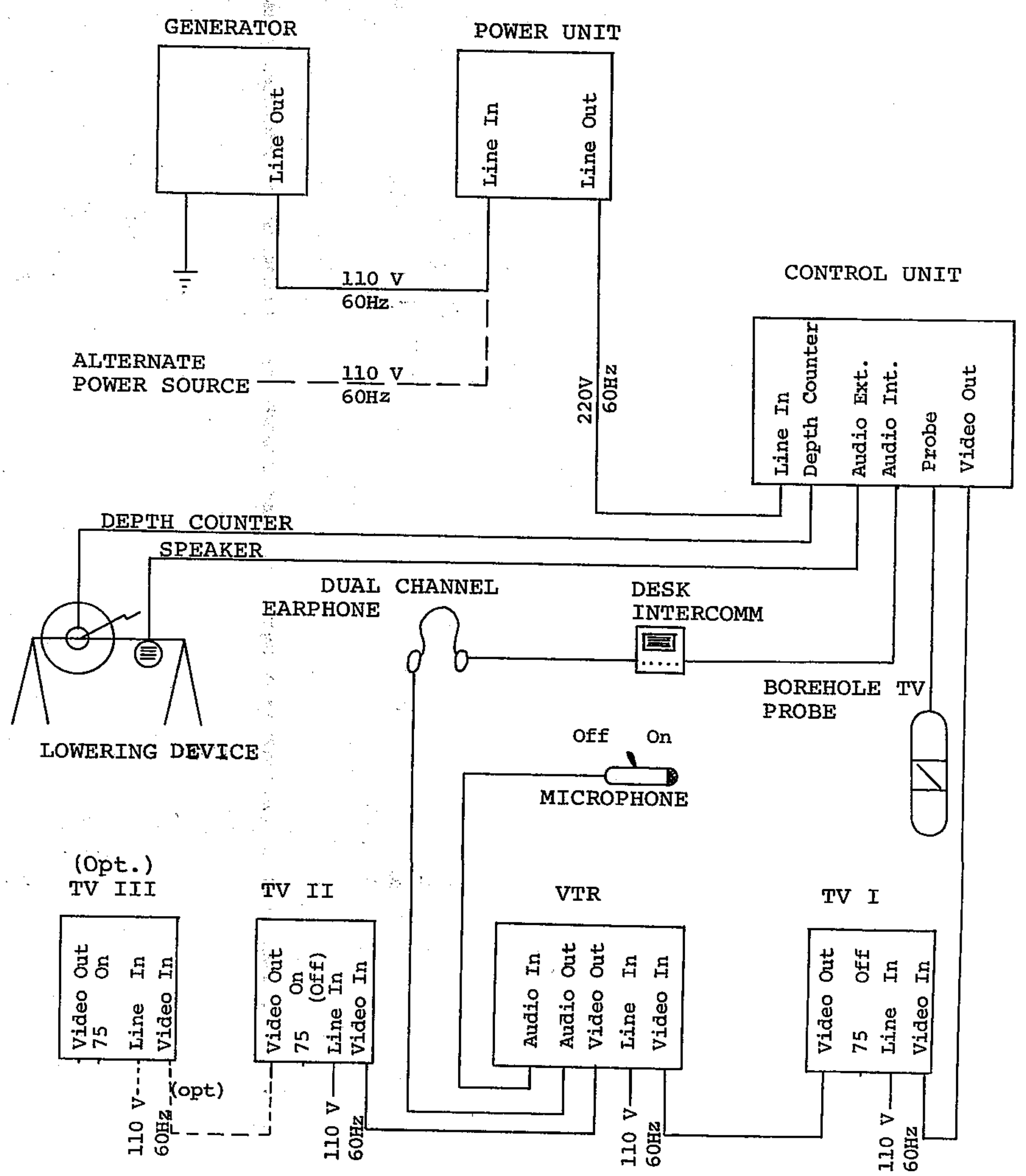
The observer should record a running commentary of what is being viewed including:

depth	joint filling material
description	slip-outs
size	lithology
structural features	texture
attitudes	water locations

An extra TV monitor may be placed outside for the lowering device operator to better position the probe during measuring operations.

Turn the microphone off when not in use. Maintain a slow scan speed while recording.

COMPONENT LAYOUT-BOREHOLE T.V. SYSTEM



BOREHOLE TELEVISION CAMERA
EQUIPMENT CHECK LIST

GENERATOR
- Ground Rod and Cable
- Gasoline and Gas Can
- Oil
- Fire Extinguisher

RADIAL PROBE
- Dry Desiccant
- Compass Card
- Weighted Compass Card
- Transport Case

AXIAL PROBE

TV CAMERA
- Radial Lens
- Axial Lens

DUMMY RADIAL PROBE
- Cable Head
- Hoisting Line and Reel

HORIZONTAL SKID FRAME
- Pull Cable and Swivel
- Hose Clamps

OVERSHOT RETRIEVER
- Guide Sleeve
- Overshot Jaws
- Bolts

AUXILLARY LIGHTING
- Bulb Mounts
- Spare System
- Light Shield
- Power Cord

LOWERING DEVICE
- Pulley Axle, Nut
- Plate
- Bolts
- Crank

INTERCOM
SPEAKER
STEREO EARPHONES
POWER UNIT
CONTROL UNIT
VIDEO TAPE RECORDER
TELEVISION MONITOR(S)
MICROPHONE

CABLES
- Control Cable
- 1300 feet
  - Reel
  - Crank Handle
  - Adaptor Cable
- 450 feet
  - Reel
  - Crank Handle
- 250 feet
- Power Unit to Control Unit
- Control Unit to Monitor
- Monitor to VTR
- VTR to Monitor
- Intercom Reel
- Depth Counter Reel
- Earphone to Intercom/VTR

SPARE PARTS
- Vidicon Tube
- Misc. Transistors
- O-Ring Kit
- Silicon Jelly
- 24 V Light Bulbs
- 18 V Light Bulbs
- Panorama Window
- Axial Window
- Servo-Motor
- Dessicant
- Mirror
- Fuses
- Silicon Adhesive

MISCELLANEOUS MATERIALS
- Protractor
- 1 inch Masking Tape
- Notebook
- Pencils
- Clip Board
- Celluloid Scale
- Felt Pen
- Greese Pencil/Filler
- Log Forms
- Poloroid Camera/Film
- Flashlight/Batteries
- Alcohol/Pan

JOB INFORMATION
- Job Number
- Location Map
- Keys
- Local Contact
- Phone Numbers
- Hole Number/Depth

MISCELLANEOUS
- Hard Hats
- Rain Gear
- Rubber Boots
- Tape Measure
- Kerplunker
- Keys to Van
- Broom
- Chairs
- Water Can/Cups

TOOLS
- Tool Box
- Allen Wrench Kit
- Metric Wrenches
- 9 inch Pipe Wrench
- Volt-Ohm Meter
- Liquid Detergent
- Rags
- Screwdrivers 3/16, 1/4
- Jewlers Screwdrivers
- Spannar Wrench
- Wire Cutters
- Needle Noise Pliers
- Soldering Iron
- Solder
- Assorted Wire
- Electrical Tape

EASTMAN BOREHOLE TELEVISION SYSTEM
FUSE CORRELATION GUIDE

	European	American
VOLTAGE LEVEL CONTROLLER (Power Unit)	T 0.5/250 B M 10/250 E	GMA 1/2 GMA 10
CONTROL UNIT	T 0.7/250 B M 0.05/250 C	GMA 7/10 GMA 5/100
MIRROR ROTATION RELAY	F 0.5/250 C M 0.2/250 C	GMA 1/2 GMA 2/10
TELEVISION UNIT	F 1/250 C	AGC 1
VIDEO TAPE RECORDER	- - - - -	AGC 1.5
EXTERNAL POWER (Illumination)	- - - - -	AGC 1

Department of Transportation
Office of Transportation Laboratory
Geotechnical Section
Borehole Television Log

Project ________________ Job No. ________ Date ________

Dist ______ Co ______ Rt ____ PM ________ Location ________________

Boring No ______ Run No _____ Reference Elev(0ft on log) _____ (ground, collar)

Hole Dia _____ Casing Depth _____ Drill Fluid Type ________ Date Flushed ________

Crew ________________ Mag Decl ________ Water Level ________

DEPTH	STRUCTURE		BORE HOLE		COMMENTS
	Strike	Dip	Strike	Dip	Texture, size, contact, fracture, void, thi-

NORTH-EAST				SOUTH-EAST				SOUTH-WEST				NORTH-WEST			
MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE
N	N17E	N45E	N62E	E	S73E	S45E	S28E	S	S17W	S45W	S62W	W	N73W	N45W	N28W
N1E	N18E	N46E	N63E	S89E	S72E	S44E	S27E	S1W	S18W	S46W	S63W	N89W	N72W	N44W	N27W
N2E	N19E	N47E	N64E	S88E	S71E	S43E	S26E	S2W	S19W	S47W	S64W	N88W	N71W	N43W	N26W
N3E	N20E	N48E	N65E	S87E	S70E	S42E	S25E	S3W	S20W	S48W	S65W	N87W	N70W	N42W	N25W
N4E	N21E	N49E	N66E	S86E	S69E	S41E	S24E	S4W	S21W	S49W	S66W	N86W	N69W	N41W	N24W
N5E	N22E	N50E	N67E	S85E	S68E	S40E	S23E	S5W	S22W	S50W	S67W	N85W	N68W	N40W	N23W
N6E	N23E	N51E	N68E	S84E	S67E	S39E	S22E	S6W	S23W	S51W	S68W	N84W	N67W	N39W	N22W
N7E	N24E	N52E	N69E	S83E	S66E	S38E	S21E	S7W	S24W	S52W	S69W	N83W	N66W	N38W	N21W
N8E	N25E	N53E	N70E	S82E	S65E	S37E	S20E	S8W	S25W	S53W	S70W	N82W	N65W	N37W	N20W
N9E	N26E	N54E	N71E	S81E	S64E	S36E	S19E	S9W	S26W	S54W	S71W	N81W	N64W	N36W	N19W
N10E	N27E	N55E	N72E	S80E	S63E	S35E	S18E	S10W	S27W	S55W	S72W	N80W	N63W	N35W	N18W
N11E	N28E	N56E	N73E	S79E	S62E	S34E	S17E	S11W	S28W	S56W	S73W	N79W	N62W	N34W	N17W
N12E	N29E	N57E	N74E	S78E	S61E	S33E	S16E	S12W	S29W	S57W	S74W	N78W	N61W	N33W	N16W
N13E	N30E	N58E	N75E	S77E	S60E	S32E	S15E	S13W	S30W	S58W	S75W	N77W	N60W	N32W	N15W
N14E	N31E	N59E	N76E	S76E	S59E	S31E	S14E	S14W	S31W	S59W	S76W	N76W	N59W	N31W	N14W
N15E	N32E	N60E	N77E	S75E	S58E	S30E	S13E	S15W	S32W	S60W	S77W	N75W	N58W	N30W	N13W
N16E	N33E	N61E	N78E	S74E	S57E	S29E	S12E	S16W	S33W	S61W	S78W	N74W	N57W	N29W	N12W
N17E	N34E	N62E	N79E	S73E	S56E	S28E	S11E	S17W	S34W	S62W	S79W	N73W	N56W	N28W	N11W
N18E	N35E	N63E	N80E	S72E	S55E	S27E	S10E	S18W	S35W	S63W	S80W	N72W	N55W	N27W	N10W
N19E	N36E	N64E	N81E	S71E	S54E	S26E	S9E	S19W	S36W	S64W	S81W	N71W	N54W	N26W	N9W
N20E	N37E	N65E	N82E	S70E	S53E	S25E	S8E	S20W	S37W	S65W	S82W	N70W	N53W	N25W	N8W
N21E	N38E	N66E	N83E	S69E	S52E	S24E	S7E	S21W	S38W	S66W	S83W	N69W	N52W	N24W	N7W
N22E	N39E	N67E	N84E	S68E	S51E	S23E	S6E	S22W	S39W	S67W	S84W	N68W	N51W	N23W	N6W
N23E	N40E	N68E	N85E	S67E	S50E	S22E	S5E	S23W	S40W	S68W	S85W	N67W	N50W	N22W	N5W
N24E	N41E	N69E	N86E	S66E	S49E	S21E	S4E	S24W	S41W	S69W	S86W	N66W	N49W	N21W	N4W
N25E	N42E	N70E	N87E	S65E	S48E	S20E	S3E	S25W	S42W	S70W	S87W	N65W	N48W	N20W	N3W
N26E	N43E	N71E	N88E	S64E	S47E	S19E	S2E	S26W	S43W	S71W	S88W	N64W	N47W	N19W	N2W
N27E	N44E	N72E	N89E	S63E	S46E	S18E	S1E	S27W	S44W	S72W	S89W	N63W	N46W	N18W	N1W
N28E	N45E	N73E	E	S62E	S45E	S17E	S	S28W	S45W	S73W	W	N62W	N45W	N17W	N
N29E	N46E	N74E	S89E	S61E	S44E	S16E	S1W	S29W	S46W	S74W	N89W	N61W	N44W	N16W	N1E
N30E	N47E	N75E	S88E	S60E	S43E	S15E	S2W	S30W	S47W	S75W	N88W	N60W	N43W	N15W	N2E
N31E	N48E	N76E	S87E	S59E	S42E	S14E	S3W	S31W	S48W	S76W	N87W	N59W	N42W	N14W	N3E
N32E	N49E	N77E	S86E	S58E	S41E	S13E	S4W	S32W	S49W	S77W	N86W	N58W	N41W	N13W	N4E
N33E	N50E	N78E	S85E	S57E	S40E	S12E	S5W	S33W	S50W	S78W	N85W	N57W	N40W	N12W	N5E
N34E	N51E	N79E	S84E	S56E	S39E	S11E	S6W	S34W	S51W	S79W	N84W	N56W	N39W	N11W	N6E
N35E	N52E	N80E	S83E	S55E	S38E	S10E	S7W	S35W	S52W	S80W	N83W	N55W	N38W	N10W	N7E
N36E	N53E	N81E	S82E	S54E	S37E	S9E	S8W	S36W	S53W	S81W	N82W	N54W	N37W	N9W	N8E
N37E	N54E	N82E	S81E	S53E	S36E	S8E	S9W	S37W	S54W	S82W	N81W	N53W	N36W	N8W	N9E
N38E	N55E	N83E	S80E	S52E	S35E	S7E	S10W	S38W	S55W	S83W	N80W	N52W	N35W	N7W	N10E
N39E	N56E	N84E	S79E	S51E	S34E	S6E	S11W	S39W	S56W	S84W	N79W	N51W	N34W	N6W	N11E
N40E	N57E	N85E	S78E	S50E	S33E	S5E	S12W	S40W	S57W	S85W	N78W	N50W	N33W	N5W	N12E
N41E	N58E	N86E	S77E	S49E	S32E	S4E	S13W	S41W	S58W	S86W	N77W	N49W	N32W	N4W	N13E
N42E	N59E	N87E	S76E	S48E	S31E	S3E	S14W	S42W	S59W	S87W	N76W	N48W	N31W	N3W	N14E
N43E	N60E	N88E	S75E	S47E	S30E	S2E	S15W	S43W	S60W	S88W	N75W	N47W	N30W	N2W	N15E
N44E	N61E	N89E	S74E	S46E	S29E	S1E	S16W	S44W	S61W	S89W	N74W	N46W	N29W	N1W	N16E
N45E	N62E	E	S73E	S45E	S28E	S	S17W	S45W	S62W	W	N73W	N45W	N28W	N	N17E

SPERRY-SUN WELL SURVEYING COMPANY

NORTH-EAST				SOUTH-EAST				SOUTH-WEST				NORTH-WEST			
[illegible]	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	TRUE	MAG.	[illegible]
N	N18E	N45E	N63E	E	S72E	S45E	S27E	S	S18W	S45W	S63W	W	N72W	N45W	N2.
N 1 E	N19E	N46E	N64E	S89E	S71E	S44E	S26E	S 1 W	S19W	S46W	S64W	N89W	N71W	N44W	[illegible]
N 2 E	N20E	N47E	N65E	S88E	S70E	S43E	S25E	S 2 W	S20W	S47W	S65W	N88W	N70W	N43W	[illegible]
N 3 E	N21E	N48E	N66E	S87E	S69E	S42E	S24E	S 3 W	S21W	S48W	S66W	N87W	N69W	N42W	[illegible]
N 4 E	N22E	N49E	N67E	S86E	S68E	S41E	S23E	S 4 W	S22W	S49W	S67W	N86W	N68W	N41W	[illegible]
N 5 E	N23E	N50E	N68E	S85E	S67E	S40E	S22E	S 5 W	S23W	S50W	S68W	N85W	N67W	N40W	[illegible]
N 6 E	N24E	N51E	N69E	S84E	S66E	S39E	S21E	S 6 W	S24W	S51W	S69W	N84W	N66W	N39W	[illegible]
N 7 E	N25E	N52E	N70E	S83E	S65E	S38E	S20E	S 7 W	S25W	S52W	S70W	N83W	N65W	N38W	[illegible]
N 8 E	N26E	N53E	N71E	S82E	S64E	S37E	S19E	S 8 W	S26W	S53W	S71W	N82W	N64W	N37W	[illegible]
N 9 E	N27E	N54E	N72E	S81E	S63E	S36E	S18E	S 9 W	S27W	S54W	S72W	N81W	N63W	N36W	[illegible]
N10E	N28E	N55E	N73E	S80E	S62E	S35E	S17E	S10W	S28W	S55W	S73W	N80W	N62W	N35W	[illegible]
N11E	N29E	N56E	N74E	S79E	S61E	S34E	S16E	S11W	S29W	S56W	S74W	N79W	N61W	N34W	[illegible]
N12E	N30E	N57E	N75E	S78E	S60E	S33E	S15E	S12W	S30W	S57W	S75W	N78W	N60W	N33W	[illegible]
N13E	N31E	N58E	N76E	S77E	S59E	S32E	S14E	S13W	S31W	S58W	S76W	N77W	N59W	N32W	[illegible]
N14E	N32E	N59E	N77E	S76E	S58E	S31E	S13E	S14W	S32W	S59W	S77W	N76W	N58W	N31W	[illegible]
N15E	N33E	N60E	N78E	S75E	S57E	S30E	S12E	S15W	S33W	S60W	S78W	N75W	N57W	N30W	[illegible]
N16E	N34E	N61E	N79E	S74E	S56E	S29E	S11E	S16W	S34W	S61W	S79W	N74W	N56W	N29W	[illegible]
N17E	N35E	N62E	N80E	S73E	S55E	S28E	S10E	S17W	S35W	S62W	S80W	N73W	N55W	N28W	[illegible]
N18E	N36E	N63E	N81E	S72E	S54E	S27E	S 9 E	S18W	S36W	S63W	S81W	N72W	N54W	N27W	N 9
N19E	N37E	N64E	N82E	S71E	S53E	S26E	S 8 E	S19W	S37W	S64W	S82W	N71W	N53W	N26W	N 8
N20E	N38E	N65E	N83E	S70E	S52E	S25E	S 7 E	S20W	S38W	S65W	S83W	N70W	N52W	N25W	[illegible]
[illegible]	N39E	N66E	N84E	S69E	S51E	S24E	S 6 E	S21W	S39W	S66W	S84W	N69W	N51W	N24W	N 6
N22E	N40E	N67E	N85E	S68E	S50E	S23E	S 5 E	S22W	S40W	S67W	S85W	N68W	N50W	N23W	N 5
N23E	N41E	N68E	N86E	S67E	S49E	S22E	S 4 E	S23W	S41W	S68W	S86W	N67W	N49W	N22W	N 4
N24E	N42E	N69E	N87E	S66E	S48E	S21E	S 3 E	S24W	S42W	S69W	S87W	N66W	N48W	N21W	N 3
N25E	N43E	N70E	N88E	S65E	S47E	S20E	S 2 E	S25W	S43W	S70W	S88W	N65W	N47W	N20W	N 2
N26E	N44E	N71E	N89E	S64E	S46E	S19E	S 1 E	S26W	S44W	S71W	S89W	N64W	N46W	N19W	N 1
N27E	N45E	N72E	E	S63E	S45E	S18E	S	S27W	S45W	S72W	W	N63W	N45W	N18W	N
N28E	N46E	N73E	S89E	S62E	S44E	S17E	S 1 W	S28W	S46W	S73W	N89W	N62W	N44W	N17W	N 1
N29E	N47E	N74E	S88E	S61E	S43E	S16E	S 2 W	S29W	S47W	S74W	N88W	N61W	N43W	N16W	N 2
N30E	N48E	N75E	S87E	S60E	S42E	S15E	S 3 W	S30W	S48W	S75W	N87W	N60W	N42W	N15W	N 3
N31E	N49E	N76E	S86E	S59E	S41E	S14E	S 4 W	S31W	S49W	S76W	N86W	N59W	N41W	N14W	N 4
N32E	N50E	N77E	S85E	S58E	S40E	S13E	S 5 W	S32W	S50W	S77W	N85W	N58W	N40W	N13W	N 5
N33E	N51E	N78E	S84E	S57E	S39E	S12E	S 6 W	S33W	S51W	S78W	N84W	N57W	N39W	N12W	N 6
N34E	N52E	N79E	S83E	S56E	S38E	S11E	S 7 W	S34W	S52W	S79W	N83W	N56W	N38W	N11W	N 7
N35E	N53E	N80E	S82E	S55E	S37E	S10E	S 8 W	S35W	S53W	S80W	N82W	N55W	N37W	N10W	[illegible]
N36E	N54E	N81E	S81E	S54E	S36E	S 9 E	S 9 W	S36W	S54W	S81W	N81W	N54W	N36W	N 9 W	N 9
N37E	N55E	N82E	S80E	S53E	S35E	S 8 E	S10W	S37W	S55W	S82W	N80W	N53W	N35W	N 8 W	[illegible]
N38E	N56E	N83E	S79E	S52E	S34E	S 7 E	S11W	S38W	S56W	S83W	N79W	N52W	N34W	N 7 W	[illegible]
N39E	N57E	N84E	S78E	S51E	S33E	S 6 E	S12W	S39W	S57W	S84W	N78W	N51W	N33W	N 6 W	[illegible]
N40E	N58E	N85E	S77E	S50E	S32E	S 5 E	S13W	S40W	S58W	S85W	N77W	N50W	N32W	N 5 W	[illegible]
N41E	N59E	N86E	S76E	S49E	S31E	S 4 E	S14W	S41W	S59W	S86W	N76W	N49W	N31W	N 4 W	[illegible]
N42E	N60E	N87E	S75E	S48E	S30E	S 3 E	S15W	S42W	S60W	S87W	N75W	N48W	N30W	N 3 W	[illegible]
N43E	N61E	N88E	S74E	S47E	S29E	S 2 E	S16W	S43W	S61W	S88W	N74W	N47W	N29W	N 2 W	[illegible]
[illegible]	N62E	N89E	S73E	S46E	S28E	S 1 E	S17W	S44W	S62W	S89W	N73W	N46W	N28W	N 1 W	[illegible]
[illegible]	N63E	E	S72E	S45E	S27E	S	S18W	S45W	S63W	W	N72W	N45W	N27W	N	[illegible]

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