Model 6140

Vertical In-Place

Inclinometer String

Instruction Manual

GEOKON®

Document Revision: Initial | Release Date: 4/05/24

Note: The Model 6140 is patent pending

WARRANTY STATEMENT

GEOKON warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by GEOKON, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY IS VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of GEOKON's control. Components that wear or are damaged by misuse are not warranted. This includes fuses and batteries.

GEOKON manufactures scientific instruments whose misuse is potentially dangerous. The instruments are intended to be installed and used only by qualified personnel. There are no warranties except as stated herein. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. GEOKON is not responsible for any damages or losses caused to other equipment, whether direct, indirect, incidental, special or consequential which the purchaser may experience as a result of the installation or use of the product. The buyer's sole remedy for any breach of this agreement by GEOKON or any breach of any warranty by GEOKON shall not exceed the purchase price paid by the purchaser to GEOKON for the unit or units, or equipment directly affected by such breach. Under no circumstances will GEOKON reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

Every precaution for accuracy has been taken in the preparation of manuals and/or software, however, GEOKON neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damages or losses that result from the use of the products in accordance with the information contained in the manual or software.

TABLE OF CONTENTS

1. INTRODUCTION

The operating principle of the GEOKON Model 6140 Vertical In-Place Inclinometer String is the utilization of MEMS (Micro-Electro-Mechanical Systems) tilt sensors to make accurate measurements of inclination over segments of an inclinometer casing.

The Model 6140 Vertical IPI String consists of a string of Biaxial MEMS tilt sensors, installed in rugged engineered polymer housings. One spring-loaded wheel and two fixed wheels allow the string to positively engage the grooves of conventional 70 or 85 mm inclinometer casing maintaining azimuth with depth. The entire string is held in tension by attaching a suspension weight from the bottom-most sensor and hanging the string from the top of the casing using a suspension cable and support bracket.

Sensors in the inclinometer string are mechanically connected with high-strength aircraft cable assemblies, which are free to pivot about the connection point. Sensors are electrically connected via a common bus cable, while the top-most sensor includes a waterproof connector that allows for easy assembly to the chosen readout device (PC, datalogger, SCADA system, etc.) through a customer-specified readout cable.

Each sensor outputs calibrated tilt (angular degrees) and temperature (degree Celsius) readings, which can be easily imported into MS Excel, or any inclinometer visualization software, without the need to convert raw data into engineering units.

The Model 6140 Vertical IPI String uses industry standard Modbus® Remote Terminal Unit (RTU) protocol to communicate. It employs an RS-485 (half duplex) electrical interface, recognized for its prevalence, simplicity, and success as a robust, industrial physical layer. Monitoring can be accomplished using GeoNet Addressable Loggers, the Model 8020-38 Addressable Bus Converter, Model 8600 Series Dataloggers, Campbell Scientific Dataloggers, or any other device capable of operating as a Modbus RTU client and having an RS-485 port.

2. INSTALLATION

Installation Video

For a visual demonstration watch the Model 6140 Installation Video.

2.1 CABLE CONNECTIONS

When making cable connections, line up the orientation dot on the outside of the male connector with the two orientation dots on the outside of the female connector (Figure 1). This will ensure the pins and receptacles of the connectors align correctly. To prevent water entry, be sure to push the connectors together until they are fully mated (Figure 2). For additional security, GEOKON recommends taping the connectors together with electrical or black mastic tape.

Note: To facilitate mating, the male connectors have dielectric grease applied. Do not remove this grease.

Caution! Care should be taken to avoid cutting or damaging the cable jacket, which could introduce moisture into the interior of the string, thereby causing irreparable damage to the sensors.

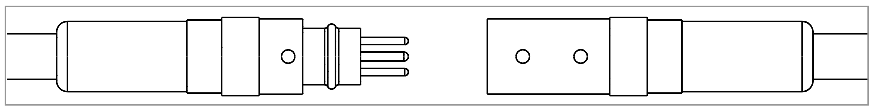

FIGURE 1: *Cable Connection Detail*

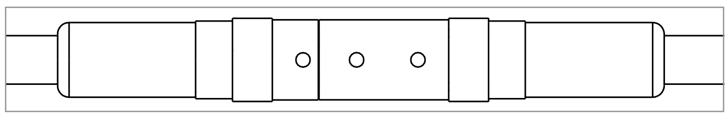

FIGURE 2: *Connected Cables*

2.2 PRELIMINARY TESTS

Prior to installation, check the sensors for proper operation by completing the steps below.

For strings containing fewer than 100 sensors, skip to Step 4.

1. Place the string sections in the correct order by referring to the labels on the shipping cartons. Do not remove from the cartons.
2. Connect the string sections together by plugging the male cable connector of one section into the female connector of the next. Connectors are marked with color-coded tape between each section. Shipping cartons are labeled in order of sequence and by string identification if applicable. (See Section 2.1 for cable connection details.)
3. Repeat this process until the entire string is connected. The aircraft suspension cable does not need to be connected at this time.
4. Plug the male cable connector of the top-most sensor of the string into the female connector of the readout cable.
5. Connect the IPI string to a datalogger or PC (Refer to Section 2.6 for details.)
6. Tilting the shipping carton from one side to another should yield increasing or decreasing readings for all sensors. The temperature indicated on the readout should be close to ambient. Repeat this process with the remaining shipping cartons. **If any of these preliminary tests fail, refer to Section 5 for troubleshooting.**

Once the preliminary tests are complete, disconnect the string from the readout device and disconnect the string sections from each other (if applicable). **When disconnecting, do not pull by the cable, grip the connectors and pull apart carefully.**

2.3 CONNECT THE SUSPENSION WEIGHT

1. Remove the locking pin from the suspension weight by depressing the barb and pulling on the ring.

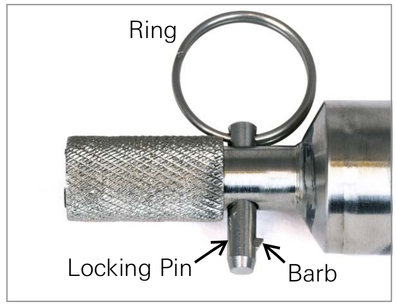

FIGURE 3: *Locking Pin Details*

2. Retract the spring sleeve on the suspension weight.

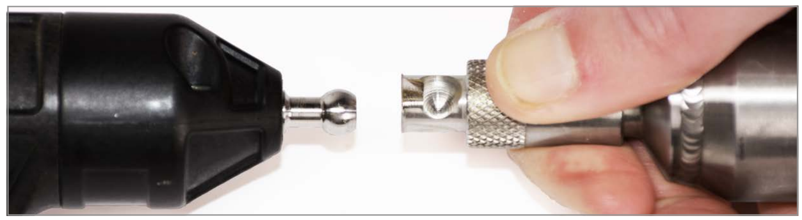

FIGURE 4: *Retract the Spring Sleeve*

3. Mate the ball stud of the terminal sensor to the receiver on the weight, then release the spring sleeve.

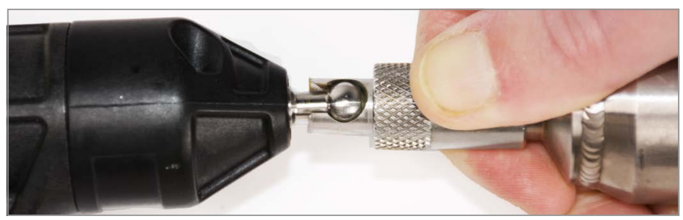

FIGURE 5: *Capture the Ball Stud*

4. Reinsert the locking pin to prevent the sleeve from accidentally retracting during use.

FIGURE 6: *Completed Connection*

2.4 SENSOR ORIENTATION

All sensors should be oriented in the same direction when installed in the casing. The MEMS device monitors both A and B directions (Figure 7). The A+ and A- directions face the sensor wheels and are marked on the sensor housing. The B+ direction is 90 degrees clockwise from the A+ direction, as viewed from above.

FIGURE 8: *Correct Vertical Orientation*

Point the A+ direction in the same direction as the anticipated movement, e.g., towards the excavation being monitored or downslope for slope evaluation applications.

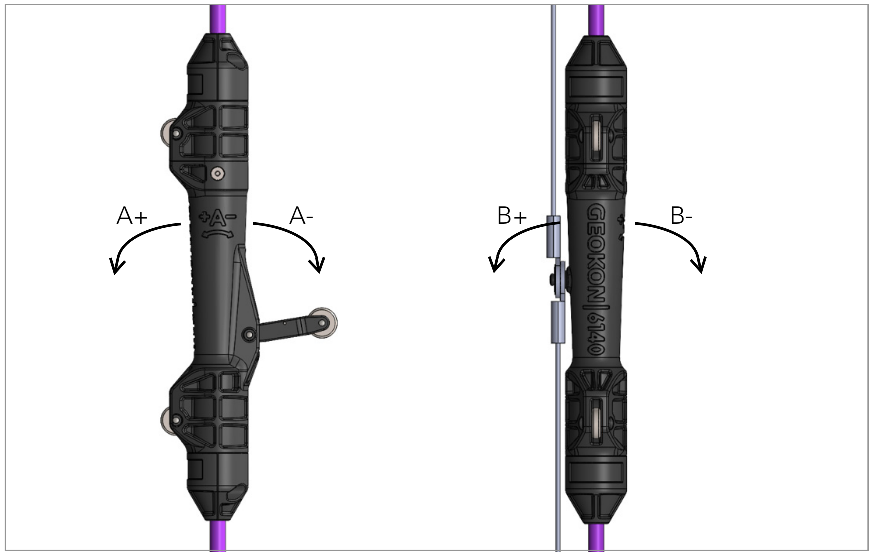

FIGURE 7: *A & B Directions*

2.5 INSTALLING THE SENSORS IN THE CASING

Important! Sensors must be held vertically so the weight of the string is placed on the aircraft cable. Failure to do so will add stress to the signal cable and may damage the string, see Figure 8.

1. Insert the suspension weight into the casing. Install the sensors directly from the shipping carton into the casing according to the following steps.
2. Insert the bottom sensor, make sure to position all three wheels of the sensor in the grooves of the casing. The sensor should be oriented in the casing as described in Section 2.4
3. Install the next sensor of the string into the borehole, and each sensor thereafter, as previously described, until the topmost sensor of the string is reached.
4. Insert the sensor hold into the casing, then insert top sensor into the holder

.

FIGURE 9: *Sensor Hold*

For strings containing less than 100 sensors, skip to Step 6.

5. Connect the next section of the string to the section already in the borehole as follows:

    a. Using the supplied screwdriver, remove the screw and washer holding the aircraft cable to the top sensor of the current string section.

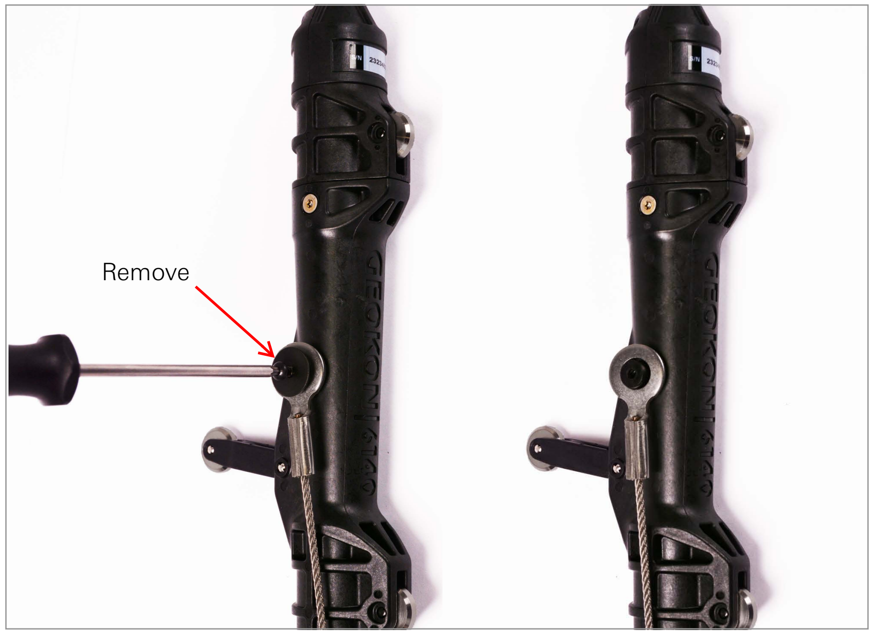

FIGURE 10: *Remove Screw*

    b. Take the aircraft cable eyelet from the bottom sensor of the next string section and arrange over the existing eyelet.

FIGURE 11: *Arrange Eyelet from the Next String Section Over Existing Eyelet*

    c. Secure both eyelets to the top sensor by reinstalling the screw and washer. Figure 12 shows the completed connection.

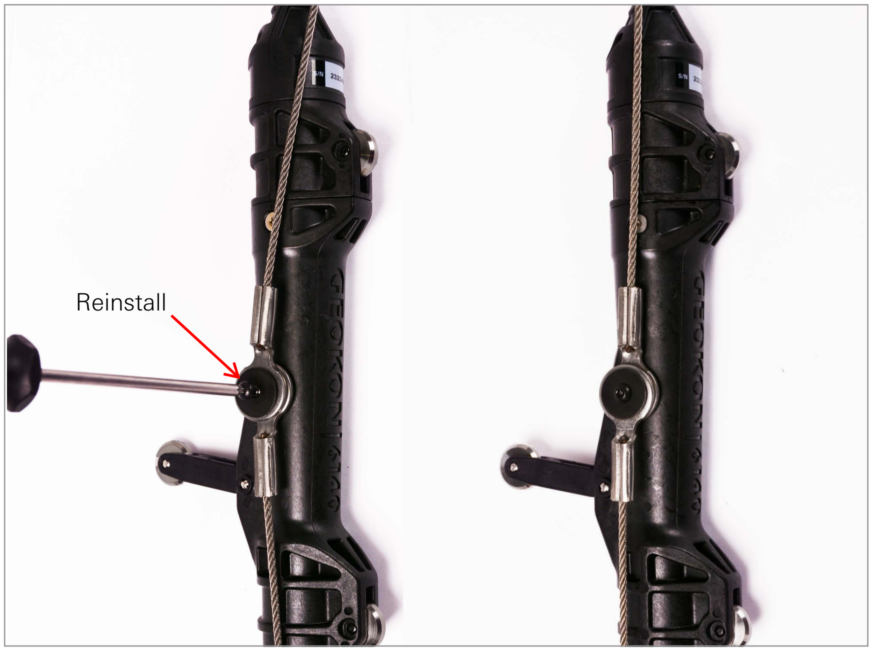

FIGURE 12: *Secure Aircraft Cable Eyelets, Completed Aircraft Cable Connection*

d. Mate the male and female cable connectors (matching color-to-color) of the two string sections. (See Section 2.1 for cable connection details.)

e. Remove the sensor hold from the casing.

f. Install the next section of the string into the borehole, and each section thereafter, as previously described, until the topmost sensor of the string is reached.

g. Insert the sensor hold into the casing, then insert the top sensor into the holder.

6. Plug the male cable connector of the top sensor into the female connector of the readout cable. (See Section 2.1 for cable connection details.)
7. Connect the aircraft cable from the top sensor to the eye bolt on the bottom of the suspension bracket using the quick link connector.

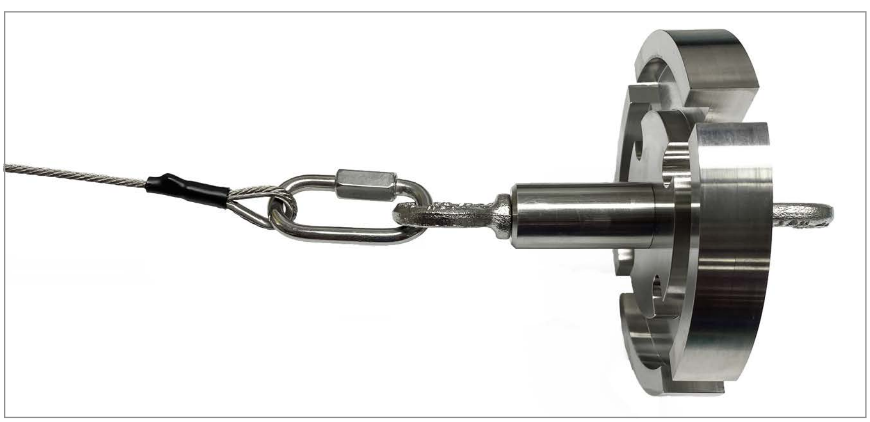

FIGURE 13: *Suspension Bracket Attachment*

8. Remove the sensor hold from the casing and install the top sensor into the borehole.
9. Position the suspension bracket on top of the casing.

Note: In order for the suspension bracket to be properly seated on the casing, the top rim of the casing must be clean and flat.

10. Connect the readout cable to a datalogger or PC (Refer to Section 2.6 for details).
11. Readings may be taken immediately after installation; however, GEOKON recommends evaluating the data over a period of time to determine when the string has sufficiently stabilized to collect an accurate zero reading.

2.6 READOUT

If your datalogger has built-in RS-485 communications, connect the readout cable using the wiring diagram below. (The datalogger must have the appropriate port available.)

Datalogger	Sensor Conductor Color
485+	WHITE
485-	GREEN
12V	RED
GND	BLACK
SHD	BARE

TABLE 1: *Addressable (RS-485) Datalogger to Sensor Wiring Table*

If your datalogger does not have built-in RS-485 communications, the converter below can be utilized.

MODEL 8020-38 ADDRESSABLE BUS CONVERTER

Model 8020-38 Addressable Bus Converter (Figure 14) can be utilized in a string with **50 sensors or less**. The Model 8020-38 allows addressable strings to be connected to personal computers, readouts, dataloggers, and programmable logic controllers. The converter acts as a bridge using the TTL or USB protocols between readers and the GEOKON RS-485-enabled sensor strings.

FIGURE 14: *Model 8020-38 RS-485 to TTL/USB Converter*

If utilizing a Model 8020-38 to connect the 6140 string to a readout, wire the connections as shown. (The dataloggers must have the appropriate port available.)

Datalogger Connection	Conductor Color	8020-38 Connection
V+	RED	12 V (IN)
TX	WHITE	TX (IN)
RX	GREEN	RX (OUT)
GND	BLACK	GND
SHD	BARE	SHIELD

TABLE 2: *Datalogger to Model 8020-38 Wiring*

8020-38 Connection	Sensor Conductor Color
12 V (OUT)	RED
485+	WHITE
485-	GREEN
GND	BLACK
SHIELD	BARE

TABLE 3: *Model 8020-38 to Sensor Wiring*

Model 8020-38 Manual

For more information, please refer to the Model 8020-38 Instruction Manual.

2.7 FOUR-PIN WATERPROOF CONNECTOR

The pinouts for the four-pin male and female connectors are shown below; the function of each wire is detailed in Table 4 below.

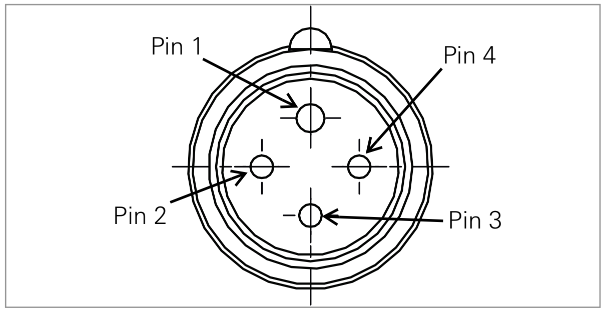

FIGURE 15: *Male Waterproof Connector*

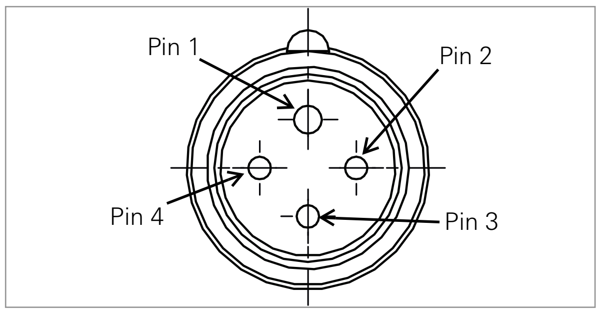

FIGURE 16: *Female Waterproof Connector*

Pin	Wire Color	Function
1	RED	Power
2	BLACK	Ground
3	WHITE	RS-485+ Data High
4	GREEN	RS-485- Data Low

TABLE 4: *Four-Pin Wiring Chart*

3. TAKING READINGS

3.1 COMPATIBLE DATALOGGERS

GEOKON can provide several datalogger options. Devices compatible with this product are listed below. For further details and instruction consult the corresponding Manual(s) at geokon.com/Dataloggers. Contact GEOKON for additional datalogger options.

Dataloggers

DATALOGGERS:

- **8600 Series**

  The MICRO-6000 Datalogger is designed to support the reading of a large number of GEOKON Vibrating Wire instruments for various unattended data collection applications through the use of GEOKON Model 8032 Multiplexers. Weatherproof packaging allows the unit to be installed in field environments where inhospitable conditions prevail. The Nema 4X enclosure also has a provision for locking to limit access to responsible field personnel.

- **8920, 8930, and 8950 Series**

  GEOKON Model 8920, 8930, and 8950 Series Loggers offer a high-value, networked data collection option for all GEOKON Vibrating Wire instruments and digital sensor (MEMS IPI and VW) strings. Each logger comes from the factory ready for deployment and may commence with data acquisition in minutes.

  Sensor data is collected and transferred via a cellular, Wi-Fi, or satellite network to a secure cloud-based storage platform where it can be accessed through the GEOKON OpenAPI. Industry leading data visualization software, such as Vista Data Vision, or the free GEOKON Agent program can be used with the OpenAPI for data viewing and reporting. Commissioning, billing and configuration are accomplished via the easy-to-use GEOKON API Portal.

4. DATA REDUCTION

4.1 INCLINATION CALCULATION

The 6140 Inclinometer Sensor outputs simple engineering units, degrees of tilt, which have been calibrated for both angular and temperature effects. Because of this, no further correction to the outputted data is required.

4.2 DISPLACEMENT CALCULATION

There are two equation sets available that calculate sensor displacement: **Lateral Sensor Displacement** and the **Simplified Lateral Sensor Displacement**. Review the descriptions below and perform the preferred calculation method. In both cases initial readings must be taken after installation to serve as a baseline. Initial measurements are then used as a reference and subtracted from any subsequent measurements in order to determine movement or change in a borehole position at various time intervals.

LATERAL SENSOR DISPLACEMENT CALCULATION

Developed specifically for the 6140 assembly, the equation below takes into account the angles of sensors at either end of any given gauge length. Utilizing this method gives the most accurate results and is recommended by GEOKON.

The relative lateral displacement (D_{rel}) of each measuring point is found using the following equation:

$$D_{1rel} = L\sin\left(\frac{\theta_1 + \theta_2}{2}\right)$$

EQUATION 1: *Relative Lateral Displacement*

Where:
L = Gauge length (i.e. sensor spacing)
θ = Inclination angle of the sensor, as described above

The profile of the borehole is approximated by accumulating these relative lateral displacements at each measuring point, starting with the bottom sensor. Refer to Figure 17 below.

The absolute lateral displacement (D_{abs}) at each measuring point is found using the following equation:

$$D_{3abs} = L\sin\left(\frac{\theta_1 + \theta_2}{2}\right) + L\sin\left(\frac{\theta_2 + \theta_3}{2}\right) + L\sin\left(\frac{\theta_3 + \theta_4}{2}\right)$$

OR

$$D_{3abs} = D_{1rel} + D_{2rel} + D_{3rel}$$

EQUATION 2: *Absolute Lateral Displacement*

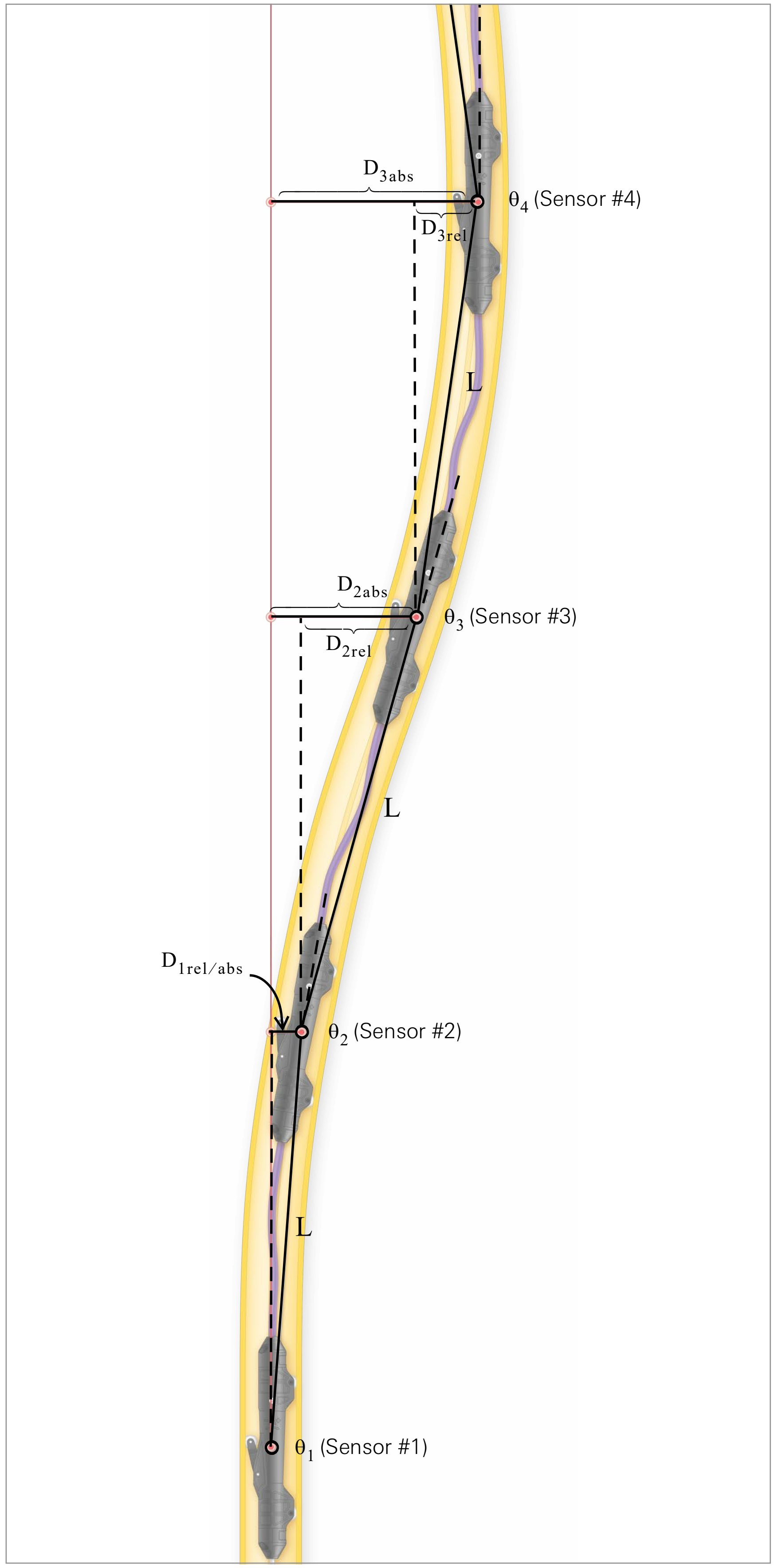

FIGURE 17: *Displacement Intervals*

SIMPLIFIED LATERAL SENSOR DISPLACEMENT CALCULATION

The Simplified Lateral Sensor Displacement equation can be used as an alternative to Equation 1. This method will introduce a small amount of error.

The relative lateral displacement (D_{rel}) of each measurement point is found using the following equation:

$$D_{1rel} = L\sin\theta_1$$

EQUATION 3: *Simplified Relative Lateral Displacement*

Where:
L = Gauge length (i.e. sensor spacing)
θ = Inclination angle of the sensor, as described above

The profile of the borehole is approximated by accumulating these relative lateral displacements at each measurement point, starting with the bottom sensor. Refer to Figure 17 above.

With this method, the topmost sensor of the string will be ignored and is not factored into the equation. The absolute lateral displacement (D_{abs}) at each measuring point is found using the following equation:

$$D_{3abs} = L\sin\theta_1 + L\sin\theta_2 + L\sin\theta_3$$

OR

$$D_{3abs} = D_{1rel} + D_{2rel} + D_{3rel}$$

EQUATION 4: *Simplified Absolute Lateral Displacement*

4.3 TEMPERATURE EFFECTS

In a given installation, temperature effects can cause real changes of tilt; therefore, each sensor is equipped with a device for measuring the sensor temperature. This enables temperature-induced changes in inclination to be distinguished from inclination due to other sources.

An important point to note is that sudden changes in temperature will cause both the structure and the sensor to undergo transitory physical changes, which will show up in the readings. The sensor temperature should always be recorded, and efforts should be made to obtain readings when the instrument and structure are at thermal equilibrium. The best time for this tends to be in the late evening or early morning hours.

4.4 ENVIRONMENTAL FACTORS

Since the purpose of the inclinometer installation is to monitor site conditions, factors that may affect these conditions should be observed and recorded. Seemingly minor effects may have real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to, blasting, rainfall, tidal or reservoir levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

Technical Support

5. TROUBLESHOOTING

Maintenance and troubleshooting of Model 6140 Vertical IPI String is confined to periodic checks of the cable connections. The sensors are sealed and there are no user serviceable parts.

Should difficulties arise, consult the list of possible solutions shown below. Visit geokon.com/Technical-Support for additional troubleshooting help.

SYMPTOM: TILT SENSOR READINGS ARE UNSTABLE OR FAIL TO READ

- ☐ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, and antennas.
- ☐ Check all cable connections, terminals, and plugs.
- ☐ Water may have penetrated the interior of the tilt sensor or connectors. Contact GEOKON.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 6140 VERTICAL IN-PLACE INCLINOMETER STRING

Range[1]	±90°
Resolution[2]	±0.00025° (±0.004 mm/m)
Precision[3]	±0.0075° (±0.13 mm/m)
Nonlinearity	±0.005° across ±30° range (±0.09 mm/m)
Temperature Dependent Uncertainty	±0.001°/°C across ±5° angular range (±0.016 mm/m) ±0.0016°/°C across ±15° angular range (±0.026 mm/m) ±0.0026°/°C across ±30° angular range (±0.042 mm/m)
Operating Temperature	-40 °C to 65 °C (-40 °F to 149 °F)
Power Supply Voltage	12 VDC ±20%
Operating Current[4]	12 mA ±1 mA
Standby Current[4]	2 mA ±0.1 mA
Maximum Supply Current[5]	500 mA
Standard Sensor Length	0.5 m (2 ft)
Sensor Weight	0.36 kg (0.8 lb)
Materials	316 Stainless Steel, Engineered Polymer
Electrical Cable	Four Conductor, Foil shield, Polyurethane jacket, nominal OD = 7.9 mm
Interface	RS-485
Protocol	MODBUS
Acquisition Cycle Time[6]	350 ms
Baud Rate	115,200 bps
Temperature Accuracy	±0.5 °C
Ingress Protection	IP68 to 3 MPa (300 m head water)
Maximum Sensors per String[7]	500

TABLE 5: *Model 6140 Inclinometer Specifications*

[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] Operating and standby current are for each individual sensor in a string.

[5] Per entire string.

[6] The time from a trigger write to when a new value is available for reading.

[7] Dependant on datalogger used. Consult datalogger manufacturer.

A.2 PARTS LIST

6140-1	Vertical IPI String Top, with readout cable connector
6140-0.5M	Vertical IPI String Middle, 0.5 m spacing
6140-2FT	Vertical IPI String Middle, 2 ft. spacing
6140-2	Vertical IPI String Bottom, with Suspension Weight connector
6140-5-1	Vertical IPI String Connector Bottom, 0.5 m spacing, for strings with >100 sensors, 1 required for every 100 sensors
6140-5-2	Vertical IPI String Connector Bottom, 2 ft. spacing, for strings with >100 sensors, 1 required for every 100 sensors
6140-3-1	Suspension Cable, <5 m length
6140-3-2	Suspension Cable, 6 to 10 m length
6140-3-3	Suspension Cable, 10 to 20 m length
6140-4	Suspension Weight
6140-6	Sensor Hold
6180-2	Suspension Bracket
6180-3-1	Readout Cable, <15 m length bare leads
6180-3-2	Readout Cable, 16 to 30 m length, bare leads
6180-3V	Readout Cable, >30 m length, bare leads

TABLE 6: *Model 6140 Parts List*

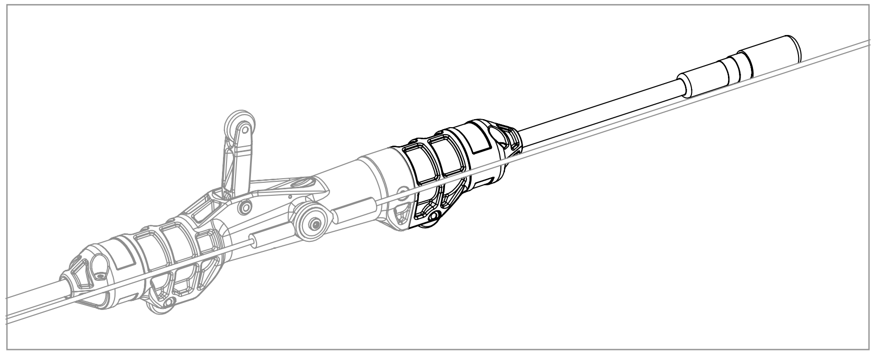

FIGURE 18: *Model 6140-1 Vertical IPI String Top, with readout cable connector*

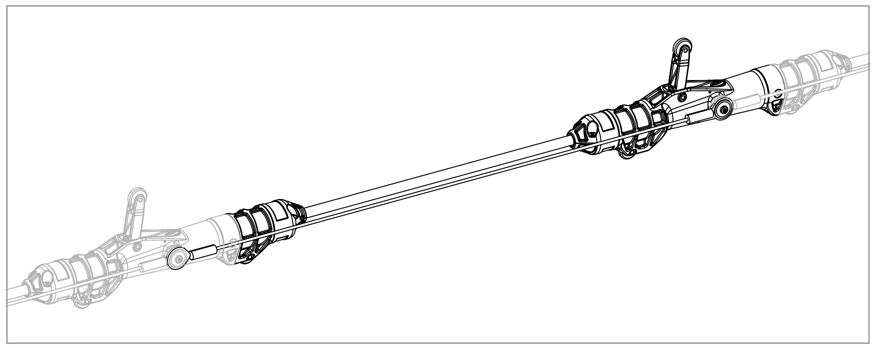

FIGURE 19: *Model 6140-0.5M / 6140-2FT Vertical IPI String Middle, 0.5 m/2 ft. spacing*

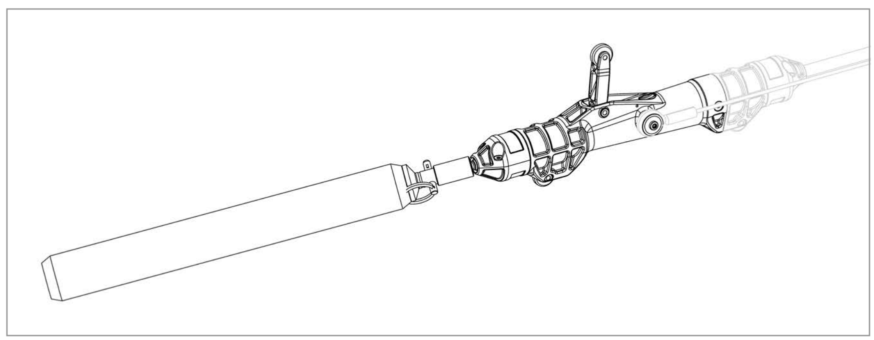

FIGURE 20: *Model 6140-2 Vertical IPI String Bottom, with Model 6140-4 Suspension Weight attached*

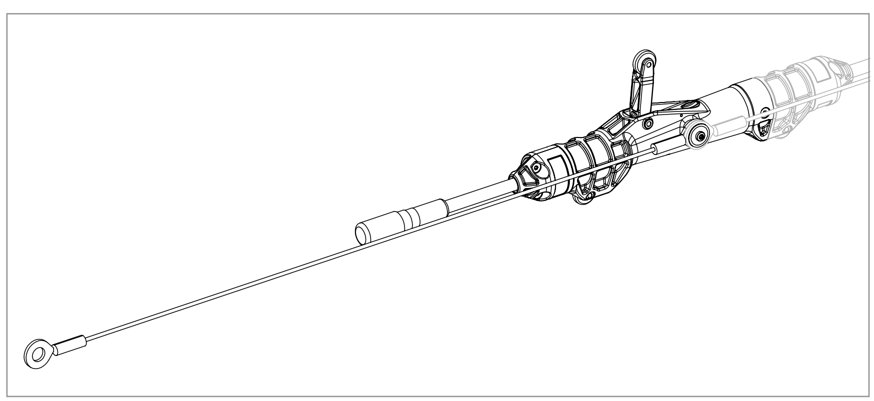

FIGURE 21: *Model 6140-5-1, -2 Vertical IPI String Connector Bottom, 0.5 m/2 ft. spacing, for strings with >100 sensors, 1 required for every 100 sensors*

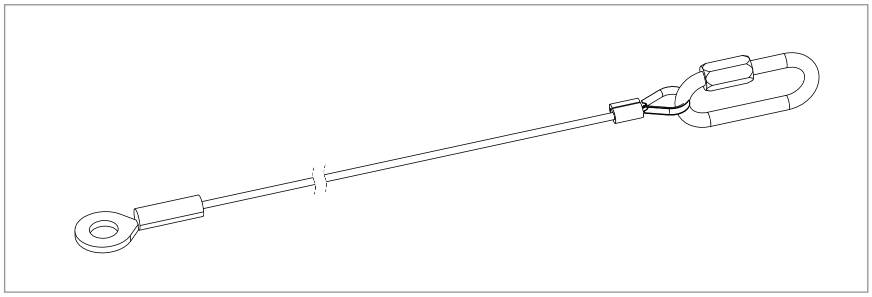

FIGURE 22: *Model 6140-3-1, -2, -3 Suspension Cable*

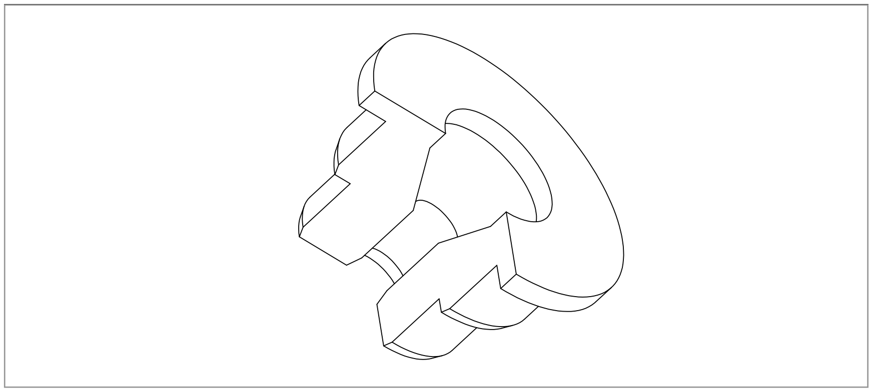

FIGURE 23: *Model 6140-6 Sensor Hold*

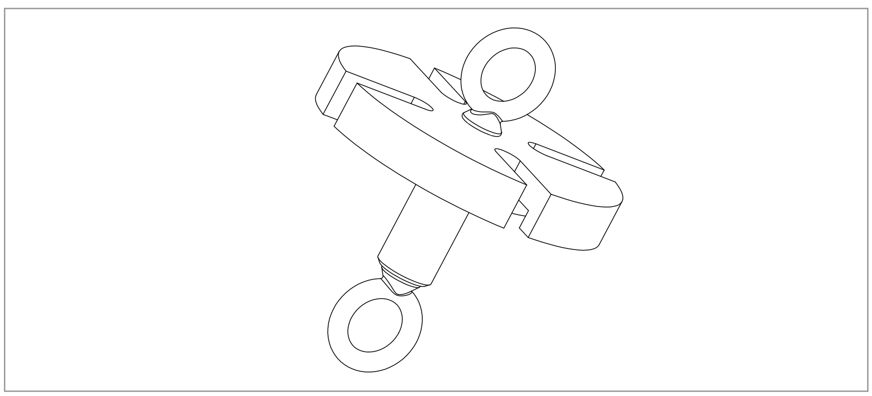

FIGURE 24: *Model 6180-2 Suspension Bracket*

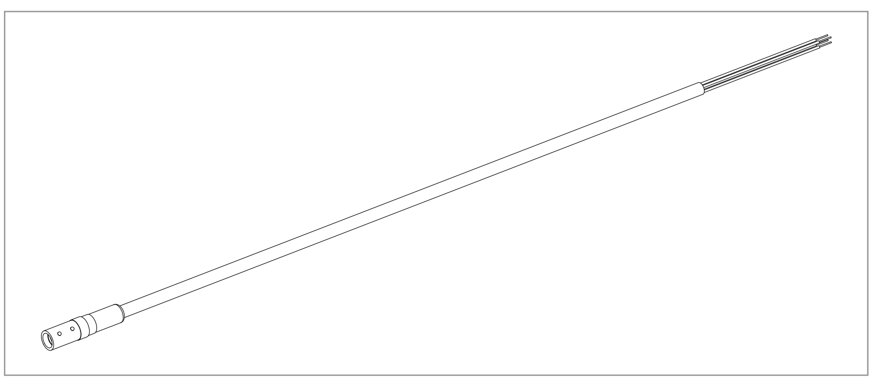

FIGURE 25: *Model 6180-3-1, -3-2 Topside Readout Cable/Bare Leads, < 50FT*

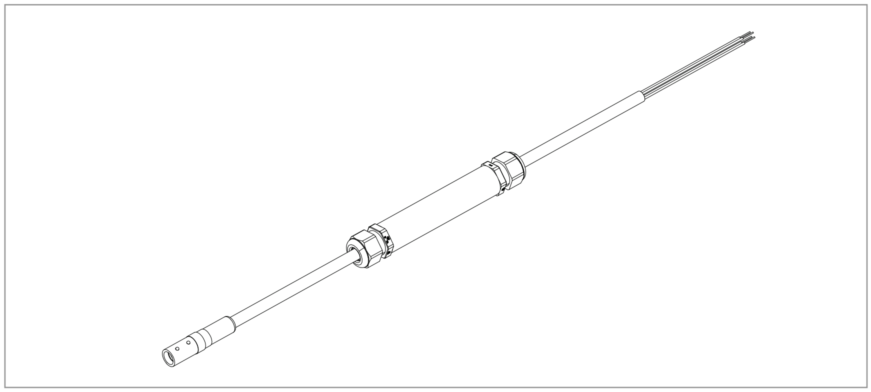

FIGURE 26: *Model 6180-3V Topside Readout Cable/Bare Leads, > 100FT*

GEOKON®

Calibration Report

Model Number: S-6140-1-CAL

Calibration Date: December 20, 2023

Serial Number: 2330066 AAxisAngular

Temperature: 22.1 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Technician: [signature]

Reference Average (Angular Degrees)	Sensor Output (Angular Degrees)	Error (Angular Degrees)
-30.0010	-30.0014	-0.0003
-20.0004	-19.9986	0.0018
-14.9999	-15.0019	-0.0020
-10.0001	-9.9986	0.0015
-4.9996	-5.0011	-0.0016
0.0002	-0.0011	-0.0014
5.0000	5.0020	0.0020
9.9998	10.0015	0.0017
15.0003	14.9989	-0.0015
20.0005	20.0000	-0.0005
30.0005	30.0007	0.0002

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

FIGURE 27: *A Axis Angular Calibration Report*

GEOKON®

Calibration Report

Model Number: S-6140-1-CAL

Serial Number: 2330066 AAxisTemperature

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Calibration Date: December 20, 2023

Temperature: 21.2 °C

Technician:

SetPoint (Degrees Celsius)	Sensor Output (Angular Degrees)	Error (Angular Degrees/Degree Celsius)
-35	0.1596	0.0000
-20	0.1586	0.0000
-5	0.1611	-0.0001
10	0.1588	0.0000
25	0.1594	0.0000
40	0.1632	0.0003
55	0.1565	-0.0001
70	0.1605	0.0000

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

FIGURE 28: *A Axis Temperature Calibration Report*

GEOKON®

Calibration Report

Model Number: S-6140-1-CAL

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisAngular

Temperature: 22.0 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Technician:

Reference Average (Angular Degrees)	Sensor Output (Angular Degrees)	Error (Angular Degrees)
-30.0010	-30.0008	0.0002
-20.0004	-20.0011	-0.0007
-14.9999	-15.0001	-0.0003
-10.0001	-9.9993	0.0007
-4.9996	-4.9984	0.0012
0.0002	-0.0004	-0.0006
5.0000	4.9996	-0.0004
9.9998	9.9987	-0.0012
15.0003	15.0012	0.0009
20.0005	20.0009	0.0004
30.0005	30.0003	-0.0002

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

FIGURE 29: *B Axis Angular Calibration Report*

GEOKON®

Calibration Report

Model Number: S-6140-1-CAL

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisTemperature

Temperature: 21.2 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Technician: [signature]

SetPoint (Degrees Celsius)	Sensor Output (Angular Degrees)	Error (Angular Degrees/Degree Celsius)
-35	-0.3092	0.0000
-20	-0.3095	0.0000
-5	-0.3089	0.0000
10	-0.3089	0.0000
25	-0.3092	0.0000
40	-0.3082	0.0001
55	-0.3098	0.0000
70	-0.3091	0.0000

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

FIGURE 30: *B Axis Temperature Calibration Report*

APPENDIX C. CRBASIC PROGRAMMING

C.1 SAMPLE CR1000 PROGRAM

The following sample program reads one sensor string with three biaxial sensors. The string in this example communicates with the CR1000 through the control ports C1 and C2, which are setup as COM1. A RS-485 to TTL converter required.

```
Public ErrorCode                'Error Code sent back from ModBus Command
Public A_Axis_Degrees(3)        'A Axis Degree Output
Public B_Axis_Degrees(3)        'B Axis Degree Output
Public Celsius(3)               'Temperature Celsius
Public Count                    'Counter to increment through sensors
```

'Define Data Tables

```
DataTable(Test,1,-1)
  Sample (3,A_Axis_Degrees(),IEEE4)      'Store Degree Reading for A Axis
  Sample (3,B_Axis_Degrees(),IEEE4)      'Store Degree Reading for B Axis
  Sample (3,Celsius(),IEEE4)             'Store Thermistor C Reading
EndTable
```

'Main Program

```
BeginProg
  'Open COMport with TTL communications at 115200 baud rate
  SerialOpen (Com1,115200,16,0,50)
    'Read 3 sensors in MEMS String every 10 seconds
    Scan (10,Sec,0,0)
      'Loop through addresses of connected String
      For Count = 1 To 3
        'Reset temporary storage for both Degrees and Temp so not to retain
        'previous reading
        A_Axis_Degrees(Count) = 0
        B_Axis_Degrees(Count) = 0
        Celsius(Count) = 0

        'Flush Serial between readings
        SerialFlush (Com1)

        'Write to register to begin reading MEMS String
        NOTE: ModbusMaster won't send 0x118 unless "&H119" is 'entered

        ModbusMaster (ErrorCode,Com1,115200,Count,6,1,&H119,1,1,50,0)
        'Delay after write register
        Delay (1,1,Sec)

        'Use Modbus command to retrieve A Axis and B Axis Degree Readings
        ModbusMaster (ErrorCode,Com1,115200,Count,3,A_Axis_Degrees(Count),&H101,1,1,50,0)
        ModbusMaster (ErrorCode,Com1,115200,Count,3,B_Axis_Degrees(Count),&H103,1,1,50,0)

        'Use Modbus command to retrieve Thermistor Celsius from string
        ModbusMaster (ErrorCode,Com1,115200,Count,3,Celsius(Count),&H107,1,1,550,0)

        'Delay before proceeding to next reading
        Delay (1,1,Sec)
      Next
    'Call Table to store Data
    CallTable Test
  NextScan
EndProg
```

C.2 SAMPLE CR6 PROGRAM

The following sample program reads one sensor string with three addressable sensors. The string in this example communicates with the CR6 through the control ports C1 and C2, which are setup as ComC1. The CR6 has built in RS 485 capability, so no RS-485 to TTL converter is required.

```
Public ErrorCode                'Error Code sent back from ModBus Command
Public A_Axis_Degrees(3)        'A Axis Degree Output
Public B_Axis_Degrees(3)        'B Axis Degree Output
Public Celsius(3)               'Temperature Celsius
Public Count                    'Counter to increment through sensors
```

'Define Data Tables

```
DataTable(Test,1,-1)
  Sample (3,A_Axis_Degrees(),IEEE4)     'Store Degree Reading for A Axis
  Sample (3,B_Axis_Degrees(),IEEE4)     'Store Degree Reading for B Axis
  Sample (3,Celsius(),IEEE4)            'Store Thermistor C Reading
EndTable
```

'Main Program

```
BeginProg
    'Open COMport with RS-485 communications at 115200 baud rate
    SerialOpen (ComC1,115200,16,0,50,3)
        'Read 3 sensors in MEMS String every 10 seconds
        Scan (10,Sec,0,0)
            'Loop through addresses of connected String
            For Count = 1 To 3
                'Reset temporary storage for both Degrees and Temp so not to retain
                'previous reading
                A_Axis_Degrees(Count) = 0
                B_Axis_Degrees(Count) = 0
                Celsius(Count) = 0

                'Flush Serial between readings
                SerialFlush (ComC1)

                'Write to register 0x118 to trigger string
                'NOTE: ModbusMaster won't send 0x118 unless "&H119" is entered

                ModbusMaster (ErrorCode,ComC1,115200,Count,6,1,&H119,1,1,10,0)
                'Delay after write register
                Delay (1,1,Sec)

                'Use Modbus command to retrieve A Axis and B Axis Degree Readings
                ModbusMaster (ErrorCode,ComC1,115200,Count,3,A_Axis_Degrees(Count),&H101,1,1,10,0)
                ModbusMaster (ErrorCode,ComC1,115200,Count,3,B_Axis_Degrees(Count),&H103,1,1,10,0)

                'Use Modbus command to retrieve Thermistor Celsius from string
                ModbusMaster (ErrorCode,ComC1,115200,Count,3,Celsius(Count),&H107,1,1,10,0)

                'Delay before proceeding to next reading
                Delay (1,1,Sec)
            Next
        'Call Table to store Data
        CallTable Test
    NextScan
EndProg
```

APPENDIX D. SUSPENSION CABLE ADJUSTMENT

The Model 6140-3 Suspension cable is shipped fully assembled to the specified length. The cable length can be shortened if required by following the instructions in this section.

D.1 CONNECTING THE SUSPENSION BRACKET

To ensure the string is installed to the correct depth, sum the length from the bottom of the weight to the tip of the top sensor and subtract this value from the desired string depth (measured from the top of the casing to the bottom of the string assembly); the resulting value is the Suspension Cable Length.

Note: GEOKON suggests suspending the sensor string at least 150 mm (six inches) above the bottom of the casing, to account for debris and settlement.

1. Measure the suspension cable out to the calculated length, minus 4.5 inches to account for the connecting clip and suspension bracket.
2. Form a loop at the measured location. Lightly secure with one of the supplied cable clamps. Do not fully tighten at this stage.

FIGURE 31: *Loop and Clamp*

3. Place the supplied thimble into the loop. Tighten the suspension cable to the thimble by sliding the cable clamp to the thimble.

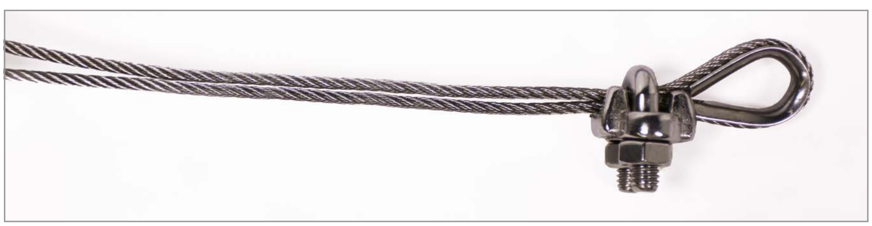

FIGURE 32: *Insert and Tighten Thimble in Loop*

4. Connect the aircraft cable to the eye bolt on the bottom of the suspension bracket using the quick link connector.

FIGURE 33: *Suspension Cable Adjusted with Bracket*

5. Adjust the suspension cable as needed so the distance from the recessed shoulder of the suspension bracket to the tip of the top sensor equals the calculated Suspension Cable Length. Secure the cable clamp fully to a torque specification of approximately 4.5 ft-lbs.
6. Secure a second cable clamp approximately 3 inches from the first cable clamp, tightening fully to the torque specification above.

FIGURE 34: *Final Adjusted Cable Assembly*

7. Secure the loose end of the suspension cable to the main length with tape.