Model GK-604D

Digital Inclinometer System

Instruction Manual



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1. INCLINOMETER THEORY

In the geotechnical field inclinometers are used primarily to measure ground movements such as might occur in unstable slopes (landslides) or in the lateral movement of ground around on-going excavations. They are also used to monitor the stability of dams, embankments, slurry walls, the disposition, and deviation of driven piles or drilled boreholes and the settlement of ground in fills, embankments, and beneath storage tanks (using horizontal inclinometers).

In all these situations it is normal to either install a casing in a borehole drilled in the ground, to cast it inside a concrete structure, or to bury it beneath an embankment or structure (for horizontal inclinometer applications). The inclinometer casing has four orthogonal grooves (see the Figure 1 below) designed to fit and position the wheels of a portable inclinometer probe (see Figure 2) within the longitudinal axis of the casing. This probe, suspended on the end of a signal cable connected to a readout device, is used to survey the inclination of the casing with respect to vertical (or horizontal) and in this way to detect any changes in inclination caused by ground movements, when compared to an established baseline survey measurement.

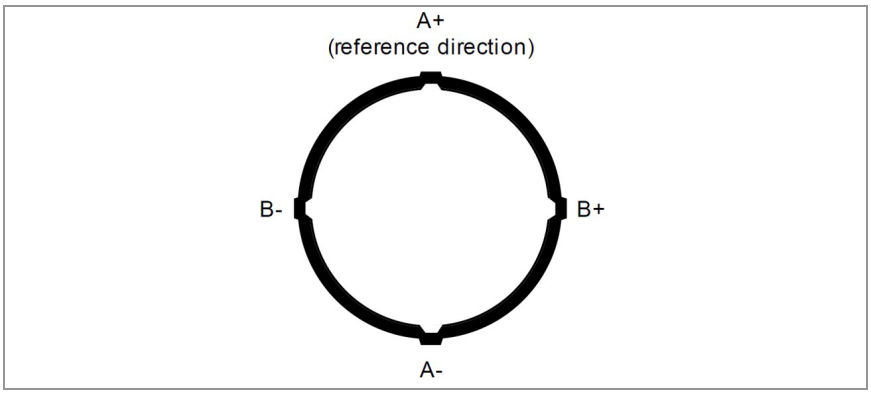


Figure 1: *Inclinometer Casing (End View)*

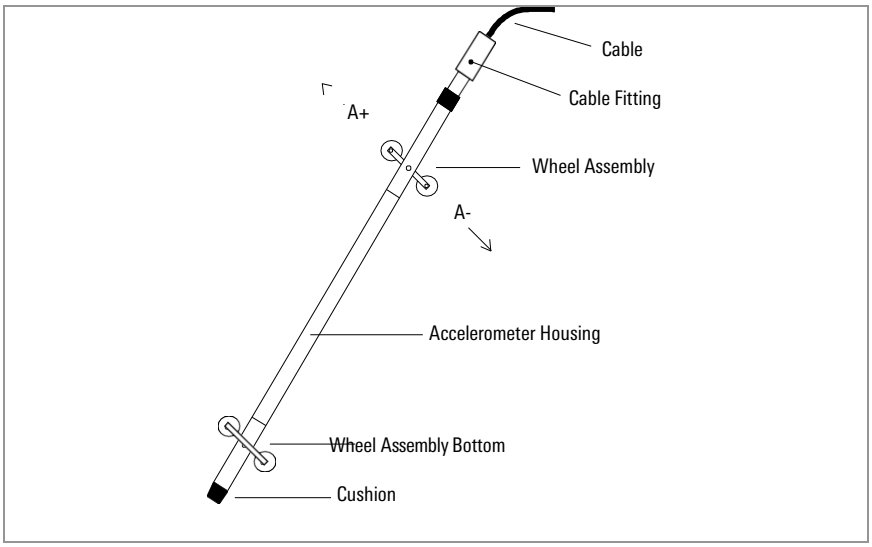


Figure 2: *Inclinometer Probe*

The probe itself contains MEMS (Micro Electro-Mechanical Sensor) technology to provide precise biaxial measurements over a range of ±90°. (The calibrated range is ±30°.)

In order to obtain a complete survey of the ground around the installed inclinometer casing it is necessary to take a series of tilt measurements along the casing. Typically, an inclinometer probe has two sets of wheels separated by a half-meter / two-feet. A casing survey would begin by lowering the probe to the bottom of the casing and taking a reading. The probe would then be raised at half-meter / two-foot intervals and a reading taken at each interval until the top of the casing is reached. The readings thus generated are called the A+ (and B+) readings. Marks on the cable at half-meter / two foot spacing facilitate the process. The probe is then removed from the casing, rotated 180 degrees, replaced in the casing, lowered to the bottom of the borehole. A- (and B-) readings are obtained at the reading interval as the probe is raised.

The A-axis is in line with the wheels (as shown in Figure 2) with the B-axis orthogonal to it. At each interval along the casing, readings from both A and B directions are measured. Thus, during the survey, as the A+, A- readings are obtained, corresponding B+, B- readings are also recorded.

During the data reduction, the two sets of readings at each depth interval (A+, A- and B+, B-) are combined (by subtracting one set of readings from the other) in such a way that the effect of any zero offset of the accelerometer is minimized.

This zero offset is the averaged reading obtained from the inclinometer probe when it hangs absolutely vertical. Ideally, the offset (or bias) would be zero, but usually there is a zero offset which can change during the life of the probe. This change can be due to a sudden shock to the transducer caused by dropping or allowing it to hit too hard against the bottom of an installed inclinometer casing, but it can also be due to drift of the transducer or wear and damage of the wheels. Each probe will also have a slight offset initially, as the alignment of the sensors and wheel assemblies is not completely perfect.

Subsequent surveys of the inclinometer casing, when compared with the original survey, will reveal any changes of inclination of the casing and locations at which these changes are taking place. Analysis of the change of inclination is best performed by calculating the horizontal offset of the upper wheels relative to the lower wheels, which has produced the tilting (θ) over the reading interval (L) of the survey (usually the 61 cm (2') wheelbase of the probe). At each position of the inclinometer, the two readings taken on each axis (A+, A- and B+, B-) are subtracted from each other leaving a measure of sine. This value is then multiplied by the reading interval (L) and the appropriate factor to output horizontal deflection in engineering units (see Figure 3).

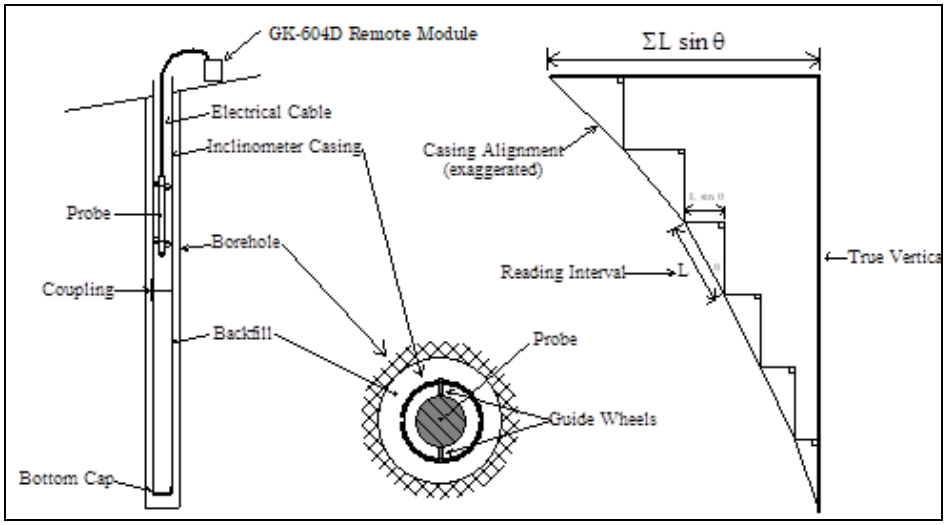


Figure 3: *Inclinometer Survey Description*

When all these incremental horizontal deflections are accumulated and plotted, beginning at the bottom of the borehole, the net result is to produce a plot of the change in horizontal deflection between the time of the initial survey and the time of any subsequent survey. From such a deflection plot, it is easy to see at which depth the movement is occurring and its magnitude (see Figure4).

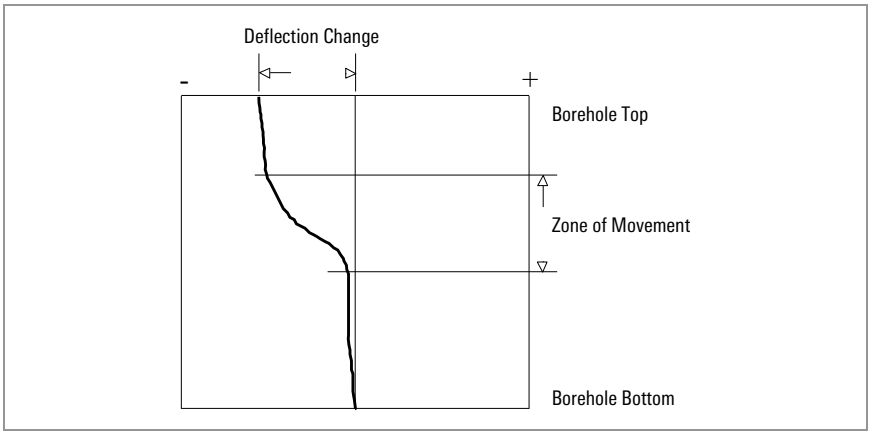


Figure 4: *Plot of Borehole Deflection*

Other methods of analysis can be used to assist with evaluation of the data and inclinometer casing condition. For example, using a single set of data, a profile of the borehole can be created to evaluate verticality of the casing. In addition, a plot can be made of the actual change in reading (inclination) at each measurement depth increment. A plot of this nature reveals the depths at which movement is occurring.

One other analysis is the Check Sum (or Instrument Check) which can be used to measure the quality of the survey data.

The quality of the data can be impaired by any or all the following:

- Skipping over or duplicating a reading.
- Not allowing the inclinometer enough time to come to rest before taking a reading.
- Not allowing enough time to allow the probe to reach temperature equilibrium before commencing the survey.
- Malfunction of the probe, cable, or readout device. This may be the result of shock, moisture, low battery conditions, opens or shorts in the cable or probe, etc.
- Carelessness when positioning the wheels so that the probe wheels do not rest on the same part of the casing from one survey to the next.
- Positioning the wheels so that they fall right on top of a casing joint, causing the reading to be unstable or simply erroneous.

The Check Sum analysis is performed by adding the A+ and A- readings or the B+ and B- readings. When this is done, the part of the reading due to the tilt is eliminated, leaving only a value that is equivalent to twice the zero offset of the inclinometer transducer.

2. INTRODUCTION

The GK-604D is made up of four components: An Inclinometer Probe, the Readout Unit, the Remote Module, and a Pulley Assembly.

2.1 INCLINOMETER PROBE

The standard model is the 6105 digital probe (see Figure 5). This probe is available in 2 sizes: English (2 feet between the wheels) and metric (0.5 meters between the wheels).



Figure 5: *6105 Digital Probe*

- Features Include:
- Waterproof, stainless steel housing.
- Rubber cushion on base to reduce shock.
- Superior quality, hermetically sealed connector with gold plated pins.
- Protective cap for connector when not in use.
- Replaceable wheels.
- Model 6105 Digital Probes feature a built-in compass.

2.2 READOUT UNIT

The Readout Unit consists of a handheld field PC (or other Android device), running the GK- 604D Reader | aos Application (see Figure 6).



Figure 6: *Handheld Field PC Running GK-604D Reader | aos application*

The FPC-3 features Include:

- Rugged
- Reliable
- All the benefits of an Android device (Cell capability, Wi-Fi, file system, USB and Bluetooth connectivity). Many apps available via Google Play
- Long battery life
- Ease of use

2.2.1 GK-604D READER APPLICATION

The GK-604D Reader | aos Application installs and runs on an Android Device such as the handheld field PC (Figure 6), and is designed to communicate via Bluetooth with Remote Modules connected to digital MEMS probes.

2.3 REMOTE MODULE

The GK-604D Remote Module is housed in a weatherproof reel enclosure containing the cable (see Figure 7), which connects directly to the inclinometer probe (see Figure 5). The Readout Unit and Remote Module components communicate wirelessly using Bluetooth®, a reliable digital communications solution. This simplifies the handling of the system in the field as well as simplifying the transfer of data to your PC workstation for final analysis.

The Remote Module is fully contained within the reel as depicted below.



Figure 7: *GK-604D Remote Module*

Features Include:

- Lightweight
- Easy to use, one button operation.
- Rugged
- Reel size based on cable length
- Lithium battery (Eight plus hours of continuous use)
- Automatic power down when the Bluetooth connection is dropped or after several minutes of inactivity.

- Reliable connection to standard inclinometer probes (shown in Figure 5) is accomplished via model 6001-2 control cable (see Figure 8), which features a lightweight, polyurethane jacket and is 8 mm in diameter. The control cable contains a central stainless steel aircraft wire and has breaking strength of 500 lb.



Figure 8: *Model 6001-2 Control Cable*

2.4 PULLEY ASSEMBLY

The pulley assembly (see Figure 9) is used to guide the cable while raising and lower the inclinometer probe and to grip the depth markers of the control cable while taking a survey. The pulley places no stress on the cable markers and removes any tendency for markers to slip over the cable as when using cable holds. The pulley assembly is designed to fit casing sold by GEOKON but will also fit most casings that have an external diameter between 85 mm (3.34") and 70 mm (2.75").

To install the pulley assembly, loosen the thumb screws to open the metal collar until it is large enough to fit over the casing. Place the pulley assembly on top of the inclinometer casing and then tighten the thumb screws so that the metal collar firmly grips the casing. (See Figure 9.)

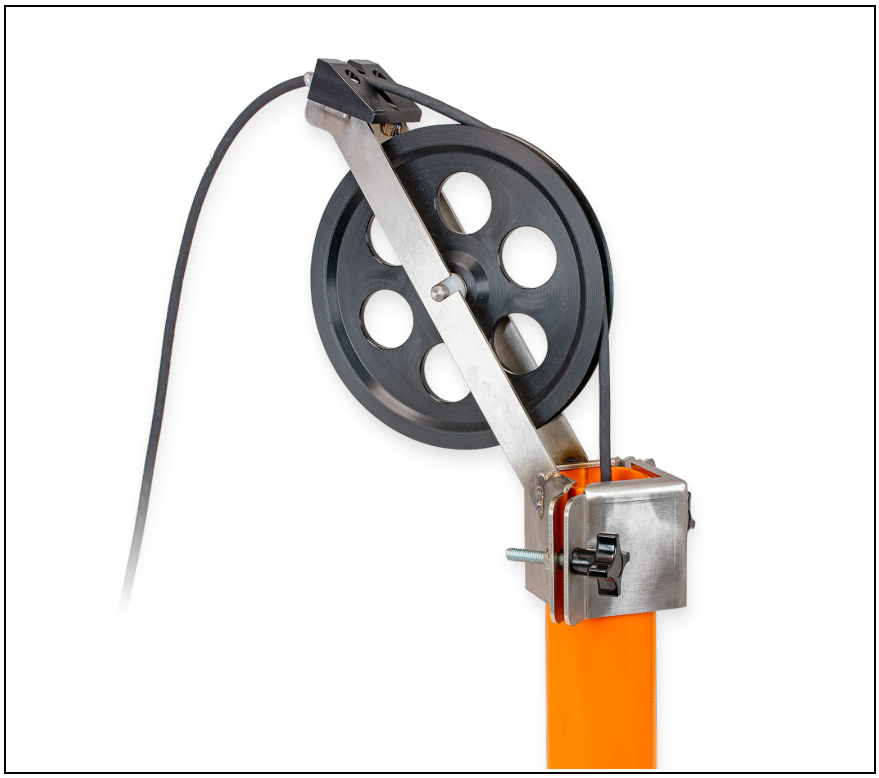


Figure 9: *Model 6000-22 Pulley Style Cable Grip*

3. INSTALLATION AND OPERATION

3.1 BEFORE USING THE GK-604D READER APPLICATION

The readout software runs as an application under the Android operating system (OS) (minimum version 6.0) installed on a handheld field PC or other Android device. If a handheld field PC has been purchased from GEOKON then the GK-604D Reader | aos will already be installed.

See the GK-604D Reader | aos User's Manual for more information on installing and updating the GK-604D Reader | aos app on an Android device.

The user should familiarize themselves with the handheld field PC and the Android OS, specifically how to:

- Accessing Bluetooth Settings in the Settings application.
- Use the on-screen keyboard to enter text and numbers.
- Review the Maintenance requirements in Section 5.

3.2 ESTABLISHING CONTACT WITH THE REMOTE MODULE

GEOKON makes every effort to ensure that the system is completely set up and working before it leaves the factory. When using another Android device, follow the instructions below to pair the Remote Module to the Android device

Tap the "Settings" icon (circled in red) in the application library and the Settings screen will be displayed (see Figure 10) .

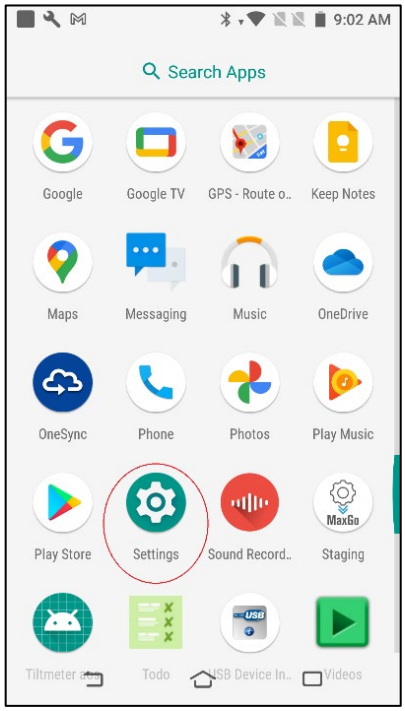


Figure 10: *Starting the Settings Application*

From the Settings screen, tap on the "Connected devices" menu item (see Figure 11) then make sure that, on the next page, the Bluetooth switch is "ON" (green and to the right) (see Figure 12).

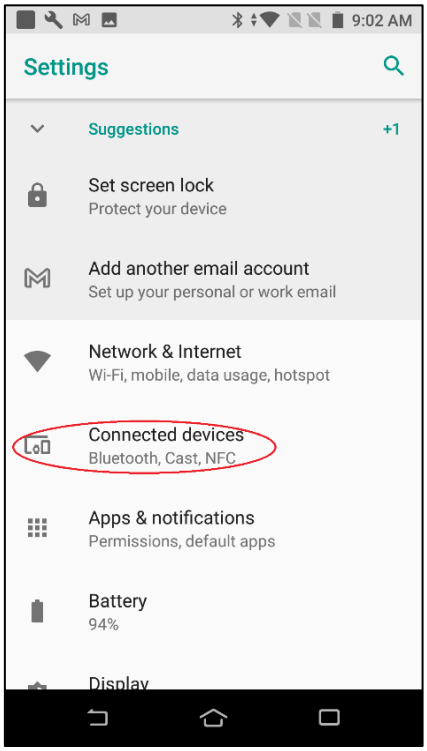


Figure 11: *Connected Devices (Bluetooth)*

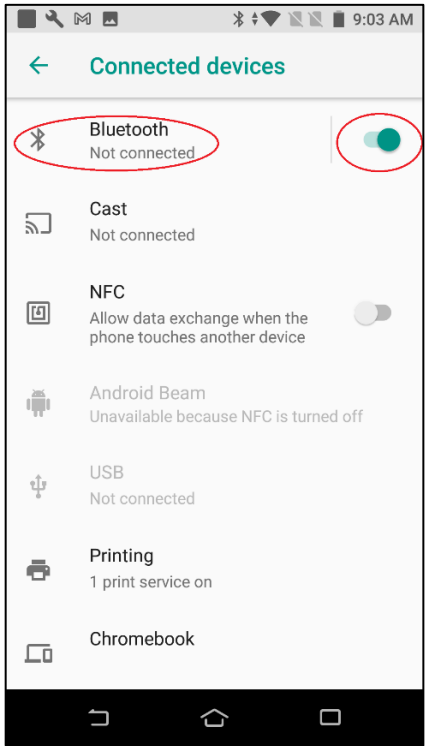


Figure 12: *Bluetooth "ON"*

When the “Connected devices” page is displayed, under “Bluetooth” there may be a line of text that reads, “Not connected”. This is perfectly normal and only means that no Bluetooth device is actively connected, at that moment (see Figure 12). Tapping on “Bluetooth” displays the “Bluetooth” page along with all paired devices (see Figure 13).

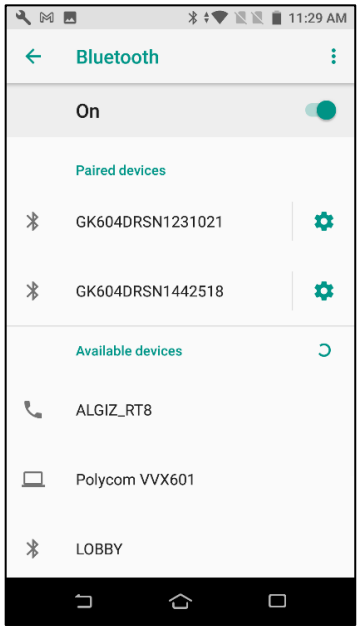


Figure 13: *Select a Bluetooth Device*

The Remote Module's Bluetooth signature appears in the list above (see Figure 13) as a string of alpha-numeric characters starting with "GK604DRSN" followed by a 7-digit serial number of the Remote Module. If your Remote Module's serial number does NOT appear in the list of "Paired devices", follow the steps below to pair your Remote Module with the Android device:

1) Press the "Power On/Off" button (older units may be labeled: "POWER ON (BLUETOOTH)"). The blue light on the Remote Module should be blinking.
2) Tap the 3 vertical dots (known as a "kebab") in the upper-right corner of the screen, then tap "Refresh" when a sub-menu is displayed.
3) If your Remote Module pre-dates January 2020, then a prompt will be displayed for a password, enter "default" at the prompt and the pairing should be complete. If the password is rejected, try "1234". With new Remote Modules, no password is necessary, but a confirmation dialog will be displayed (see Figure 14). Tap "PAIR" to finish pairing the Remote Module to the Android device.

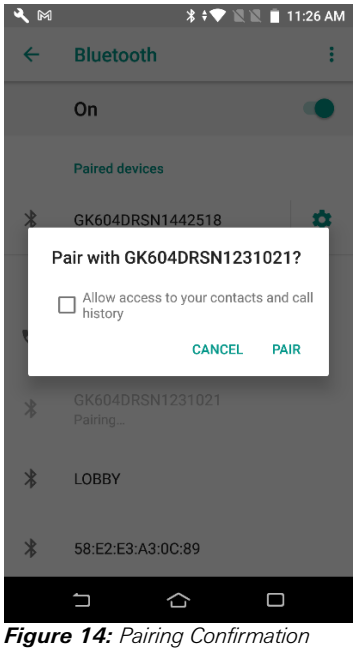


Figure 14: *Pairing Confirmation*

3.3 INSTALLING THE GK-604D READER | AOS APPLICATION

The installation of the GK-604D Reader requires a handheld field PC or other Android device. Please see the GK-604D Reader | aos User's Manual for more information regarding application installation.

4. FILES, FOLDERS, AND TRANSFERRING DATA

The GK-604D Reader | aos uses several types of files and dedicated folder locations to keep track of database and exported data files. The default locations and names for most of these appear in Table 1. The base path name for these folders varies between Android versions and will often appear as “Internal Storage” in later versions. Some manufacturers don’t identify this folder, it is simply “below” where other user folders appear.

CAUTION! Manual editing of the database file mentioned above will likely result in data loss or unexplained operation and **is strongly discouraged**.

Purpose	Default Folder	File Name
GK-604D Reader | aos backup database	(Internal Storage)/IncloData/	GK604D_Tab_SQLite.db3
Data Files Export Location (per Hole)	(Internal Storage)/DataFiles	*.gkn
Log Files	(Internal Storage)/LogFiles	GK604D_Tablet.log
Backup and other files	Some Android version (10 and up) may not allow access to the above folders. In this case the following should be used: (Internal Storage)/Download	

Table 1: *Folder Paths and File Names*

4.1 FILE TRANSFER

In general, the only files generated by the GK-604DReader that will have to be transferred (exported) are the "hole" data files, although exporting log files and database files offsite can be useful for troubleshooting. Connecting the handheld field PC to a desktop or laptop PC using the supplied USB cable (Type A to USB C) is straightforward and allows the user to view the handheld field PC’s storage as a flash drive on the desktop/laptop; you can then simply drag the files around to any folder on the desktop/laptop. Please reference the GK-604D Reader | aos Application Manual, using the link below, for more information regarding import and export of files and data.

http://www.GEOKON.com/manuals/

4.2 BACKING UP CONFIGURATIONS

To guard against accidental data loss, the GK-604DReader | aos database should be periodically backed up. Backing up all data and configuration information is a simple process and is outlined in the GK-604D Reader | aos Application Manual. Use the link below, to access the aforementioned manual.

http://www.GEOKON.com/manuals/

5. MAINTENANCE

The inclinometer probe is a totally sealed unit and, as such, field adjustments are not required.

5.1 O-RING

Maintenance of the "O" ring on the connector requires that it be kept clean, as well as free of cuts and nicks. Periodic greasing with "O" lube is recommended. A worn or damaged "O" ring should be replaced with a new one (five "O" rings are supplied with each new probe).

5.2 WHEEL ASSEMBLIES

Wheel assemblies should be kept dry when in storage. They should be kept free of dirt by using a compressed air gun to blow away grit. **After every survey, spray the springs, pivots and axles with light oil**. **This is very important and should not be neglected.**

5.3 WATER ENTRY

One of the main problems encountered is caused by a failure to keep the cable and probe connectors dry. Failing to fully tighten the cable connector to the probe connector can cause water ingress. This connection must be tight enough to compress the O-ring in the end of the probe connector.

Caution: To avoid corrosion, spray the pins of the probe connector periodically with DEOXIT #DN5 spray contact cleaner and rejuvenator. Each inclinometer probe is shipped with a container of this spray. After each daily use, always make sure that the connectors are completely dry before replacing the protective caps.

5.4 ZERO SHIFT CHANGES

If the zero shift changes due to aging or rough handling, this will not affect the quality or accuracy of the readings because the shift is removed by taking two sets of readings in the A+ and A– directions. However, if the zero shift changes by more than 5000 digits then the probe should be returned to the factory for repairs.

5.5 SELF CALIBRATION CHECK

It is good practice to have a piece of inclinometer casing permanently fastened to a fixed immovable structure in the laboratory. This casing is used as a periodic check on the calibration of the probe. Placing the probe in the casing should give a reading that does not change with time.

5.6 DATA BACKUP AND TRANSFER

Remember, from time to time, to backup and remove the survey data from the handheld field PC. This guards against data loss in the event of a catastrophic failure of the Android device.

6. TROUBLESHOOTING

6.1 BLUETOOTH CONNECTION

6.1.1 BLUETOOTH DEVICE NOT SELECTED

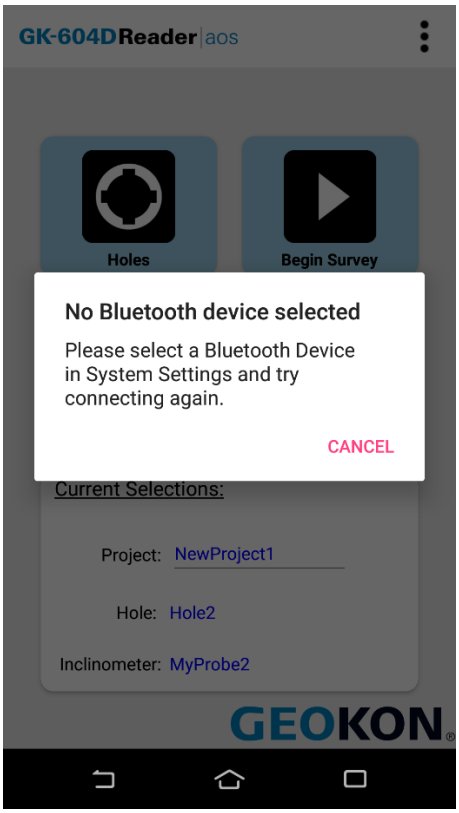


Figure 15: *No Bluetooth device selected*

This message is displayed (see Figure 15) when no Bluetooth Device has been selected in the System Settings. See the GK-604D Reader | aos manual for information regarding System Settings. Select a Bluetooth Device on the System Setting page then try again.

6.1.2 CANNOT CONNECT TO GEOKON REEL SYSTEM

After the "Begin Survey" button is tapped, a message is displayed prompting the user to press the "Power On" button on the GEOKON reel (see Figure 16). This message is normal and serves as a reminder to turn on the reel. If the message shown in Figure 17 is displayed after pressing "OK", one of three things may have happened:

1. The "Power On" button was not pressed. *Press the "Power On" button and try again to connect.*
2. The "Power On" button was pressed but the blue light did not come on and start blinking or the blue light went off soon after the button was pressed. *Connect the reel to its charger for 2 hours then try again to connect.*
3. The "Power On" button was pressed, the blue light came on and started blinking but the blue light never went to solid on. *This reel may not be the device that was selected in the System Settings.*

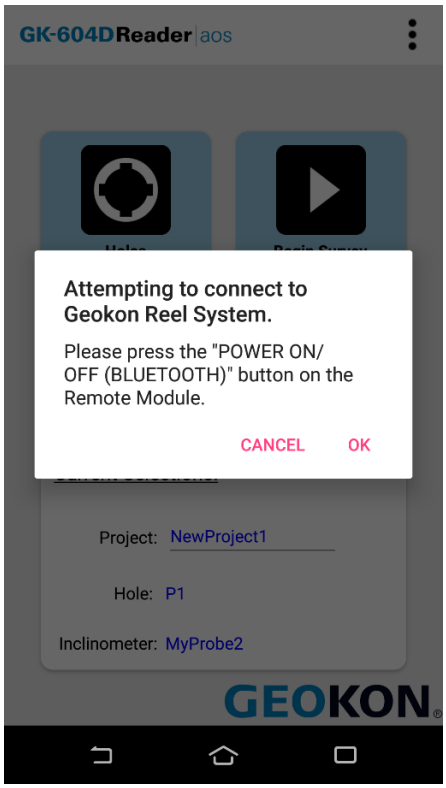


Figure 16: *Pre-Connection Message*

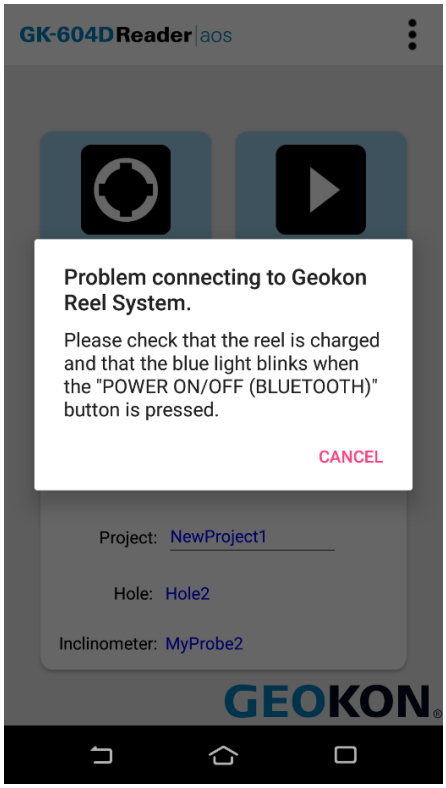


Figure 17: *Connection Problem*

6.1.3 UNABLE TO CONNECT

The error displayed in Figure 18 most commonly occurs when the probe is disconnected from the cable reel when a Bluetooth connection is initiated. Verify the probe is connected and attempt a Bluetooth connection again. If the error persists, there may be damage to the probe or cable.

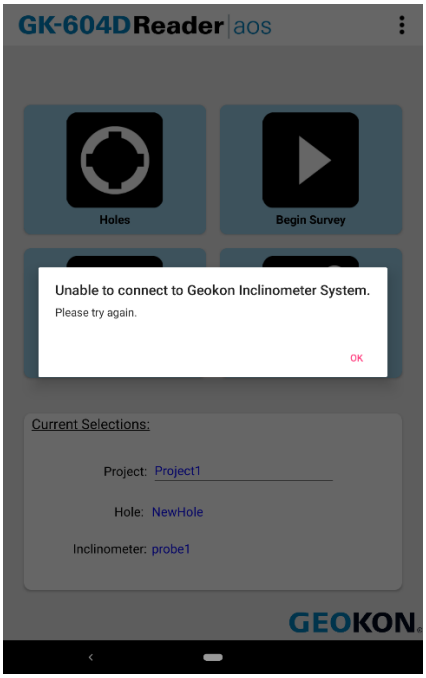


Figure 18: *Unable to Connect Error*

6.2 COMMON TROUBLESHOOTING SOLUTIONS

PROBLEM	SOLUTION
Handheld field PC does not power up	Charge the handheld field PC for two hours, then try again.
When adding a Hole**,** UNKNOWN is the only choice for Probe name**.**	The Android device may not have been purchased as part of the GK-604D system or the Inclinometer was deleted from library. Please refer to Section 5 of the GK-604D Reader Application manual
The blue indicator light does not blink when the POWER ON/OFF (BLUETOOTH) button is pressed on the Remote Module**.**	Attach Remote Module charger for two hours, then try again.
After tapping on the **"**Begin Survey" button, the blue light never goes solid blue and an error screen is displayed.	Check that the Bluetooth on the Android Settings page is "**On**." Check that there is a valid Bluetooth pairing in the Bluetooth Setting screens of the FPC-3. Please refer to Section 3.2 of this manual.
The GK-604D Reader appears to be "hung" or "frozen" and will not respond to any key press.	Check for a **background** error message; one may exist behind the main window that requires user input. Tap **the hardware "Back"** button to see if there is another window hidden.
Blue light on Remote Module does not go off after Live Readings window has been exited.	If the above solution does not apply, press the **POWER ON/OFF (BLUETOOTH)** button on the Remote Module.

Table 2: *Common Troubleshooting Problems and Solutions*

APPENDIX A. CHECKSUM ERRORS

A.1 INCLINOMETER PROBE CHECKSUMS AND "FACE ERRORS"

Many users have expressed concern about **checksums** or "**face errors**" on inclinometer probes. They are concerned with the effect of the "face error" on the accuracy of the readings. The purpose of this section is to show that under normal circumstances the effect of the "face error" or checksum is negligible even with checksums as large as 2000. **The only time a problem would arise is if the face error or checksum was to change between the two halves of a survey. Therefore, it is extremely important not to bang the probe on the bottom of the borehole between survey halves, and not to handle the probe roughly while out of the hole.**

The term "face error" comes from surveying terminology. It is normal for all theodolites to have a "face error" which is caused by imperfections of alignment of the collimation axis and other misalignments. These "face errors" are removed routinely by taking two readings of the theodolite: one angle is measured with the face of the vertical scale on the left of the theodolite and another with the face of the vertical scale on the right of the theodolite. The average of the two readings "face right" and "face left" gives the **true angle since the "face error" cancels out**.

Similarly, with the inclinometer probe: the "face error" arises from the fact that the axis of the inclinometer probe is not parallel with the electrical axis of the internal, force-balance, servo- accelerometer transducer. Once again, the "face error" is eliminated by taking two surveys of inclinometer readings one with the wheels of the inclinometer probe pointing in one direction and another with the wheels of the probe at 180° to the first direction. If the first set of readings are all too large by the amount of the "face error", then the second set of readings will be too small by the amount of the "face error". Thus, the average (or sum) of the two readings will be a measure of the true inclination since the effect of the face error will be eliminated.

A.1.1 EFFECT OF "FACE ERROR" ON READING ACCURACY

The "face error" or checksum can only affect the accuracy of the readings if it affects the calibration of the probe. This is possible because the output of the probe transducer is proportional to the sine of the inclination from the vertical and the sine function is nonlinear.

Imagine, for a moment, that the electrical axis of the transducer is five degrees away from being parallel with the axis of the inclinometer. This would give rise to a "face error" of 1743. (The inclinometer reader displays 20,000 sin ∅). This would cause one set of readings to be all too large by this amount and the other set of readings from a normal inclinometer survey would be too small by this amount, but the sum of the two readings would be accurate, the "face errors" having canceled out. However, if we assume that the hole is almost vertical then the transducer will be tilted at an angle of 5°. The difference in the slope of the sine function at any point is equal to the cosine of the angle at that point. The cosine of 0° is 1.0000 the cosine of 5° is 0.996, so that the effect of this "face error" on the calibration of the probe is to increase it by a factor of
1 / 0.996 = 1.004.

The practical implication of this would mean that if the apparent deflection of a borehole was 100 mm, the true deflection would be 100.4 mm. For practically all applications in the real world, the difference is insignificant and is a lot less than the differences that normally occur from survey to survey, i.e., a lot less than the precision of the inclinometer probe survey. (Lack of precision can be caused by a failure to position the wheels of the probe in exactly the same place from survey to survey, failure to wait sufficiently long to allow the probe transducer to come to rest before reading, and random dirt in the inclinometer casing).

Note that the normal system accuracy of an inclinometer probe is ±3 mm in 30 meters. By comparison, it can be seen that the normal system accuracy or precision is very much larger than the calibration error caused by the "face error" and that for all practical purposes the "face error" is of no consequence and can be completely discounted if it is less than 2000 digits.

(As another example, supposing the checksum was as large as 5000 digits. This is equivalent to a gross angular error of misalignment of almost 15 degrees. The effect on the calibration would be a little over 3% so that the apparent deflection of 100 mm would be out by 3 mm, which again is smaller than the normal data spread due to imprecision).

A.1.2 MEASUREMENT OF "FACE ERROR"

The "face error" is the reading shown by the inclinometer probe when it is perfectly vertical. In practice, the easiest way to obtain the "face error" is to run a normal inclinometer survey, with the two sets of readings at 180°, and then to run a profile or deflection report (see Section 8 of the GK-604D Reader Application manual). Examination of the data will reveal the **average checksum, which is equal to twice the "face error"**.

A.1.3 SETTING OF THE "FACE ERROR" TO ZERO

There are two ways of setting the "face error" to zero. None of them is necessary from the point of view of improving accuracy. These methods are detailed in the subsections below.

ELECTRICALLY

Electronic circuitry can be included in the probe so that the output of the transducer can be adjusted to zero when the probe is vertical. The disadvantage of this method is that it introduces electronic components into the inside of the probe which may alter with time, temperature and humidity and which, if the "face error" changes due to wear and tear or rough handling, will require the probe to be dismantled and the electronic circuitry readjusted. In addition, this form of correction does not really remove the "face error", it only masks it, and if the "face error" is very large, the calibration will be affected.

BY SOFTWARE

The best way for setting the "face error" to zero is by applying an automatic correction to the measured readings using the software capabilities of the inclinometer readout box.

At calibration, GEOKON sets the "face error" to zero by programming the Inclinometer Probe "Zero Shift" parameters to their calibrated values for both the A and B axes. The “Zero Shift” parameters are the same as "face errors". These values cannot be easily changed by the user as this may adversely affect the probe calibration. If the probe is ever sent back to GEOKON for re-calibration, the “Zero Shift” values would be updated at that time.

A.1.4 CONCLUSION

Checksums of less than 2000 digits are of no consequence and can be completely ignored providing that the inclinometer survey is conducted with two sets of readings at 180°.

APPENDIX B. TECHNICAL SPECIFICATIONS

B.1 6105 INCLINOMETER PROBE SPECIFICATIONS

Range[1]:	±90°
Resolution: (99% Confidence Interval[2])	0.00025° (0.004 mm/m)
Precision (99% Confidence Interval[3])	±0.0075° (±0.13 mm/m)
Nonlinearity	±0.005° across ±30° range (±0.09 mm/m)
Temperature Dependent Uncertainty	±0.001° across ±5° range (±0.016 mm/m) ±0.0016° across ±15° range (±0.026 mm/m) ±0.0026° across ±30° range (±0.042 mm/m)
Operating Temperature	-40 °C to 65 °C (-40 °F to 149 °F)
Wheelbase:	0.5 m or 2 ft.
Length x Diameter[4]:	700 x 25 mm or 32 x 1 in.
Casing Size I.D.[5]:	48 to 89 mm (2 to 3.5 in.)
Weight (with case):	7.5 kg (16 lb.)
Shock Survival[6]:	5000 g
Maximum Cable Length	500 m (1640 ft.)

Table 3: *6105 Specifications*

NOTES:
[1] Calibrated Range: ±30°.
[2] 99% confidence interval (i.e. 99 out of 100 individual readings fall within this tolerance).
[3] Includes random walk (changes between consecutive readings that have no discernible cause) and seismic noise during testing.
[4] The cable connector adds 150 mm to the length of the probe.
[5] The probe is designed for use in all standard inclinometer casing up to a maximum diameter of 89 mm (3.5 inches).
[6] The Inclinometer Probe is a highly sensitive device and should be treated with great care at all times in order to maintain calibration. Particular attention should be given to preventing the probe from hitting the bottom of the casing with any impact.

B.1.1 COMPASS SENSOR SPECIFICATIONS

The table below contains specifications for the Digital Compass sensor embedded in digital inclinometer probes.

Resolution:	±0.1°
Repeatability:	±1.6°

Table 4: *Compass Sensor Specification*

B.1.2 HANDHELD FIELD PC SPECIFICATIONS

System	• Operating system: Android™ 14 • GMS (Google Mobile Services) certified using EDLA • Upgradeable through Android 18 • Processor: Qualcomm® QCM4490 octa-core up to 2.4 GHz
Storage	• Memory (RAM): 8 GB • Internal Storage (ROM): 128 GB • MicroSDXC Card Storage up to 512 GB
Display	• 500 Nits typical • Screen size (diagonal): 6.26" (159 mm) • Screen resolution: 2280 x 1080 FHD+ • Capacitive multi-touch interface for wet conditions • Chemically-strengthened Gorilla® Glass 5 • Optimized for extreme environments including wet touch
Connectivity	• 5G with 4G LTE fallback, Dual Nano SIM card slots • Cellular: LTE-FDD: (B1/B2/ B3/B4/B5/B7/B8/B12/B13/B14/B20/B25/ B26/B28a/B66/B71), LTE-TDD: (B38/B40/B41), 5G: (N1, N2, N5, N28, N41, N66, N71, N77, N78, N79) • Wi-Fi®: 6E 802.11 2.4/5 GHZ a/b/g/n/ac, 802.11 ax • Bluetooth® 5.2 • Duel-band GPS, GLONASS, Beidou, Galileo, QZSS • NFC • USB Type-C (5Gbps, 5V power delivery), OTG
Ruggedness	• Ingress protection: IP68 waterproof & dustproof • Operating Temperature: -4 F to 140 F (-20 C to 60 C) • Meets MIL-STD-810H test procedures: Method 500.6 Low Pressure, Method 501.7 High Temperature, 502.7 Low Temperature, 503.7 Temperature Shock, 506.6 Rain, 507.6 Humidity, 510.7 Sand and Dust, 512.6 Immersion, 514.8 Vibration, 516.8 Shock
Physical	• Weight: .72 lbs (325 g) • Dimensions: 174 x 85 x 15 mm • 2 user programmable buttons
Camera	• Front: 16 MP • Rear: 48 MP with LED illumination
Battery	• Removable Li-ion battery • Battery size: 4500 mAh • Internal 300 mAh battery allows for hot-swapping

Table 5: *Handheld Field PC Specification*

APPENDIX C. COMMONLY ASKED INCLINOMETER PROBE QUESTIONS

CAN INCLINOMETER PROBES BE SWAPPED FREELY TO PERFORM SURVEYS IN THE SAME BOREHOLE?

Immediately after leaving the factory, probes may be swapped freely as they will meet the system accuracy specification, which is ±3 mm/30 m (±.125'/100").

CAN CORRECTIONS BE MADE TO THE DATA WHEN INSTRUMENTS ARE SWAPPED? SUCH AS AN OFFSET OR FORMULA?

As time passes, correcting the output of one probe to match that of another probe becomes quite difficult, and would involve a tremendous amount of time and effort spent recording, calculating, and converting every data point for every level in every survey.

Unfortunately, there is not a universal formula, any simple corrections, or offsets that can be used to correct one probe to another.

WE RECENTLY SENT OUR PROBE IN FOR CALIBRATION. AFTER RECEIVING IT BACK FROM GEOKON, THE OLD SURVEYS DO NOT MATCH UP WITH THE NEWLY CALIBRATED PROBE'S SURVEYS AND ARE SHOWING SIGNIFICANT DISPLACEMENT. IT IS THE SAME PROBE, SO WHY DON'T THE SURVEYS MATCH?

For the same reasons that two different probes will show differences in the same borehole, a newly calibrated probe will also show differences (from its old calibration) even though it is physically the same piece of equipment. Essentially, after a recalibration you are working with a "new" probe.

HOW CAN I COMPARE MY OLD DATA WITH MY NEW DATA?

The recommended method to check compatibility between two sets of probes is to take at least three surveys with the new probe and compare them to the most recent survey taken with the old probe. If the resulting **cumulative displacement** plots performed with the new system overlay the latest survey from the old system, consider yourself lucky. However, if you see significant differences, we recommend the following method.

From the old series of surveys performed with the original system, create a final summary of cumulative displacement and a summary of displacement vs. time. Also, create a comparison of the final survey with the old system to the initial surveys taken with the new system. Then archive these summaries and data.

Next, use one of the three surveys obtained with the new system that you feel is most accurate. Use that survey to establish a new baseline survey and start a new series. This is the most accepted method in the long term.

The reason GEOKON recommends this method is that you already know the magnitude and rate of movements you were detecting with the old system. This will be based on the final cumulative displacement plot and the displacement vs. time summaries created earlier. When movements occur, you will catch them with the new series based on the new system.

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