Inclinometer Readings and Maintenance

General Considerations. Inclinometers are used to measure lateral ground movements in abutments, foundations, embankments, structures, and consolidation induced settlement in embankments and foundations. Measuring settlement by the vertical movement of inclinometer casings has now largely replaced the earlier method using Internal Vertical measurement devices. Thus, the same installation now measures both settlement and lateral movement.

Inclinometer casing are installed with slip joints as embankment construction progresses or in compressible foundations providing the opportunity for settlement measurements. Casings may be installed in drill holes with butt joints in abutments or completed embankments if no significant settlements are anticipated.

a. Taking readings. - The inclinometer installations are monitored at predetermined intervals which are used again in all future surveys of the casing. Inclinometer deflection devices consist of a servo accelerometer probe, cable, cable reel, and a digital readout unit. The probes are designed to fit 1.9-, 2-3/4-, and 3-3/8-inch-outside-diameter casings. While setting up this instrument to take a set of readings, the guide wheels should be checked for bearing free play and tightened if necessary. A small amount of lubricant should be applied to each wheel bearing assembly. The cable connectors should be protected with caps to prevent damage or contamination to the connector contacts. An O-ring usually provides a water-tight seal between the cable and the probe; however, some probes are permanently connected to the cable. In that case, especially with lighter cables, the cable should be checked for damage near the connection.

The readout unit is turned on and the system checked by holding the bottom of the probe stationary and moving the top along the measurement axis (the two upper wheels are used as this axis). The readout unit should display values with polarity corresponding to the given tilt angles. A calibration stand may be used if desired.

A pulley assembly is attached to the top of the inclinometer casing. Usually, the probe must be inserted in the casing before the pulley wheel can be fitted to the pulley wheel assembly. It is important that the wheels of the probe are properly seated in the marked casing grooves before the pulley is installed. The groove used for measurement should be marked on the casing collar for all future references. The probe is carefully lowered to the bottom of the casing with power on from the readout unit trying to avoiding severe shocks to the instrument near the bottom of the hole. On the Slope Indicator type of pulley assembly, a jam cleat is located at the top of the pulley assembly. The cleat is used to secure the cable and to provide a convenient depth index during the data collection process. The distance from the top of the casing to the jam cleat is 1 foot. The depth is controlled by pulling the cable through the cleat until the end of the foot mark has reached the rear of the jam cleat block. After the probe reaches the bottom of the casing, it is raised to the nearest footmark and the distance from the top of the casing to the probe is measured by means of the cable markings. When the inclinometer casing is initially surveyed, it is important that the downhill groove be clearly marked and that the uppermost wheel is aligned with this mark for taking of the initial set of readings. This is very important because the orientation of the readings is governed by the direction of this upper wheel. For every subsequent set of readings in this casing, the same wheel should be placed in the same groove

used for the initial set of readings. Accurate records should be kept of a reference system used on a particular project.

Inclinometer measurements are generally recorded as readings in opposite grooves (180 Degrees apart) at each depth. The sum of the readings in opposite grooves at any given depth should be approximately constant for all measurements. Small differences between these sums indicate that opposite sides of the casing wall are not parallel. Comparing these sums in the field will eliminate large errors resulting from mistaken transcriptions, faulty equipment, or improper technique. When the sums are not nearly constant, the sensor, readout, and casing should be rechecked before each use.

The data collected if using a manual type readout unit are written on the field data sheet and formatted to facilitate quick conversion to computer coding or entered onto tape if a tape unit recorder is being used. The newest unit's record the data into RAM memory of the readout unit and it is then transferred to a computer system for data reduction. Because all inclinometer readings are referenced to an original set of measurements, extreme care must be taken to obtain an accurate and reliable set of initial observations. Measurements of the original casing profile should be established by a double set of data. If any set of readings deviates from the previous or anticipated pattern, the inclinometer should be checked and the readings repeated.

Careful attention must be given to depth measurements on the cable to realize the potential accuracy of the inclinometer system. The wheels of the inclinometer probe provide measuring points between which the inclination of the instrument is measured. To achieve optimum accuracy, the distance between each reading interval should equal the distance between the upper and lower wheels of the probe. Taking two readings (0 and 180 degrees apart) or more data sets each time also improve the accuracy.

Despite precision manufacturing techniques used by most casing suppliers, the grooves in any section of casing may be slightly spiraled or twisted. During installation, the casing may become even more twisted so that at some depth, the casing grooves will not have the same orientation as at ground level. Because significant errors in the assumed direction of movement may result, casing for deep inclinometer installations should be selected with great care and checked for spiraling before installation. Spiral measuring probes are available from the manufacturers, but they have had a somewhat unreliable performance record. Spiraling does not contribute to an error in magnitude of deformation, but it may prevent determination of the true direction of casing movements.

Automatic data recording and processing can reduce the time and labor involved in office computation of the data. Although the field recording is speeded up slightly, two experienced technicians can usually read and record at about the same speed as the automatic system. Automatic data recording contributes to the complexity of the measurement operation and can introduce an additional and significant source of error. With manual data recording, the technician can scan the data for errors in the check sums and make corrections or reread the casing on the spot. Some data recording systems do allow for this advantage, the unit will calculate the check sums of a set of reading, other units may require that the data must be scanned for errors after being printed out in the office and before computer processing. However,

one data recording systems now allows a review of the data as it is being taken, so that corrections can be made as measurements are accumulated. This unit also allows field reduction of the data and comparison of the data with initial data files. This unit also has reduced the time necessary to take a set of data in the field. Use of the same observers and instruments for all measurements on a particular project is still strongly recommended.

When obtaining readings with the older MAG-TAP indicator's, make sure that the red DATA RECORD light glows and the cassette tape advances when the DATA RECORD button is pushed, otherwise that particular piece of data is not recorded. There is not a way to review this data on the unit until it is played back into a computer. Always allow enough time at each depth for the accelerometers of the probe time to "settle down" before recording any reading value. Upon completion of any set of readings (0 and 180 degrees in each casing), either rewind the tape completely or advance the tape beyond the last recorded data a minimum of 2 seconds to ensure that no data is lost by turning POWER off or on. If readings are to be obtained during freezing weather, special MIL specification cassette tapes should be used to prevent breakage or skips in the data. Further, temperatures colder than 20 degree F and warmer than 110 degree F require special protective measures for the indicator

When raising the probe during a set of readings, use extreme care in duplicating the depths between the 0 degree and 180 degree runs (and also in subsequent data sets) so that errors contributed by casing irregularities are minimized. If it becomes necessary to power the indicator from a vehicular electric source, make sure that no vehicle accessories (heater fans, radio, etc.) are on and that the engine is not running (voltage peaks when the voltage regulator kicks in and out may damage the indicator) to eliminate electrical interference with the indicator's electronics.

Inclinometer settlement measurement equipment consists of a settlement probe, settlement collar device with survey chain, and a safety rope. The measurement of settlement in an embankment installation is initiated by surveying to establish the top elevation of the casing. A reference benchmark off the dam is used for consistency in data. Starting at the top, the settlement probe is lowered to each slip joint in the casing usually set at every 5- or 10-foot distance, and the depth to each point is read directly off the tape to the nearest 0.01 foot reference to a mark placed on the settlement collar attach to the top of the casing. If you measuring a casing that is being installed during the construction of an embankment, each casing section as it are added, the above-mentioned settlement measurements are taken including the top of casing elevation. Groove orientation should also be measured at this time.

See appendixes for actual reading methods, and step by step procedures for taking inclinometer readings.

b. Problems with readout equipment. - The major problems that will occur while the taking of a set of inclinometer deflection readings are (1) the battery drop in power, (2) the probe not functioning properly, (3) probe becoming stuck within a casing, (4) probe slipping out of the require measurement grooves during a survey, (5) data not being recorded on the tape or being save in digital recording unit, (6) pulling the probe through the casing too fast, and (7) exposing indicators to direct sunlight for a long period of time, causing an offset in the voltage regulator.

Some different items to observe while taking readings are: (1) the battery voltage before and after taking a set of readings, do not operate indicators below 6.0 volts; (2) hard bumps to the probe can misalign and/or break the accelerometers or break internal electrical connections; (3) hard bumps to the indicators can dislodge the internal batteries, break electrical connections, shift the LED/LCD readouts, damage the tape drive, or rupture the water-tight case seals; (4) exposing any of the indicators to direct sunlight for long periods of time can raise internal temperatures beyond the tolerance level of the units and may crack circuit boards or overheat the batteries.

Bending the monitoring connecting cable over sharp objects or walking on it can sever internal conductors or puncture the outer waterproof coating. Dragging the cable through the cable brake/holder on the pulley wheel assembly and this will wearing off the cable markings.

Never put the indicator probe away wet - let it dry with the lid open - or pressure may build up from steam forming in a closed case and damage internal components and the various seals. When large changes of altitude are encountered, use the pressure relief valve on the front of the indicator case prior to opening the lid.

The batteries in the indicators should not be overcharged. Maximum recharge time is 16 hours or twice the period of operation since the last recharge. Do not attempt to recharge the internal batteries or operate from an external power source when the temperature of the indicator is below 40 degrees F.

The major problems that will occur during the taking of a set of inclinometer settlement readings are: (1) the probe will not close at the bottom of the hole after taking readings; (2) the survey chain can break; (3) the probe can get stuck within the casing; and (4) the safety rope hanging up in the hole.

c. Maintenance. - A regular maintenance program is essential to proper inclinometer monitoring. Repair or replacement of an inclinometer probe or readout unit because of misuse or improper maintenance can be expensive and may result in a period of data loss due to of downtime.

Upon completion of field work, the unit should be checked for superficial damage. Wheel fixtures and bearings should be checked for tightness, cleaned, and oiled. If worn these parts should be replaced as soon as possible. Metal surfaces should be cleaned and protected with a light coat of oil. The cable should be inspected for damage to the outer coating material and to the depth markers. If depth markers are not vulcanized to the cable, they may move resulting in erroneous depth readings. Never use WD-40 on the internal connections of the electrical cable connections of the readout unit, probe, connecting cable, or cable reel.

Cable connectors should remain capped when not in use and should be thoroughly cleaned after each use. Most readout units are not completely weatherproof and they should be protected from moisture. The introduction of a few drops of water into the electronic circuitry can cause a galvanometer to read incorrectly or induce a drift on a digital voltage display. If readings are being made rapidly or if an automatic recorder is used, this drift may not be detected. Equipment should be protected from shock and excessive vibration during transportation. Storage of this

sensitive electronic equipment in a closed vehicle during the summer or in an unheated area in the winter should be avoided.

Periodic maintenance of the automatic data recorder, including the batteries, is required. Battery maintenance guidelines require the batteries to be completely discharged after several charge/discharge cycles. Nickel cadmium batteries retain a form of memory capacity such that if they are repeatedly discharged to 10 percent of their capacity and then recharged to full capacity, they may soon deliver only about 10 percent of their potential capacity. Complete discharge is defined as 5.0 volts. The minimum voltage of the internal batteries that will safely operate the unit should be carefully monitored because low voltage can result in lost data. The tape cassettes used with the recorder should be protected against dust, dirt, and temperature extremes and should be cleaned periodically as prescribed by the instrument manufacturer.

Use an alcohol or a spray cleaner suitable for electronics that will not damage the outer cable covering or panel finish to keep all electrical connects clean. Periodically clean the plug connectors and other components. Never use WD-40 on the internal connections of the electrical cable connections of the readout unit, probe, connecting cable, or cable reel. Replace probe wheels and axles if they become wobbly or sticky. Constantly check the condition of the "0"-rings in the cable connections to maintain a watertight seal. Keep the protective plugs in place on all electric outlets to prevent physical damage or liquids from spilling into them.

The settlement probe should be cleaned by wiping it dry and then oiling the wheel and springs. Clean and oil the sliding parts so that the probe will latch. The survey chain should be wiped clean and oiled before storage and grease the gears on the collar device.

In short, the inclinometer is like other delicate equipment and its use requires common sense and reasonable care!

APPENDIX

Field Operating Instructions for SINCO Model 50325 SENSOR
SINCO Model 50306 DIGITILT INDICATOR (Manual)

The following operations are to be performed with the readout indicator (Digitilt Indicator 50306) POWER-OFF:

1. Attach the pulley brake mechanism to the inclinometer casing collar.

Note: Mark each casing to be monitored in some way so that the pulley brake mechanism can be attached to each casing collar the same way for each set of data obtained. This will align the A+ groove.

2. Remove the protective caps from sensor (probe) head, readout indicator, and interconnecting cables. Inspect neoprene "O" ring and replace if damaged.

3. Clean any dirt or moisture from all pins, connector sockets, and threads. Coat the "O" rings with a thin film of silicon lubricant.

Note: Aerosol products such as "Kontact Clean" is recommended for cleaning electrical contacts. Never use WD-40 on the internal connections of the electrical cable connections of the readout unit, probe, connecting cable, or cable reel.

4. Attach the cable to the probe head (POWER-OFF)), tighten firmly with a wrench (no more than 12-14 ft/lb) and connect the cable to the readout indicator.

POWER-ON Operations

5. Suspend the probe by the cable, turn the readout box power on, and observe readings. Tilt the top of the probe in the direction of the upper spring loaded wheel and check that the reading increases in the positive A direction (POLARITY OF TILT ANGLE).

6. Remove the guide wheel from the pulley brake mechanism (POWER-ON) and insert the probe into the casing with the upper wheels in the A+ groove and lower in the A- groove. Replace the guide wheel, place the cable over guide wheel, and lock the cable in the brake, with the top of the probe close to the casing collar.

7. Observe to see the readout unit is operating correctly as the readings show both the A and B positions and observe the displayed readings.

Note: Unless the casing is extremely vertical, the A and B readings will be quite different.

8. Lower the probe to the bottom of the casing (CAUTION – Do not allow the coiled cable to KINK at any time as the internal conductors may be damaged. Do not allow the probe to hit the bottom of the casing), lower gently the last few feet, also do not apply any sharp jolts to the

cable, such as allowing the probe to descend rapidly and abruptly stopping it - decelerate gradually.

9. Upon reaching the bottom of the casing, allow 5 minutes so that the biaxial accelerometers in the probe can settle down, and the temperatures in the electronic package (probe and readout indicator) can stabilize.

10. Record the depth (in a field book) of the probe to the bottom of the casing by setting the nearest cable marking to the clamp at the top of the pulley cable clamp of the pulley brake mechanism.

Note: All subsequent measurements and recording of depths are to be made to the same point.

11. Begin to take reading, if you are using a manual readout unit start with the readout box switch in the A position. Record your depth and allow the digital readout fluctuations to minimize before recording the numbers on the data sheet. If taking the data a recording unit the display will lock with a symbol once it has a reading that is expectable.

Note: When the numbers repeatedly cycle back and forth between three and four digits in the extreme right side of the display or thousandths column, the reading may be recorded on the data sheet.

12. Switch the manual readout box to the B position and repeat step No. 11. The digital recording unit will record depth, A position and B position.

13. If you are using a manual readout box record all data on form 7-1884A (Revised 4-74). Record A+ and B+ readings under the column marked A+ and B+ across from the appropriate depths.

14. Pull the probe up 2 feet. (Example: If casing bottom is recorded at 100 feet from the top of the cable clamp, the next reading will be at the 98th footmark of the cable with the collar clamp gripping the cable immediately beneath the 98th footmark.)

Note: It will be exactly 1 additional foot to the top portion of the cable pulley brake at the top of the pulley holder. The depth from the top of the casing will be written in the column labeled DEPTH on the field recording sheets.

15. Repeat the readings of the A and B switch positions as in steps 11 and 12 above. Allow the readout to stabilize before recording the readings.

16. While continuing up the casing, obtain readings every 2 feet until collar of the hole is reached.

17. **Do not switch power off** - Remove the pulley wheel from the pulley brake mechanism, remove the probe from casing, rotate probe 180 degrees (1/2 circle) and reinsert probe into casing with upper wheels in A- groove and lower wheel in A+ groove. Replace pulley wheel

into pulley brake mechanism, lay cable into groove of pulley wheel, and lower probe again to the bottom of the casing. When nearing bottom of casing slow the probe's descent and stop probe several feet from bottom. Lower the probe slowly from this point on so that probe contacts the bottom of the casing gently.

18. Check that the depth to the bottom is exactly the same as in the previous run. Allow 2 to 3 minutes so that biaxial accelerometer can settle down from the rapid movements of going down the hole and then begin readings as in steps 11 through 15 above. Record the data on field sheets written under the A- and B- columns of the field sheets across from the appropriate depths.

Note: When taking readings be sure that the same cable markings are at precisely the same position on the pulley brake mechanism as they were on the previous run. In addition, all future runs are to be obtained with the same cable markings at the same position.

19. Upon reaching the casing collar for the final A- run, remove the pulley wheel from the pulley brake mechanism, and remove the probe from the casing. If you are using a manual readout unit, turn POWER-OFF. Other readout units you might need to advance the tape some or save your data file. Next wipe all dirt and moisture off the probe and connectors, disconnect all electrical connections, spray Kontact Clean into the connectors again to remove moisture and replace protective caps on cables, probe, and readout indicator. Use an aerosol can of WD-40 and liberally spray the wheel bearings and axle pivot points. This will flush any debris and moisture from these critical areas and provide rust protection and lubrication during storage.

APPENDIX

Field Operating Instructions for SINCO Model 50325 SENSOR
SINCO Model 50308 Mag Tape INDICATOR

The following operations are to be performed with the readout indicator (Mag Tape Indicator 50308) POWER-OFF.

1. Attach the pulley brake mechanism to the inclinometer casing collar.

Note: Mark each casing to be monitored in some way so that the pulley brake mechanism can be attached to each casing collar the same way for each set of data obtained. This will align the A+ groove.

2. Remove the protective caps from the sensor (probe) head, readout box, and interconnecting cables. Inspect the neoprene "O" ring, and replace if damaged.

3. Clean any dirt or moisture from all pins, connector sockets, and threads. Coat "O" rings with a thin film of silicon lubricant.

Note: Aerosol products such as "Kontact Clean or WD-40" are recommended for cleaning electrical contacts.

4. Attach the cable to the probe head (POWER-OFF)), tighten firmly with a wrench (no more than 12-14 ft/lb), and connect the cable to the readout indicator.

POWER-ON Operations

5. Suspend the probe by the cable, turn readout box power on, and observe the readings. Tilt the top of the probe in the direction of the upper spring loaded wheel and check that the reading increases in the positive A direction (POLARITY OF TILT ANGLE).

6. Remove the guide wheel from the pulley brake mechanism (POWER-ON) and insert the probe into the casing - upper wheel in the A+ groove and lower in the A groove. Replace the guide wheel, place the cable over the guide wheel, and lock the cable the in brake, with top of the probe close to the casing collar.

7. Observe the A and B displayed readings.

Note: Unless the casing is extremely vertical the A and B readings will be quite different.

8. Lower the probe to the bottom of the casing (CAUTION - Do not allow the coiled cable to KINK at any time as the internal conductors may be damaged. Do not allow the probe to hit the bottom of the casing). Lower the probe gently the last few feet and do not apply any sharp jolts to the cable, such as allowing the probe to descend rapidly and then abruptly stopping it.

Decelerate gradually.

9. Upon reaching the bottom of the casing, allow 5 minute for that the biaxial accelerometers in the probe to settle down and the temperatures in the electronic package (probe and mag tape) to stabilize.

10. Record the depth (in a field book) of the probe to the bottom of the casing by setting the nearest cable marking to the clamp at the top of the pulley cable clamp for the pulley brake mechanism.

Note: All subsequent measurements and recording of depths are to be made to the same point.

11. While waiting for the accelerometer to stabilize at the down hole temperature, record the date and borehole number on the recording tape.
 a. Set the date and hole number on the appropriate thumb wheels. Set orientation code digit to zero.
 b. Depress the DATELINE RECORD pushbutton.
 c. After the tape has advanced and the DATELINE RECORD lamp has gone out, set the thumb wheels to zero. Use the well digits positions to enter set number for the readings (set number should also be recorded in a field book).
 d. Again, depress the DATELINE RECORD pushbutton to record the set number on tape.
 e. After the tape has advanced and the DATELINE RECORD lamp has gone out, it is possible to start borehole recording (AO & B0).

12. By means of the cable, raise the sensor until the first available cable marking aligns with the top of the casing. Note: It will be exactly 1 additional foot to the top portion of the cable pulley brake at the top of the pulley holder. On the MAG-TAPE indicator, this depth is set into the automatic depth counter, and the desired recording interval (1, 2, or 5 foot) is selected. The USBR normally records readings at 2-foot intervals. After a few seconds, or whenever the accelerometers have settled down (this is determined by watching the LCD readout displays), the A+ inclinations, B+ inclinations and the depth are recorded by pushing the DATA RECORD button on the indicator panel. If the indicator accepts the reading, the red record light will function and go out, and the tape will advance a short length.

13. The probe is then raised 2 feet (usual USBR practice), allowed to stabilize, and subsequent the readings recorded as described above. This process continues until the probe reaches the top of casing.

14. When the probe is at the top of casing, remove the pulley wheel and withdraw the probe from the casing (leaving POWER ON).

15. Rotate the probe 180 degrees (1/2 circle), reinsert the probe into the casing so that the uppermost wheel (spring-loaded wheel opposite the fixed wheel on some probes) fits into the A-casing grooves and the lower wheels (fixed wheels on some probes) fit into the A+ casing grooves. Then, lower the probe to the same depth as in the first run and let the accelerometers inside the probe stabilize. Note: The POWER switch must be on whenever the probe is raised

and lowered inside the casing to prevent damage to the accelerometers.

16. On the MAG-TAPE unit, set nines into the dateline record, reset the depth counter and record the same data via the DATELINE RECORD button. The nines tell the CYBER computer program that this is the second run (180`) of this data set.

17. After recording the data, the probe is raised 2 feet and the process repeated as above until the probe reaches the top of the casing.

18. Upon reaching the top of the casing, the MAG-TAPE unit, the cassette tape is rewound (if not to be used for other data in which case advance the tape for 2 seconds), removed the tape from the indicator and battery voltage noted before switching off the power and closes the case.

19. Remove the pulley wheel, remove the probe from the hole, turn the POWER switch off, wipe the probe clean and disassemble it by removing the cable from the probe, replace the protective caps onto the cable and the probe, oil the wheel bearings and axle pivots, pack the probe in its case, and rewind the cable onto the cable reel.

APPENDIX
Field Operating Instructions for SINCO Model 50325 SENSORS
SINCO Model 50368 RECORDER PROCESSOR PRINTER (RPP)

The following operations are to be performed with the RPP readout
POWER-OFF:

1. Attach the pulley brake mechanism to the inclinometer casing collar.

Note: Mark each casing to be monitored in some way so that the pulley brake mechanism can be attached to each casing collar the same way for each set of data obtained. This will align the A+ groove.

2. Remove the protective caps from the sensor (probe) head, readout box, and interconnecting cables. Inspect the neoprene "O" ring and replace if damaged.

3. Clean any dirt or moisture from all pins, connector sockets, and threads. Coat "O" rings with a thin film of silicon lubricant.

Note: Aerosol products such as "Kontact Clean or WD-40" are recommended for cleaning electrical contacts.

4. Attach the cable to the probe head (POWER-OFF), tighten firmly with a wrench (no more than 12-14 ft/lb) and connect the cable to the RPP.

POWER-ON Operations

5. Suspend the probe by the cable and turn the RPP unit power on, and enter command DS (display sensor) return, observe the readings. Tilt the top of the probe in direction of the upper spring loaded wheel and check that the readings increases in the positive A direction (POLARITY OF TILT ANGLE).

6. Remove the guide wheel from the pulley brake mechanism (POWER-ON) and insert the probe into the casing - upper wheels in the A+ groove and the lower wheel in the A groove. Replace the guide wheel, place cable in the guide wheel, and lock the cable in the brake with the top of the probe close to the casing collar.

7. Observe the A and B displayed readings.

Note: Unless the casing is extremely vertical the A and B readings will be quite different.

8. Lower the probe to the bottom of the casing (CAUTION - Do not allow the coiled cable to KINK at any time as the internal conductors may be damaged. Do not allow the probe to hit the bottom of the casing). Lower the probe gently the last few feet and do not apply any sharp jolts to the cable, such as allowing the probe to descend rapidly and then abruptly stopping it. Decelerate gradually.

9. Upon reaching the bottom of the casing, allow 5 minutes for the biaxial accelerometers in the probe can settle down and the temperatures in the electronic package (probe and RPP) to stabilize.

10. Record the depth (in a field book) of the probe to the bottom of the casing by setting the nearest cable marking to the clamp at the top of the pulley cable clamp for the pulley brake mechanism.

Note: All subsequent measurements and recording of depths are to be made to the same point.

11. While waiting for the accelerometers to stabilize to the down hole temperature, fill in the parameters on the RPP or copy them from a previous file from the tape. After the probe has stabilized, the casing deflection readings at 2-foot intervals can be taken. The following steps should be followed when taking data on the RPP:
a. Press the RS (record sensor) return on the RPP. This command enables the recording of Digitilt data.
b. The RPP will ask on the display "GET PARAMETERS FROM FILE?" The parameters are information about locations and depth of hole needed by the RPP and our CYBER computer programs. Parameters may be taken from another data file on the cassette tape or created through the keyboard. If an initial set of parameters need to be created then press return. The following questions will be asked, Parameters are as follows: (answers are in brackets) (use down arrow to move through parameters which need not to be changed)

(1) Time = Time data are starting to be taken and date; (C) return will enter the date and time from the real time clock in RPP's memory.
(2) Digitilt/Spiral - (D) Inclinometer data or spiral data.
(3) English/Metric = (E) Units data will be taken in.
(4) Hole # = (I-1) Hole number being measured.
(5) Project = (San Justo Dam) Location of inclinometer casing.
(6) Job Desc. = (1) This is the set number or the number of observations made in the inclinometer casing.
(7) Dir code = (D/S) Direction of the inclinometer probe A+ wheel at the starting depth.
(8) Probe serial # = (12345) Serial number of probe being used.
(9) Operator = (Smith) Person taking data.
(10) Start depth = (100) Depth is to bottom of the hole in which readings are being taken.
(11) End depth = (2) Elevation at the top of the hole where readings will stop being taken.
(12) Increment = (2) Distance between readings.
(13) Instr. Const = (+2E4) Instrument constant. Instrument constant for a 30` probe is +2E4 and for a 90` probe is +2E5.
(14) Rotational Corr A = (0) Calibration changes made to probe.
(15) Rotational Corr B = (0) Calibration changes made to probe.
(16) Sensitivity Factor A = (0) Calibration changes made to probe.
(17) Sensitivity Factor B = (0) Calibration changes made to probe.

Use the down arrow to move through the parameters which need not to be changed. Shift Q on

the key board will exit the parameters.

12. After the parameters are set up, the actual data recording can be started. The display shows the probe depth to be recorded and a set of continuously updated readings. The display shows the AO and BO readings. If all is correct (depth, AO and BO orientation) the DATA RECORD button is pushed.

13. The data record process can then be repeated for each probe depth once the probe is moved to the next increment. This is repeated for all depths.

14. After the 2-foot depth (or last measured depth) is measured, the RPP will display "Continue Taking Digitilt Data," at this time, the probe is removed from the casing and rotated 180` (1/2 circle) and replaced in the casing and lowered to the bottom depth. Then press the Y key and take the 180` set of data for the hole in the same manner as previously described (steps 12 and 13).

15. Once all data are taken, the RPP will display "Write data to tape?" Answer Y, and tell the RPP which file to write the data to. After the data are stored in the file, check the data by the command VF, file number. This check will verify that the data have been stored correctly.

16. Upon reaching the top of the casing the pulley wheel is removed and the probe taken from the hole, the POWER switch is turned off, the probe is wipe clean and disassembled by removing the cable from the probe, protective caps are replaced onto the cable and the probe, the wheel bearings and axle pivots are oiled, the probe is packed in the case, and the cable is rewind onto the cable reel.

17. On the RPP, turn the power on, rewind the tape using RW command return, reset the tape using by command RT return, remove the tape from the RPP tape head and note battery voltage by pressing command DB (display battery) return, switch off the power and close the case.

APPENDIX
Field Operating Instructions for SINCO Model 50325 SENSORS
SINCO Model 503109 Digitilt Data Mate

Note: To select an item from the Data Mate Menu push enters. To move to different items in a menu use the left and right arrows or the up and down arrows, then push enters. To backup a menu or stop a function pushes the escape key.

The following operations are to be performed with the Data Mate readout POWER-OFF:

1. Attach the pulley brake mechanism to the inclinometer casing collar.

Note: Mark each casing to be monitored in some way so that the pulley brake mechanism can be attached to each casing collar the same way for each set of data obtained. This will align the A+ groove.

2. Remove the protective caps from the sensor (probe) head, readout box, and interconnecting cables. Inspect the neoprene "O" ring and replace if damaged.

3. Clean any dirt or moisture from all pins, connector sockets, and threads. Coat "O" rings with a thin film of silicon lubricant.

Note: Aerosol products such as "Kontact Clean or WD-40" are recommended for cleaning electrical contacts.

4. Attach the cable from the cable reel to the probe head (POWER-OFF); tighten firmly with a wrench (no more than 12-14 ft/lb).

5. Connect jumper cable from cable reel to Data Mate (sensor socket).

6. Connect hand switch to Data Mate (I/O socket).

7. Make sure that the proble is standing vertical before turning on power. "Do not lay the Probe down on its side."

POWER-ON Operations

8. Turn on power to Data Mate, select utilities menu, select battery. Voltages should be 2.9 not lower than 2.4 volts for LithBatt, and 6.2 to 6.4 volts for Data Mate battery.

9. Suspend the probe by the cable and select read from main menu. From read menu select manual and observe the readings. Tilt the top of the probe in direction of the upper spring loaded wheel and check that the readings, increases in the positive A direction (POLARITY OF TILT ANGLE).
10. Remove the guide wheel from the pulley brake mechanism (POWER-ON) and insert the probe into the casing - upper wheels in the A+ groove and the lower wheel in the A- groove.

Replace the guide wheel, place cable in the guide wheel, and lock the cable in the brake with the top of the probe close to the casing collar.

11. Observe the A and B displayed readings.

Note: Unless the casing is extremely vertical the A and B readings will be quite different.

12. Lower the probe to the bottom of the casing (CAUTION - Do not allow the coiled cable to KINK at any time as the internal conductors may be damaged. Do not allow the probe to hit the bottom of the casing). Lower the probe gently the last few feet and do not apply any sharp jolts to the cable, such as allowing the probe to descend rapidly and then abruptly stopping it. Decelerate gradually.

13. Upon reaching the bottom of the casing, allow a few minutes for the biaxial accelerometers in the probe can settle down and the temperatures in the electronic package (probe and Data Mate) to stabilize.

14. Push escape and then select Read from the main menu. Select record, site and installation, press down arrow to select installation. Data Mate should show the parameters for the installation, press enter to go by parameters or you can edit parameters if needed by using arrow keys. Get to start depth.

Parameters are information about locations and depth of hole needed by the Data Mate. Parameters are taken from site and installation information. Parameter is usually setup in the office on your PC and down loaded to the Data Mate. The following is a list of the Parameters is as follows: (answers are in brackets)

(1) Time = Time data are starting to be taken and date. The date and time from the real time clock in Data Mate's memory.
(2) Shallowest depth = (2) Depth is at the top of the hole in which readings are being taken.
(3) Deepest depth = (100) Depth at the bottom of the hole where readings will be taken.
(4) Increment = (2) Distance between readings.
(5) Dir code = (D/S) Direction of the inclinometer probe A+ wheel at the starting depth.

The following is entering into the sensor record:

(1) Sensor serial # = (12345) Serial number of probe being used, read from the sensor file (see below).
(2) Sensor model # = (50302500) typical English model number
(3) English/Metric = (E) Units data will be taken in.
(4) Instr. Const = (+2E4) Instrument constant. Instrument constant for a 30` probe is +2E4 and for a 90` probe is +2E5.

15. The display on the Data Mate indicates a diamond symbol in the upper line indicating that the reading is live. When two diamonds appear the reading is stable and data can be taken.

16. Record the depth (in a field book) of the probe to the bottom of the casing by setting the

nearest cable marking to the clamp at the top of the pulley cable clamp for the pulley brake mechanism.

Note: All subsequent measurements and recording of depths are to be made to the same point.

17. After the probe has stabilized, the casing deflection readings at 2-foot intervals can be taken. The following steps should be followed when taking data on the Data Mate:

a. The actual data recording can be started. The display shows the probe depth to be recorded and a set of continuously updated readings. The display shows the AO and BO readings. If all is correct (depth, AO and BO orientation) press the Hand Switch, this records the data.

b. The data record process is then repeated for each probe depth once the probe is moved to the next increment. This is repeated for all depths.

c. After the 2-foot depth (or last measured depth) is measured, the Data Mate will display "Continue" at this time, the probe is removed from the casing and rotated 180 degrees (1/2 circle) and replaced in the casing and lowered to the bottom depth. Then press the enter key and take the 180 depth set of data for the hole in the same manner as previously described (steps b and c above).

18. Once the last reading is taken, the Data Mate will display saving the data to memory. After the data are saved push escape key and return to the main menu.

19. The data should be checked before leaving the site. To check the data select "Validate" from the Datasets menu. The check sum is the sum of the zero and 180 degree reading at the same depth. This process can reveal patterns or anomalies in data. The checksum statistics are presented in two levels: 1) checksums and standard deviations for the entire data set, and 2) checksums and standard deviations for groups of readings. Review the checksums by pressing the enter key. Note any depths and checksums for A and B axes that have large checksums or large deviations from the mean checksum. Press escape to exit.

20. Upon reaching the top of the casing the pulley wheel is removed and the probe taken from the hole, the POWER switch is turned off, the probe is wipe clean and disassembled by removing the cable from the probe, protective caps are replaced onto the cable and the probe, the wheel bearings and axle pivots are oiled, the probe is packed in the case, and the cable is rewind onto the cable reel.

APPENDIX

Field Operating Instructions Inclinometer Settlement Measurements

The following operations are to be performed to obtain settlement measurements for embankment inclinometer installations:

1. Attach collaring device with the survey chain mechanism to inclinometer casing collar, make sure mechanism is set at same position for each consecientive measurement.

2. Attach survey chain to measuring probe, close probe making sure probe will latch.

3. Check probe constant in closed position (distance from zero on survey chain to bottom of probe). Record this constant measurement on the data sheet.

4. Open probe, measure probe constant PC in open position (distance from zero on survey chain to top of pawls on probe). This PC will remain the same for all measurement. If necessary the PC measurement may be adjusted by the screw on tip of the probe. Record the measurement PC on data sheet.

5. Place probe with safety rope in casing grove and start lowing probe into the hole.

6. At the first casing joint encountered from the top of the hole, pull back on survey chain until pawls engage the joint. Record the survey chain reading on the data sheet (this is the distance from the top of the casing to the first open joint).

7. Lower probe to next joint usually 10 feet distance and pull back on the chain to engage pawls against the casing joint, record this chain reading on data sheet.

8. Repeat step 7 until all casing joints has been measured.

9. The typical data sheet should be set up from the top of the hole down. The first casing joint on the data sheet will actually be the last joint installed during construction and the last casing joint of the data sheet will be the first joint that was installed.

10. The as built elevations listed on the data sheets were obtained during construction by survey the top of the inclinometer installation then subtracting 10 feet (for 10 foot casing sections) from that elevation. This gives the as built elevation and repeating this procedure until completion of the inclinometer installation.

11. The settlement of each joint is calculated by adding the probe constant (PC) to the chain reading and subtracting at quality from the current elevation obtained for the top of the installation. This gives the current elevation of each joint casing joint. Subtracting the current measurement from the as built elevation results in the settlement at the joint from the time it was installed.

12. After measuring the bottom casing joint, the probe should be lowered to the pin at the bottom of the hole. This pin serves two purposes, (1) to allow the probe to close, and (2) a method of measuring the deep foundation settlement. These pins may be set as much as forty feet below the bottom casing joint.

13. The pin measurement is made the same as the casing joint measurements, except the probe is closed requiring the use of a different PC. Also the probe may be required to be raised and then lowered again to remove all stack from the survey chain.

14. After the pin measured has been made and the probe which is closed is removed from the casing. Make sure that the safety rope and survey chain are pulled at the same rate of speed so that neither can get catch against the probe's wheels and the casing causing it to become stuck.

APPENDIX

Locating Inclinometer Casings during Construction

Locating inclinometer casings. - The contractor shall, after grouting the inclinometer casing in a drill hole but before the grout has set up, locate and align the top section of the inclinometer casing for the following information: station, offset, elevation, and the alignment of the "A" + groove, which usually shall be aligned 90` to the centerline of the dam and with a tolerance of ±4-inch. As additional casings are added, the Contractor shall perform the following work:

(1) Survey a temporary point in for station, offset, and elevation usually downstream of inclinometer casing.
(2) An azimuth angle, 90° to dam centerline is turned from the temporary point.
(3) Place an alignment bar in the inclinometer casing parallel with the azimuth angle.
(4) Measure the distance from the azimuth angle to both ends of the alignment bar.
(5) calculate the azimuth of the "A" + groove.
(6) Survey the station, offset, and elevation of the top of the casing.
(7) Calculate the present station and offset and check this location against the original station and offset measured at the top of the drill hole measured before embankment placement. The allowable total tolerance is ±4-inches. If the casing does not meet this tolerance, this casing section shall be removed and replaced.
(8) Add the next casing section only after current casing meets the allowable tolerance.
(9) Survey the new casing section for station and offset and force the casing section into the tolerance circle.
(10) Attach a leveling plate to the new casing and adjust the levels so that they are level with the new location of the casing. The fill can be brought up and around this new casing section. The contractor shall compact the fill and level the casing according to the levels on the leveling plate.

Leveling plate consists of an inclinometer settlement flange which fits the inclinometer casing that is being installed, and a level all bubble attached to the settlement plate. The level all has two line level bubbles which are perpendicular to each other, and three leveling screws to adjust these bubbles so that they can be level.

Alignment bar consists of a 2- by 2- 90° steel angle, 6 feet in length, attached at the center of the angle to a 4-inch-long round bar stock which has two square bars attached. The square bars will align the alignment bar in the inclinometer casing. The bar should fit snuggly into the inclinometer casing grooves. The 90° angle should be scribed on both ends for alignment measurements and also have small scales attached at both ends of the alignment bar for the measurements made of the new location.

APPENDIX

Field Operating Instructions for Tilt Meters and In Place Inclinometers

The following operations are to be performed with the readout indicator POWER-OFF:

1. Remove the protective covers from the connecting cable ends, readout indicator, and junction box.

2. Clean any dirt or moisture from all pins, corrector sockets, and threads. Coat "O" rings with a thin film of silicon lubricant. Note: Aerosol products such as "Kontact Clean. Never use WD-40 on the internal connections of the electrical cable connections of the readout unit, probe, connecting cable, or cable reel.

3. Attach the cable to the junction box (POWER-OFF) and connect the cable to the readout indicator.

POWER-ON Operations

4. Turn the power switch ON the readout indicator and allow the readout to warm up for 10 minutes.

5. Turn the power switch to BATTERY TEST. The digital display should indicate 6.0 volts for a fully charged battery. Do not operate the readout unit if the voltage is below 5.0 volts.

6. Set the junction box selector switch to SENSOR number 1 allowing at least 1 minute for the sensor to stabilize.

7. Record the magnitude and polarity of the reading displayed. Both the A and B components should be recorded. Some readout devices require switching from the A component to the B component. Record the data on the data sheet.

8. Set the junction box selector switch to the next sensor and repeat steps 5-7. Whenever the selector switch is set to a new sensor, 1 minute should be allowed for the sensor to stabilize.

9. After the last sensor has been measured, turn the POWER-OFF, wipe all dirt and moisture off of the connectors and cables, disconnect all electrical connections, spray Kontact Clean into the connectors again to remove moisture, and replace the protective caps on the cables, junction box, and readout indicator.

APPENDIX

Field Maintenance Procedures for Inclinometers

A regular maintenance program is essential to proper inclinometer, tilt meter, and in place inclinometer monitoring. Repair or replacement of an inclinometer probe or readout unit due to of misuse or improper maintenance can be expensive and can result in a shortage of data because of downtime.

Upon completion of field work, the unit should be checked for superficial damage. Wheel fixtures and bearings should be checked for tightness, cleaned, and oiled. Worn parts should be replaced as soon as possible. Metal surfaces should be cleaned and protected with a light coat of oil. The cable should be inspected for damage to the outer coating material and to the depth markers. If depth markers are not vulcanized to the cable, they may move and cause erroneous depth readings.

Cable connectors should remain capped when not in use and should be thoroughly cleaned after each use. Because most readout units are not completely weatherproof, they should be protected from moisture. The introduction of a few drops of water into the electronic circuitry can cause a galvanometer to read incorrectly or induce a drift on a digital voltage display. If readings are being made rapidly or if an automatic recorder is used, this drift may not be detected.

Equipment should be protected from shock and excessive vibration during transportation. Storage of this sensitive electronic equipment in a closed vehicle during the summer or in an unheated area in the winter should be avoided.

Periodic maintenance of the automatic data recorder, including the batteries, is required. Battery maintenance guidelines require that the batteries be discharged completely after several charge/discharge cycles. Nickel cadmium batteries retain a form of memory capacity such that if they are repeatedly discharged to 10 percent of their capacity then recharged to full capacity, they may soon deliver only about 10 percent of their potential capacity. Complete discharge is defined as 5.0 volts. The minimum voltage of the internal batteries that will safely operate the unit should be carefully monitored because low voltage can result in lost data. The tape cassettes used with the recorder should be protected against dust, dirt, and temperature extremes and should be cleaned periodically as prescribed by the instrument manufacturer. Keep all electrical connections clean - use alcohol or a spray cleaner suitable for electronics which will not damage the outer cable covering or panel finish. Periodically clean the tape head and drive components.

Replace the probe wheels and axles if they become wobbly or sticky. Constantly check the condition of the "0"-rings in the cable connections to help maintain a watertight seal. Keep the protective plugs in place on all electric outlets to prevent physical damage and liquids from spilling into them.

In short, the inclinometer is like other delicate equipment. Its use requires common sense and reasonable care!

APPENDIX

Field Maintenance Procedures for Inclinometer Settlement Devices

The measuring devices must be kept clean and free of grit. It is suggested that the measuring device be disassembled, as far as practicable, and either cleaned or flushed with clear water after each day's readings and oiled. The measuring tape should be carefully dried and inspected for kinks and breaks. An application of silicon grease on the tape will retard corrosion. If the pawls on the torpedo probe refuse to latch during measurements when the device reaches the pin at the bottom of the casing, a section of 3/4-inch pipe, 2 feet long or longer, can be slipped over the tape and safety rope and then lowered by wire or rope into the installation until it rests on the probe. This added weight should latch the probe so that is can be removed. Some casings become pinch at a depth causing the settlement probe to get stuck in the hole. The pawls will not close or the probe will not go to the bottom of the casing to close the pawls. If this occurs, use the previous described pipe method to remove the probe. This pinched casing will usually remain in the installation, so to obtain settlement data the probe can be slightly modified so that it can be closed from the surface by the operator or the wheels removed from the probe, allowing it to past the pinched section. The safety rope should be attached around the probe with a guide added to the bottom of probe so that when the rope is pulled, the probe will latch for removal.

Some inclinometer casings become plugged with silt or corrosion, necessitating periodic cleaning. Such cleaning can normally be accomplished by jetting with water under high pressure or use of chimney brushes for casing sidewall cleaning. The silt enters the installation at the measurement locations or joints. The silt will settle to the bottom. During jetting, use a 1/2-inch-diameter PVC pipe lowered to the bottom of the hole so the silt will be lifted out by the rising water. Some corrosion will build up on the interior of the casings requiring the use of bushes.

APPENDIX

Maintaining Instrument Batteries

A large quantity of the instruments used by the Bureau is powered by batteries. Batteries are usually troublesome to maintain in the field and can cause erroneous data to be taken. Batteries can be divided into two main categories: nonrechargeable batteries and rechargeable batteries. Field units are listed in the table below according to battery type.

Nonrechargeable and Rechargeable Batteries

1. Water level indicators vibrating wire indicators
2. Shear strips Inclinometer indicators
3. Voltmeters
4. Temperature readouts

The advantages and disadvantages, of each battery are: Nonrechargeable batteries have a low initial cost, high energy to volume or weight ratio, are dependable, and have a low self discharge rate or long shelf life. The most common batteries were originally the Leclanche (carbon zinc) variety. These batteries work well if used intermittently with long rest periods after each use. The alkaline manganese dioxide, mercuric oxide, silver oxide, and lithium batteries have met the needs of heavier duty cycles and longer shelf life. The disadvantage of nonrechargeable batteries is that they are impractical or uneconomical in applications requiring moderate or large currents for frequent operation, and deteriorate or are corrosive if left in instruments for extended periods of time.

Rechargeable batteries are advantageous since they can be recharged repeatedly. This results in a lower net cost, particularly in applications requiring heavy usage. The most commonly used rechargeable battery is the sealed nickel cadmium (NiCad) cells, another common battery would be the sealed lead acid (gel) type. The disadvantages of rechargeable batteries are that they are heavy, have a high shelf discharge rate, possess the risk of venting flammable gases and corrosive liquids during recharging, and must be maintained on a charge/discharge cycle to obtain satisfactory battery performance.

Gel type, lead acid batteries have a self discharge rate of approximately 10 to 20 percent per month at temperatures below 80 `F. They must be recharged at least once a month when stored below 110 `F or at least once every 3 months when stored below 80 `F. Undercharging degrades the battery performance and some overcharging may be required to restore all electrodes to their fully charged rate. Excessive overcharging causes electrode deterioration.

NiCad batteries have a wide discharge temperature range, and are unaffected by deep discharge and by severe duty cycles. One disadvantage, besides higher initial costs, is the tendency of the NiCad cells to temporarily lose storage capacity as a result of no optimum charging, discharging, and storage procedures. The incorrect procedures can create what is called the "memory effect" of the battery. This effect is caused when the crystals within the cell have become too large providing less surface area for the potassium hydroxide electrolyte crystal volume. These crystal

growth effects can be greatly reduced by periodical charging followed by a complete discharge and then recharging prior to next use. Scheduling operation to consume a larger proportion of rated capacity between recharges will also reduce the effects of the crystal growth.

NiCad batteries which are to be stored for a month or more at temperatures below 80 `F should be discharged completely prior to storage. At temperatures up to 110 `F, batteries stored for more than a week should be discharged completely prior to storage. Recharging is neither necessary nor desirable during prolonged storage; however, prior to being put back in service, a complete recharge followed by a complete discharge is recommended before final recharging and ultimate usage. These procedures are diametrically opposed to those recommended for lead acid batteries. Unlike lead acid batteries, NiCad batteries do not normally produce hydrogen during recharging and therefore, are not as hazardous as gel type batteries. However, they do produce a relatively large quantity of oxygen, which must be converted to cadmium oxide. The maximum recommended charge rate should not be exceeded during overcharge, especially at temperatures below 65 `F. Recharging at temperatures below 40 `F is especially risky. Since the cadmium oxygen recombination is slowed to the point where excessive pressure can be created within the cell during overcharge. Unless special precautions are taken, restrict the charge rate and avoid overcharge, the cell's pressure relief system could vent and cause a loss of electrolyte. This will permanently degrade battery performance in addition to exposing surrounding equipment to damage from the highly corrosive electrolyte.