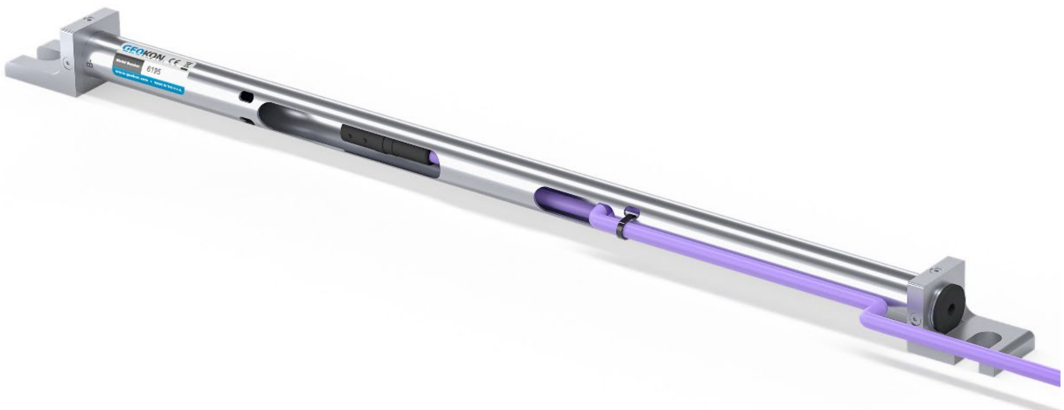
Model 6195

Tilt Beam

Instruction Manual



GEOKON®

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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.

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TABLE OF CONTENTS

1. INTRODUCTION

The Geokon Model 6195 Tilt Beam is designed for remote, continuous, and automatic monitoring in building and retaining walls, concrete dams, and structures adjacent to or above tunnels and underground openings. As well as for monitoring deflections in structures subject to compensation grouting and measuring differential settlements along embankments, railroad tracks, and pipelines. And other similar applications.

The basic principle of operation uses MEMS accelerometers to measure static tilt of the structure being studied. Monitoring by the instrument allows for very precise measurements of inclination to be collected.

Each beam is comprised of an addressable, triaxial, Micro-Electro-Mechanical Systems (MEMS) device inside a sealed stainless steel housing. The device measures inclination along three axes, of which two will be of interest for any given installation. Each beam also contains a digital temperature sensor for measuring temperature.

Beams are coupled to the structure of interest using adjustable mounting hardware. Beams may be used individually or in combination with others. Electrically, beams are connected to each other with four-wire bus cable and molded waterproof connectors.

Each beam is individually serialized and calibrated. A calibration sheet for each beam is provided, showing the relationship between beam output and inclination.

The Model 6195 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.

Data can be collected 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

2.1 PRELIMINARY TESTS

Prior to installation, check the beams for proper operation. Complete the following steps:

1. Place the beams in the correct order by referring to the labels on the beams and the provided paperwork.
2. Starting with the first beam, connect the beams by plugging the male connector from second beam into the female connector from the first beam. Proceed in this manner until the full string is connected.

NOTE: A termination beam (6195T) must be used as the last beam for each string.

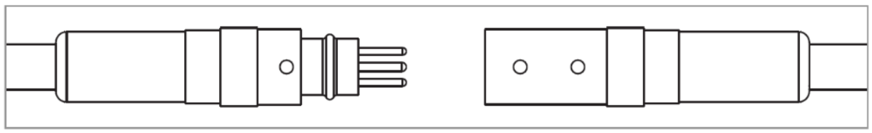

FIGURE 1: *Cable Connection Detail*

Caution! When connecting the beams, make sure to line up the orientation dot on the outside of the male connector with the two orientation dots on the outside of the female connector. This will ensure the pins and receptacles on the interior of the connectors align correctly. Push the connectors together until they are completely mated.

NOTE: To facilitate mating, the male connectors have dielectric grease applied. Do not clean or remove the grease.

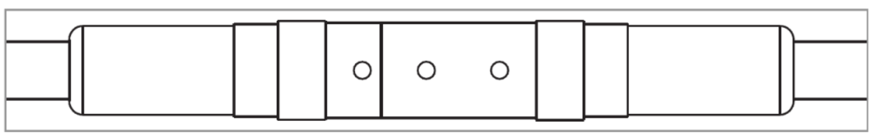

FIGURE 2: *Connected Cables*

3. Connect the completed string to a Model 8020-38 converter, PC, or datalogger (refer to Section 2.4).
4. Hold the first beam in a vertical position and observe the reading. The tilt beam must be held steady while taking the reading. The observed reading should be close to the factory vertical reading. Tilting the beam in one direction should cause the readings to increase. Tilting the beam in the opposite direction should cause the readings to decrease. The temperature indicated on the readout should be close to ambient. Repeat this process with the remaining beams.
5. Once the preliminary tests are complete, disconnect the string from the readout device and disconnect the beams from each other.

If any of these preliminary tests fail, refer to Section 5 for troubleshooting.

2.2 BEAM ORIENTATION

As triaxial capable devices, model 6195 Tilt Beams measure inclination along three axes, and may be used in both vertical and horizontal installations.

For vertical installations, orient the beam with the indicator arrow pointing up or down.

For horizontal installations, orient the beam with the arrow pointing right or left.

Detailed beam orientation descriptions are provided in Appendix E.

2.3 BEAM INSTALLATION

1. Place the beam on the mounting surface and position it is in the intended orientation, as described above.
2. Mark the location of the mounting points as shown in Figure 3.

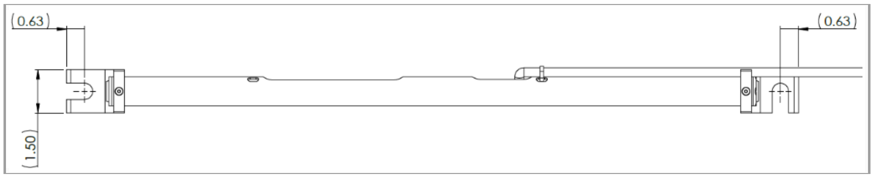

FIGURE 3: *Mounting Points*

3. Using a hammer drill, drill two 12 mm (1/2 inch) diameter holes approximately 40 mm (1.6 inch) deep.
4. Clean out the holes thoroughly. (Use compressed air if possible.)
5. Insert the two 3/8 inch drop-in anchors into the holes. The threaded end should be closest to the opening of the hole.
6. Insert the small end of the setting tool into an anchor. Expand the anchor by hitting the large end of the setting tool with several sharp hammer blows. Repeat this process for the second anchor.
7. Thread the supplied 3/8-16 anchor rods into the anchors. (Thread-locking compound can be used to ensure the hardware remains secure.)
8. Attach the beam to the mounting surface by arranging the mounting hardware as shown in Figure 4. (Thread-locking compound can be used to ensure the hardware remains secure.)

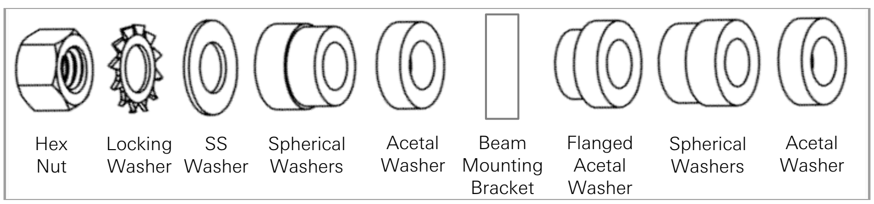

FIGURE 4: *Mounting Hardware*

9. Adjustments to the beam position may be made in two directions; the spherical washers allow the beam to be rotated in respect to the anchor bolt, and the slots in the mounting brackets allow the beam to rotate about its center-point.

   To facilitate beam adjustment, use an 8020-38 addressable bus converter and PC to observer the tilt readings while the adjustments are being made.

10. Repeat steps 1 through 9 for each subsequent sensor.
11. Plug the female connector of the first beam into the male connector of the second beam. If using an extension cable, connect the first and second beams together using the extension cable. (For additional security, tape the connectors together.) **NOTE:** To facilitate mating, the male connectors have dielectric grease applied. Do not clean or remove the grease.

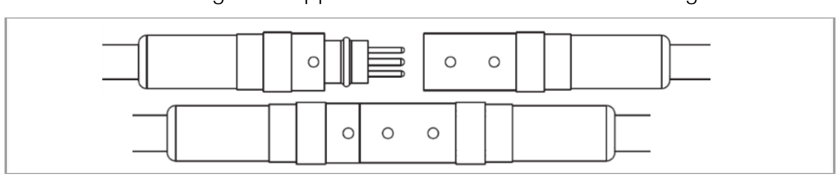

FIGURE 5: *Cable Connection Detail*

12. Repeat step 11 until all beams are connected in a string.
13. Plug the male cable connector of the first beam to the female connector of the readout cable (6180-3-#). Connect the other end of the readout cable to the readout device or data-logger.

2.4 READOUT

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

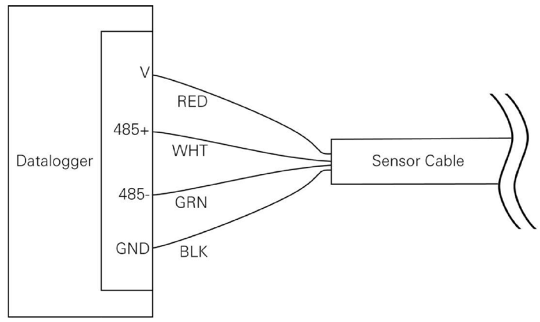

FIGURE 6: *Wiring of Datalogger with built-in RS-485 Conversion*

If your datalogger does not have built-in RS-485 communications, a Model 8020-38 Addressable Bus Converter (Figure 13) can be utilized. 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 7: *Model 8020-38 RS-485 to TTL/USB Converter*

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

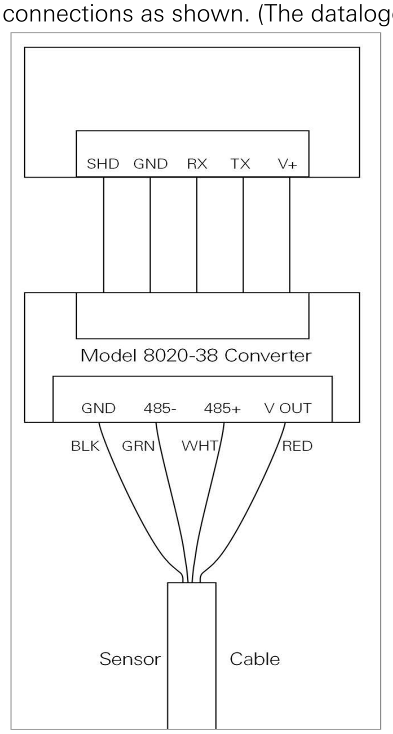

FIGURE 8: *Wiring of Datalogger without built-in RS-485 Conversion*

For more information, please refer to the Model 8020-38 instruction manual.

2.5 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 1 below.

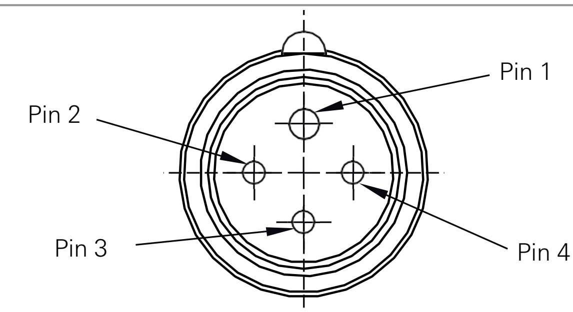

FIGURE 9: *Male Waterproof Connector*

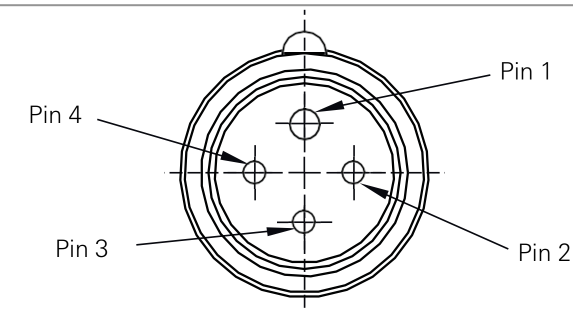

FIGURE 10: *Female Waterproof Connector*

Pin	Wire Color	Function
1	Red	Power
2	Black	Ground
3	White	RS-485+ Data High
4	Green	RS-485- Data Low

TABLE 1: *Four-Pin Wiring Chart*

3. MODBUS RTU PROTOCOL

3.1 INTRODUCTION TO MODBUS

Model 6195 Tilt Beams use the industry standard Modbus Remote Terminal Unit (RTU) protocol to communicate with the chosen readout method. As the name suggests, Modbus was designed to work on what is known as a **bus network**, meaning that every device receives every message that passes across the network. Model 6195 Tilt Beams use the RS-485 electrical interface because of its prevalence, simplicity, and success as a robust, industrial physical layer.

More information about Modbus can be found at the following website:

http://www.modbus.org/specs.php

3.2 MODBUS RTU OVERVIEW

The Modbus RTU protocol uses packets (messages made up of multiple sections) to communicate and transfer data between devices on the network. The general format of these packets is as follows:

1. Modbus Address (one byte) – The address of the specific device on the bus. (Labeled on the beams as #1, #2, #3, etc.)
2. Function Code (one byte) – The action to be carried out by the slave device.
3. Data (multi-byte) – The payload of the function code being sent.
4. Cyclic Redundancy Check or CRC (two bytes): A 16-bit data integrity check calculated over the other byes in the packet.

3.3 MODBUS TABLES

The most recent beam readings are stored in memory registers, read using a Modbus command. Angle and temperature readings are available in processed or precursor formats. Register addresses and formats are described in Table 2. The outputs of the A, B, and C, axes are corrected values.

GEOKON stores the gauge factor and offsets in the beam during the factory calibration process.

Table 3 shows device control addresses. Any nonzero value written to the trigger address initiates a measurement cycle, updating the angle and temperature measurement registers. Any anomalies detected during the most recent measurement cycle produce a non-zero error code. Refer to Appendix C for an explanation of these codes.

The flash password prevents unintended writes to the nonvolatile memory in Table 4 and the preprogrammed device information in Table 5. Contact GEOKON for instructions.

Register Address	Byte	Word	Parameter	Units	Type	Access
0x100	0 1	LSW	A-Axis	degrees	float	RO
0x101	2 3	MSW				
0x102	4 5	LSW	B-Axis	degrees	float	
0x103	6 7	MSW				
0x104	8 9	LSW	C-Axis	degrees	float	
0x105	10 11	MSW				
0x106	12 13	LSW	Temperature	°C	float	
0x107	14 15	MSW				
0x108	16 17	LSW	Uncorrected A-Axis	degrees	float	
0x109	18 19	MSW				
0x10A	20 21	LSW	Uncorrected B-Axis	degrees	float	
0x10B	22 23	MSW				
0x10C	24 25	LSW	Uncorrected C-Axis	degrees	float	
0x10D	26 27	MSW				

TABLE 2: *Register Addresses and Formats*

Register Address	Byte	Word	Parameter	Units	Type	Access
0x118	48 49		Trigger	N/A	uint16	RW
0x119	50 51	LSW	Password	N/A	uint32	
0x11A	52 53	MSW				
0x11B	54 55		Measure Cycle	N/A	uint16	

TABLE 3: *Device Control Addresses*

Register Address	Byte	Word	Parameter	Units	Type	Access
0x200	0 1		Drop Address	N/A	uint16	RO
0x201	2 3		Sensor Type	N/A	string	
0x202	4 5					
0x203	6 7					
0x204	8 9					
0x205	10 11					
0x206	12 13					
0x207	14 15					
0x208	16 17					
0x209	18 19	LSW	Serial Number	N/A	uint32	
0x20A	20 21	MSW				
0x20B	22 23		Software Version	N/A	uint16	
0x20C	24 25		Hardware Version	N/A	uint16	

TABLE 4: *Non-Volatile Memory*

Register Address	Byte	Word	Parameter	Units	Type	Access
0x20D	26	LSW	A Offset	degrees	float	RO
	27					
0x20E	28	MSW				
	29					
0x20F	30	LSW	B Offset	degrees	float	
	31					
0x210	32	MSW				
	33					
0x213	38	LSW	A Gauge Factor	degrees	float	
	39					
0x214	40	MSW				
	41					
0x215	42	LSW	B Gauge Factor	degrees	float	
	43					
0x216	44	MSW				
	45					

TABLE 5: *Preprogrammed Device Information*

4. DATA REDUCTION

4.1 INCLINATION CALCULATION

The output of the 6195 Tilt Beam is a corrected angle of inclination. The standard beam has a full range of ±90° and a calibrated range of ±30°. The registers for the Gauge Factor and Offset are written to the Modbus registers for each beam using calibration data.

4.2 ENVIRONMENTAL FACTORS

Since the purpose of the Tilt Beam 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.

5. TROUBLESHOOTING

Maintenance and troubleshooting of Model 6195 Tilt Beam is confined to periodic checks of the cable connections. The beams are sealed and there are no user serviceable parts.

Should difficulties arise, consult the list of possible solutions shown below. Refer to Appendix C for Modbus error codes. Consult the factory for additional troubleshooting help.

SYMPTOM: TILT BEAM 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 beam. There is no remedial action.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 6195 TILT BEAM

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)
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
Beam Diameter	25.4 mm (1 inch)
Standard Sensor Length[6]	0.5 m, 1 m, 2 m, 3 m, 2 ft., 5 ft., 10 ft.
Beam Weight	0.5 m: 0.80 kg (1.77 lb), 1 m: 1.20 kg (2.65 lb), 2 m: 2.01 kg (4.42 lb), 3 m: 2.81 kg (6.19 lb), 2 ft: 0.89 kg (1.96 lb), 5 ft: 1.62 kg (3.58 lb), 10 ft: 2.85 kg (6.28 lb),
Beam Materials	316 Stainless Steel, Engineered Polymer
Electrical Cable	Four Conductor, Foil shield, Polyurethane jacket, nominal OD = 7.9 mm
Interface	RS-485
Protocol	MODBUS
Baud Rate	115,200 bps
Ingress Protection	IP68 to 3 MPa (300 m head water)
Operating Temperature	-40 to 65 °C (-40 to 149 °F)
Temperature Accuracy	±0.5° C

TABLE 6: *Model 6195 Tilt Beam 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] Operating and standby current are for each individual beam in a string.

[5] For the entire string.

[6] Custom lengths available on request

A.2 PARTS LIST

6195	MEMS Digital Tilt Beam, Triaxial
6195-T	MEMS Digital Tilt Beam, Triaxial Terminal Beam
6195-2	Mounting Hardware Kit
6180-3-1	Readout Cable, lengths <15 m (50 feet), bare leads
6180-3-2	as above, 16 m to 30 m (50 feet to 100 feet)
6180-3V	as above, lengths >30 m (100 feet)
6195-1-10FT	Extension cable, 10 ft. length
6195-1-25FT	Extension cable, 25 ft. length
6195-1-50FT	Extension cable, 50 ft. length
6195-1-100FT	Extension cable, 100 ft. length
6195-1-150FT	Extension cable, 150 ft. length
6195-1-200FT	Extension cable, 200 ft. length

TABLE 7: *Model 6195 Tilt Beam Parts List*

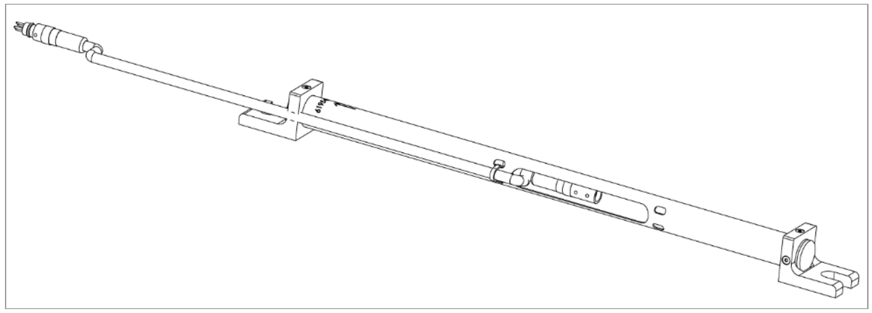

FIGURE 11: *Model 6195 Tilt Beam*

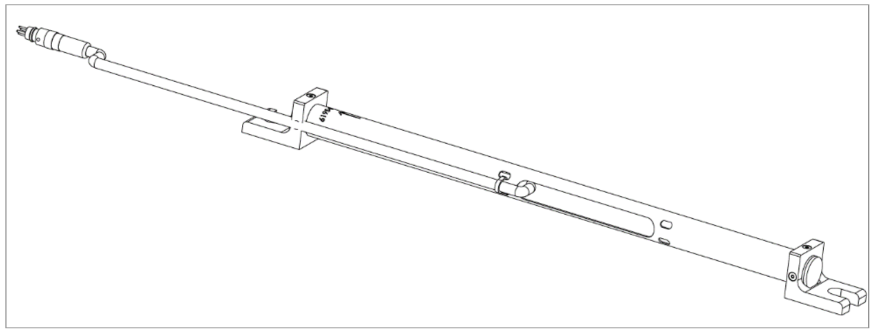

FIGURE 12: *Model 6195T Terminal Tilt Beam*

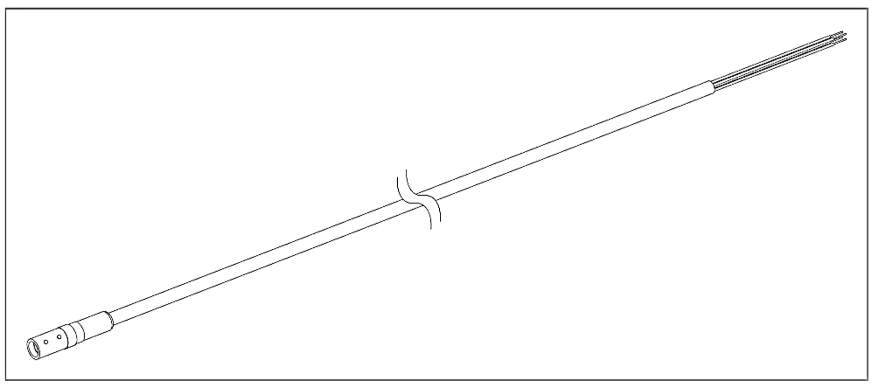

FIGURE 13: *Model 6180-3-# Readout Cables, <30 m, bare leads*

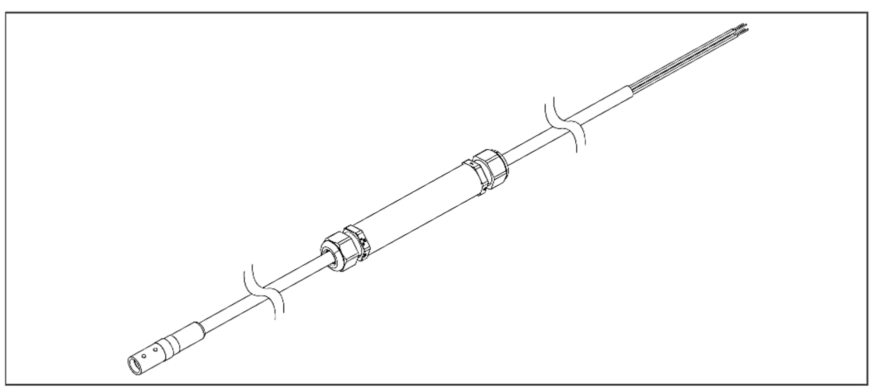

FIGURE 14: *Model 6180-3V Readout Cable, >30 m, bare leads*

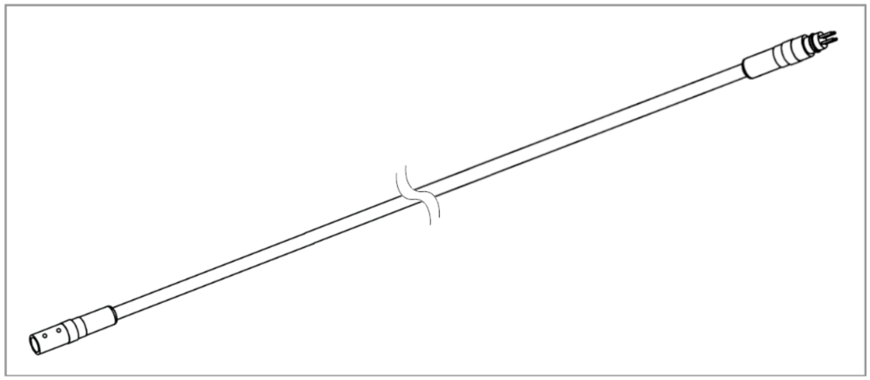

FIGURE 15: *Model 6195-1 Extension Cable*

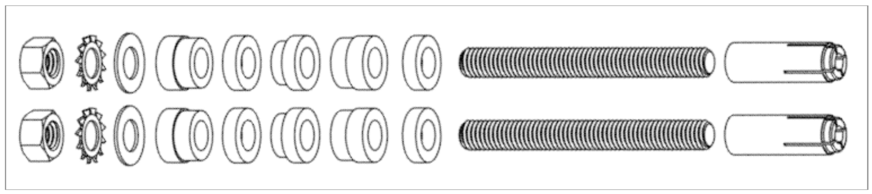

FIGURE 16: *Model 6195-2 Mounting Kit*

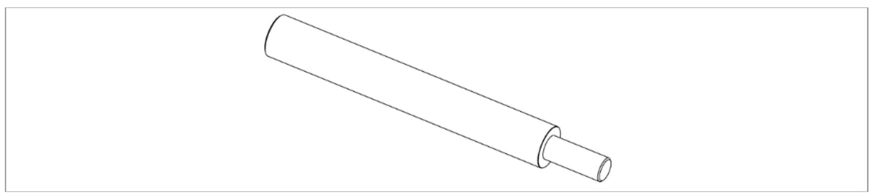

FIGURE 17: *TLS-209 Rawl Setting Tool, 3/8"*

APPENDIX B. SAMPLE CALIBRATION SHEETS

GEOKON

Calibration Report

Model Number: 6195-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 AAxisAngular

Temperature: 22.1 °C

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

Technician:

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.

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FIGURE 18: *Sample Model 6195 Calibration Sheet, A Axis Angular*

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Calibration Report

Model Number: 6195-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 AAxisTemperature

Temperature: 21.2 °C

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

Technician: K Bellavance

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 19: *Sample Model 6195 Calibration Sheet, A Axis Temperature*

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Calibration Report

Model Number: 6195-0.5M

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.

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FIGURE 20: *Sample Model 6195 Calibration Sheet, B Axis Angular*

GEOKON

Calibration Report

Model Number: 6195-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisTemperature

Temperature: 21.2 °C

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

Technician: KBellavance

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.

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FIGURE 21: *Sample Model 6195 Calibration Sheet, B Axis Temperature*

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Calibration Report

Model Number: 6195-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 CAxisAngular

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 22: Sample Model 6195 Calibration Sheet, C Axis Angular

GEOKON®

Calibration Report

Model Number:	6195-0.5M	Calibration Date:	December 20, 2023
Serial Number:	2330066 CAxisTemperature	Temperature:	21.2 °C
Calibration Instruction:	CI-MEMS PCBA (IPI_TILT, Triaxial)	Technician:	KBellavance

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.

This report shall not be reproduced except in full without written permission of Geokon.

FIGURE 23: *Sample Model 6195 Calibration Sheet, C Axis Temperature*

APPENDIX C. MODBUS ADDRESSABLE SYSTEM

C.1 MODBUS COMMUNICATIONS PARAMETERS

Port Setting	Required Value
Bits per Second	115,200
Data bits	8
Parity	None
Stop bits	1
Flow Control	None

TABLE 8: *Modbus Communications Parameters*

C.2 ERROR CODES

Number	Name	Cause	Remedy
2	Temperature Sensor Range	Measured temperature out of range. Thermistor may be too hot or too cold, or it may be damaged.	Use adjacent beams to validate or estimate temperature.
4	Temperature Sensor Verify	Secondary temperature beam differed too much from high accuracy primary beam.	Use adjacent beams to validate or estimate temperature.
8	System Reset	Unexpected interruption in prior measurement cycle.	Ensure supply voltage is sufficient.

TABLE 9: *Error Codes*

Note: The beam stores and transmits errors in binary code to compact the information. Though unlikely, two errors could occur in one measurement cycle. The resulting code will be the sum of the error numbers, e.g., error 4 plus error 8 appears as number 12.

APPENDIX D. CRBASIC PROGRAMMING

D.1 SAMPLE CR1000 PROGRAM

The following sample program reads one 6195 beam 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
```

D.2 SAMPLE CR6 PROGRAM

The following sample program reads one 6195 beam 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.

```
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
```

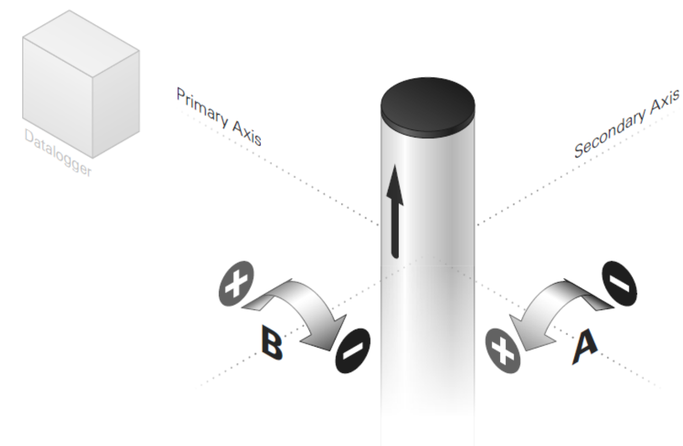
'Main Program

```
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 E. TILT BEAM ORIENTATION

WALL MOUNT: ARROW POINTED UP



SENSOR CONFIGURATION

- Mounted to **WALL, VERTICAL** installation
- **DATALOGGER** positioned **ABOVE,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **UP**, facing **FRONT**

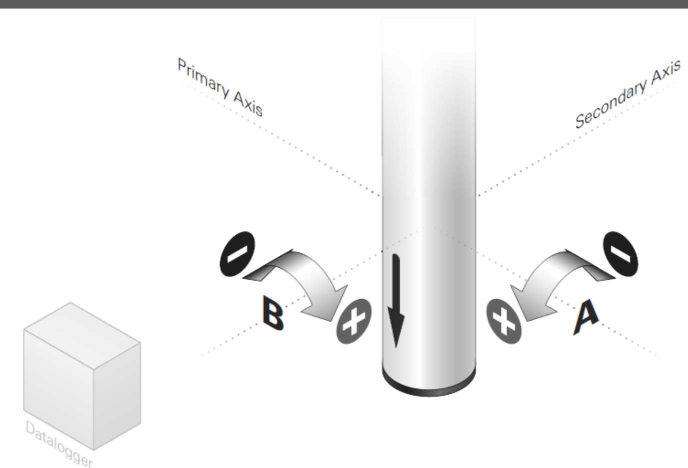
PRIMARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Top Toward
  - ⊖ Top Away

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Counterclockwise
  - ⊖ Clockwise

WALL MOUNT: ARROW POINTED DOWN



SENSOR CONFIGURATION

- Mounted to **WALL, VERTICAL** installation
- **DATALOGGER** positioned **BELOW,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **DOWN**, facing **FRONT**

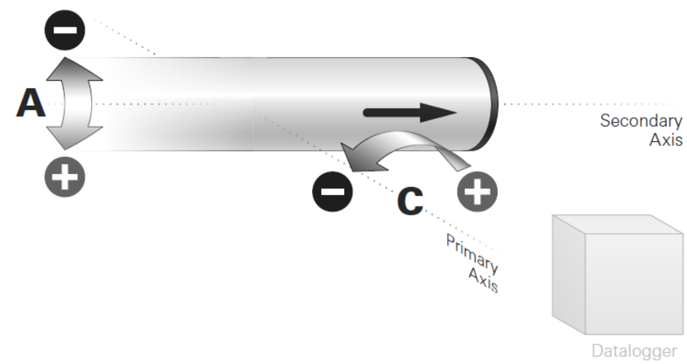
PRIMARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Top Toward
  - ⊖ Top Away

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Clockwise
  - ⊖ Counterclockwise

WALL MOUNT: ARROW POINTED RIGHT



SENSOR CONFIGURATION

- Mounted to **WALL, HORIZONTAL** installation
- **DATALOGGER** positioned **RIGHT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **RIGHT**, facing **FRONT**

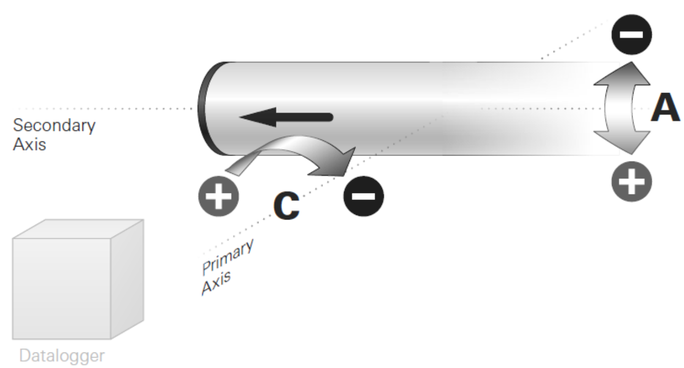
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Clockwise
  ⊖ Counterclockwise

SECONDARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Toward
  ⊖ Top Away

WALL MOUNT: ARROW POINTED LEFT



SENSOR CONFIGURATION

- Mounted to **WALL, HORIZONTAL** installation
- **DATALOGGER** positioned **LEFT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **LEFT**, facing **FRONT**

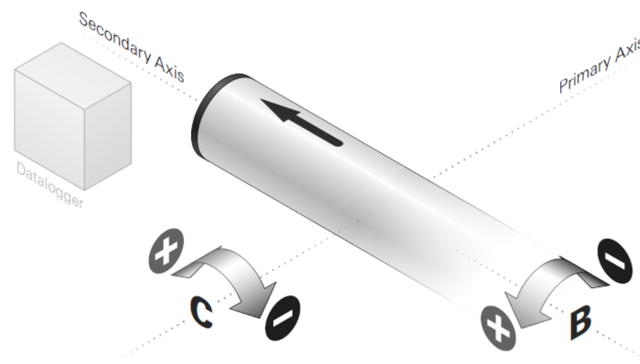
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Counterclockwise
  ⊖ Clockwise

SECONDARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Toward
  ⊖ Top Away

FLOOR MOUNT: ARROW POINTED LEFT



SENSOR CONFIGURATION

- Mounted to **FLOOR, HORIZONTAL** installation
- **DATALOGGER** positioned **LEFT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **LEFT**, facing **UP**

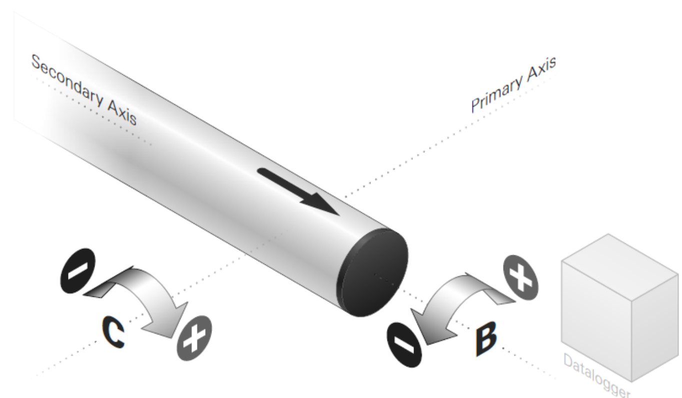
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Counterclockwise
  ⊖ Clockwise

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Toward
  ⊖ Top Away

FLOOR MOUNT: ARROW POINTED RIGHT



SENSOR CONFIGURATION

- Mounted to **FLOOR, HORIZONTAL** installation
- **DATALOGGER** positioned **RIGHT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **RIGHT**, facing **UP**

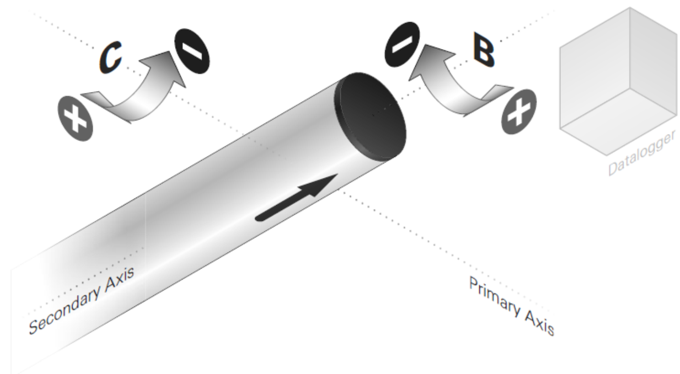
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Clockwise
  ⊖ Counterclockwise

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Away
  ⊖ Top Toward

CEILING MOUNT: ARROW POINTED RIGHT



SENSOR CONFIGURATION

- Mounted to **CEILING, HORIZONTAL** installation
- **DATALOGGER** positioned **RIGHT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **RIGHT**, facing **DOWN**

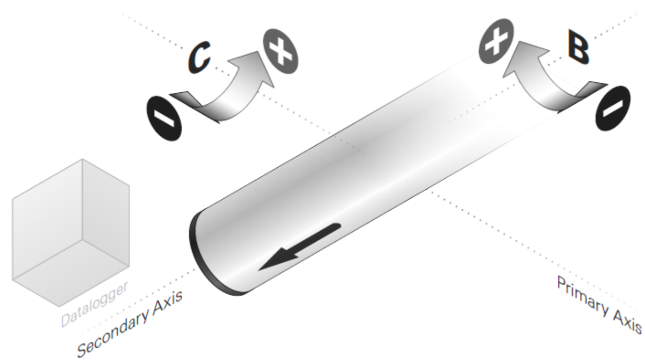
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  (+) Clockwise
  (−) Counterclockwise

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  (+) Top Toward
  (−) Top Away

CEILING MOUNT: ARROW POINTED LEFT



SENSOR CONFIGURATION

- Mounted to **CEILING, HORIZONTAL** installation
- **DATALOGGER** positioned **LEFT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **LEFT**, facing **DOWN**

PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  (+) Counterclockwise
  (−) Clockwise

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  (+) Top Away
  (−) Top Toward