EL Sled Sensor

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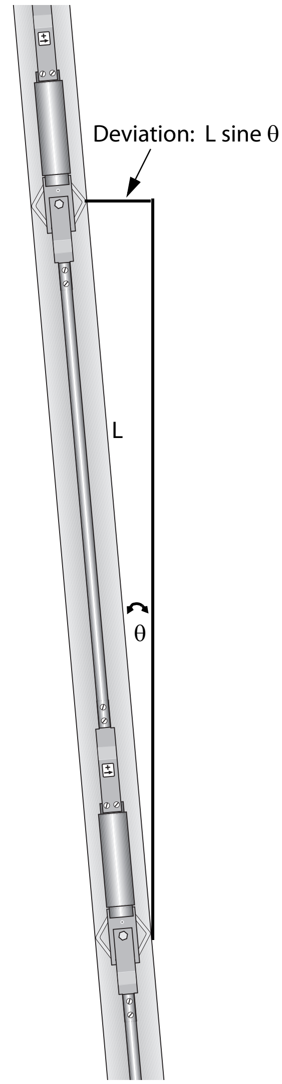
Introduction

In-Place Inclinometer with EL Sled Sensors



An in-place inclinometer system consists of inclinometer casing and a string of tilt sensors, EL sled sensors, in this case.

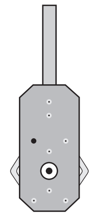
The inclinometer casing is installed in a vertical borehole that passes through a suspected zone of movement. The sensors, each connected to the next at a pivot point, are positioned inside the casing to span the zone of movement. Ground movement displaces the casing, causing a change in the tilt of the sensors inside.

The sensors measure tilt, the angle of inclination from vertical. The tilt measurement is converted to lateral deviation using the formula L sine θ, where L is the gauge length of the sensor and θ is the tilt.

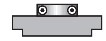
Displacement, the lateral distance the casing has moved, is calculated by finding the difference between the current and initial deviations.

In most applications, sensors are connected to a data acquisition system that continuously monitors movements and can trigger an alarm when it detects a change, or a rate of change, that exceeds a preset value.

Components

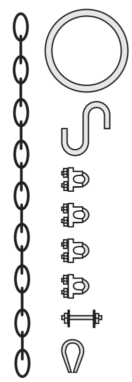


Top Sled terminates the sensor string or completes the gauge length of a single sensor. The guide rod at the top of the sled lets you push the sensor string deeper into the casing.

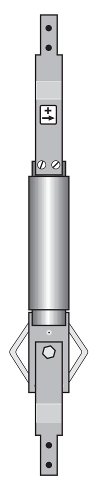


Top clamp fits directly onto gauge tubing and holds the sensor string at the top of the casing. The top clamp is a useful alternative to the top sled if the sensor string does not need to be pushed deeper into the casing.

Gauge Tubing is sized to complete the gauge length of the sensor.



Suspension Kit includes S-hook, chain, and cable clamps. Used with 3/16th inch aircraft cable and top sled.



Sled Sensor

Preparation

Required Tools

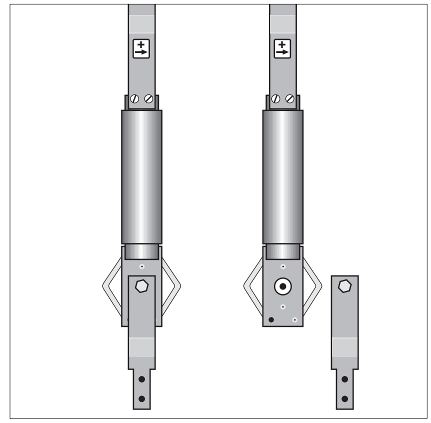
- Screwdriver (slot) for joining sensors and gauge tubing.
- Vice grips (clamping pliers) for holding gauge tubing during installation.
- Cable ties and vinyl tape for securing cable to gauge tubing.
- Allen wrench for securing top clamp, if used.
- Adjustable wrench for tightening cable clamps, if top sled is used.

Identify and Check Sensors

1. Test each sensor. See "Manual Readings" for instructions.
2. Make a note of the serial number and the intended installation depth of each sensor.
3. Check that cable lengths are correct.
4. Mark sensors for order of installation and attach sensor ID tags to ends of signal cables.
5. Lay out sensors in order of installation.

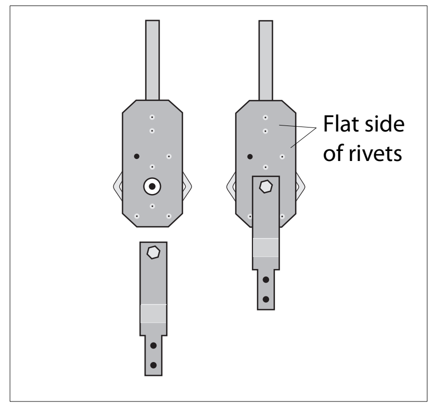
Prepare Bottom Sensor

The swivel arm is not required for the bottom sensor. Remove it, as shown in the drawing. Keep the swivel arm for use in the step below.



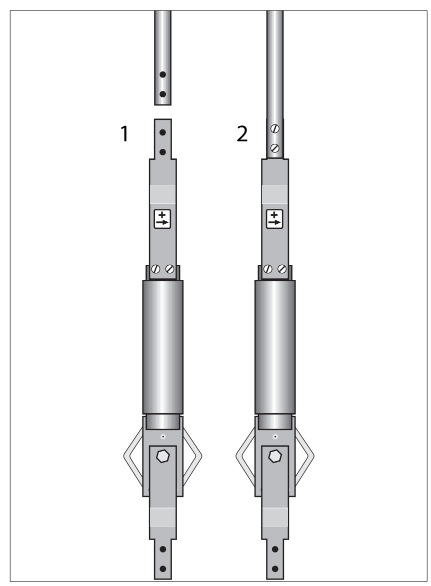
Prepare Top Sled

Attach the swivel arm to the top sled, as shown in drawing. Omit this step if you are using a top clamp.



Attach Gauge Tubing to Each Sensor

1. Slide gauge tubing onto each sensor as shown in the drawing.
2. Secure with screws.



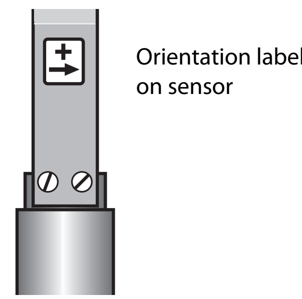
Installation

Overview

1. Determine the proper orientation of the sensor.
2. Install sensors.
3. Terminate the sensor string.

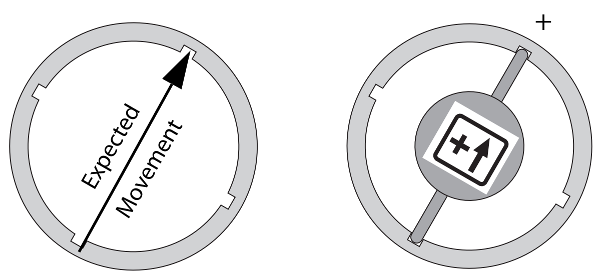
Sensor Orientation

Each sensor has an orientation label, as shown in the drawing. Use this label for orienting the sensor, as explained below.



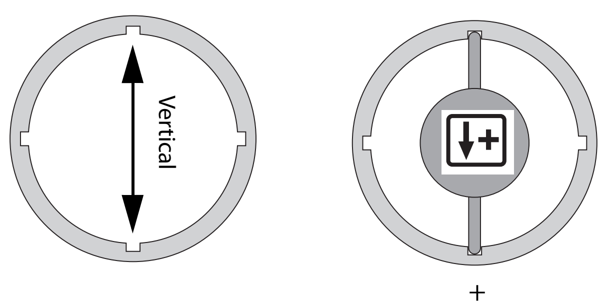
Vertical Installations

In vertical installations, one pair of casing grooves is aligned with the expected direction of movement. The sensor should be installed so that the arrow on the orientation label points in the same direction, as shown in the drawing.



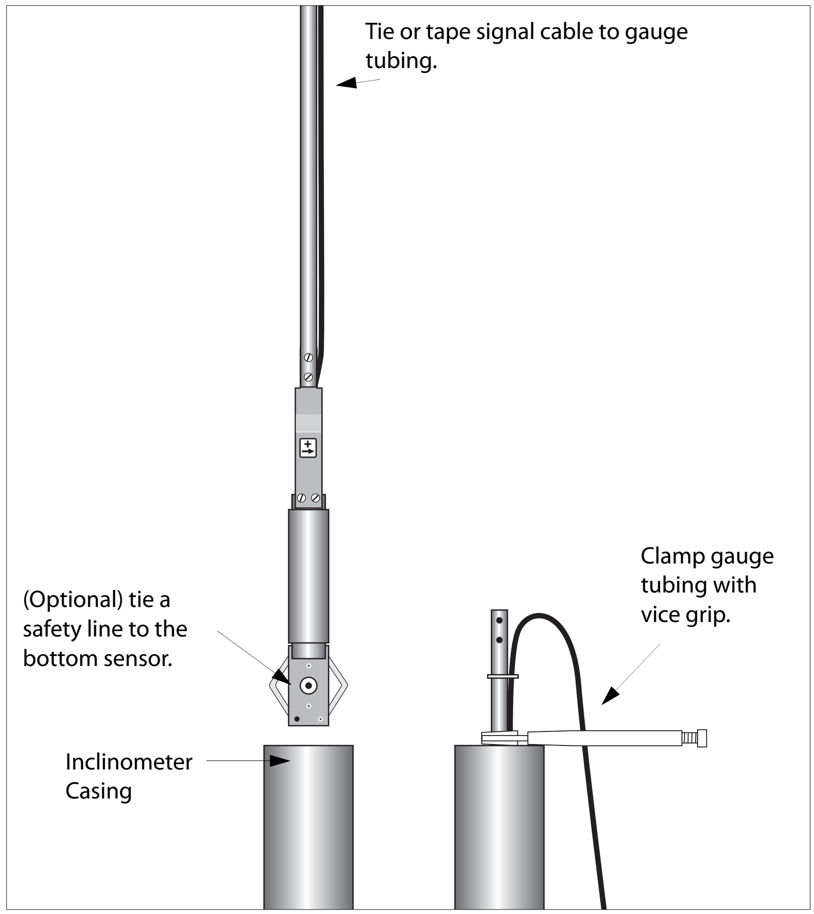
Horizontal Installations

In horizontal installations, one pair of grooves is aligned with the vertical plane. The sensor should be installed with the arrow pointing down.



Install Bottom Sensor

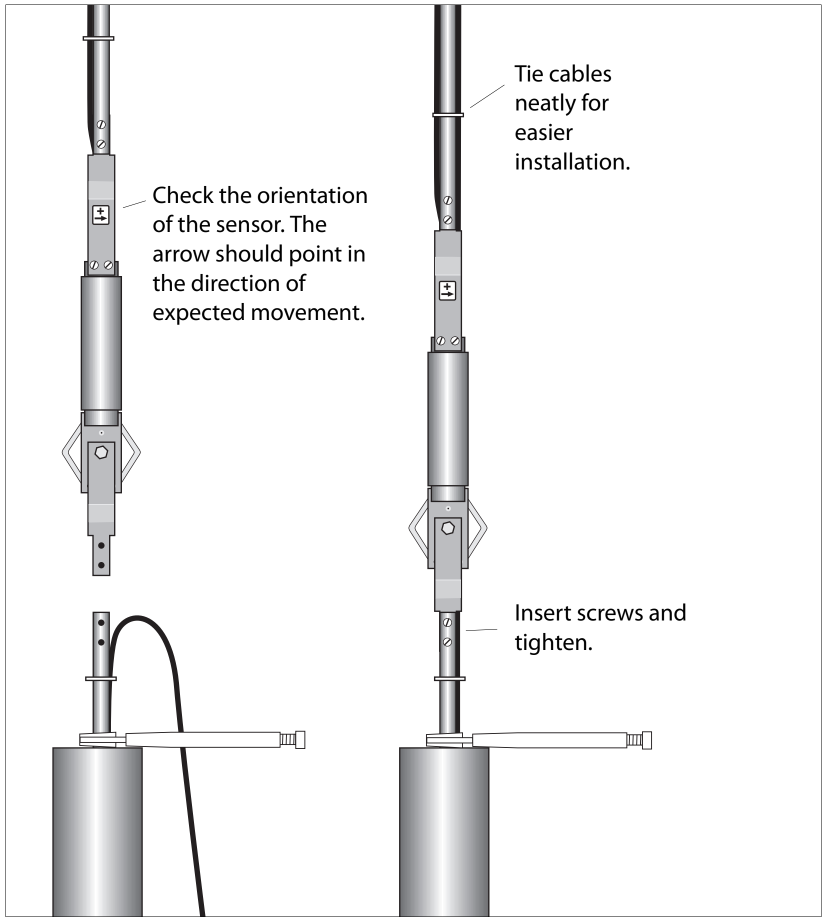
1. (Optional) Attach safety line to bottom sensor and secure the free end of the line. This may not be required, since the sleds are a tight-fit in the casing grooves.
2. Align bottom sensor with the preferred set of casing.
3. Push the sensor into the casing. Tie signal cable to gauge tubing. Use vice grips to clamp top of gauge tubing. Now the next sensor can be installed.



Install More Sensors

1. Join the next sensor to the gauge tubing of the sensor below, as shown in the drawing.
2. Continue adding sensors until the sensor string is complete.
3. Keep the following points in mind:

- Always check the orientation of the sensor.
- Tie cables neatly, so that they do not cross each other.

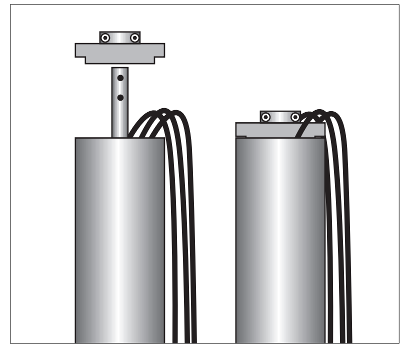


Terminate Sensor String

You can terminate the sensor string - or the gauge length of a single sensor - with a top clamp or a top sled.

Top Clamp

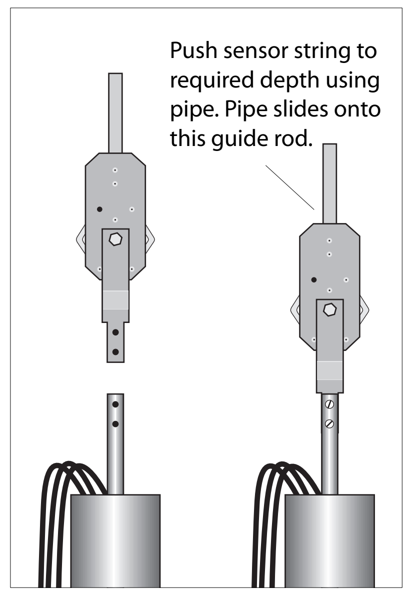
The top clamp holds the gauge tubing of the top sensor at the top of the borehole.



1. The top clamp has a split collar. Loosen the screws, slide the collar onto the gauge tubing, and then tighten the screws.
2. Push the top clamp and sensor into the casing until the top clamp rests on the casing.

Top Sled

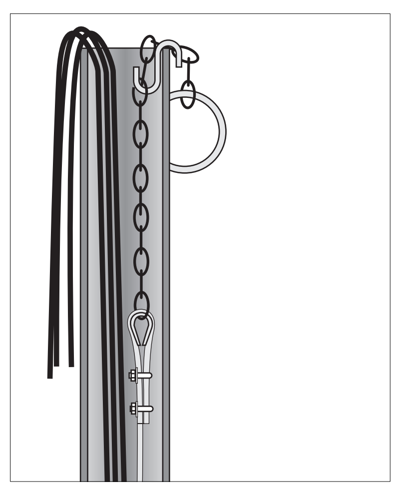
The top sled allows the string to be pushed deeper into the casing. A steel cable is usually attached to allow later retrieval. The cable is secured with the suspension kit.



1. Attach a steel cable to the top sled. Use the cable clamps in the suspension kit to secure the cable.
2. Use a pipe to push the top sled to the required depth. Slide the pipe onto the top sled's guide rod.

Suspension Kit

The suspension kit provides hardware to secure the steel cable.



1. Insert the thimble and cable into the lowest chain link. Then clamp the cable.
2. Position the S-hook at the top of the casing and hook the chain onto it.

Manual Readings

EL Data Recorder

1. Connect sensor to readout as shown in the table below.
2. Switch on. Choose uniaxial sensor. Tilt is displayed in volts. Temperature is displayed in degrees C.

Data Recorder Terminal	Signal Cable Wire
1 Tilt A	Orange
2	
3 Temp	Red
4 Sig Common	Yellow
5 Sense	Violet
6 Power +	Green
7 Power -	Black
8 Shield	Drain Wire

DataMate MP

DataMate MP must have firmware version 05/01/02 AA or later.

1. Connect sensor as shown in table below
2. Switch on. Choose Manual mode. Choose EL SC RO. "A-axis" tilt is displayed in volts. Ignore "B-axis" value. Temperature is displayed in degrees C.

Bare Wire Adapter	7-Wire Cable	Function
1	Orange	Tilt
2	Yellow	Signal Reference
5	Red	Temperature
6	Black	Power Common
	Violet	Analog Common
7	(Yellow)	Signal Reference
8	Green	Power
Use a jumper wire to connect terminals 2 and 7 of the bare-wire adapter. Black and violet wires are both connected to terminal 6.		

Voltmeter

Reading with a voltmeter requires a device capable of displaying values in the low millivolt dc range. You will also need a power source, such as an alkaline 9-volt battery to supply between 5.5 and 15 Vdc to the sensor.

1. Connect green wire to the + terminal of the power source. Connect the violet wire and black wire to the - terminal of the power source.
2. To read the A-axis sensor, connect the voltmeter to the orange wire (signal) and yellow wire (reference).
3. To read the thermistor, connect the voltmeter to the red and yellow wires.

Test Readings

1. When the sensor body is vertical, you should see a reading of about 0.0 Vdc.
2. Tilt the sensor in the direction of the arrow on the label. Reading should be positive. Tilt in direction opposite the arrow. Reading should be negative.
3. The sensor calibration record shows tilt vs volt output. You can make a rough comparison using your readout and a tilt table or equivalent.
4. If you are using a voltmeter, the thermistor reading should be about 1 Vdc at 25 degrees C.

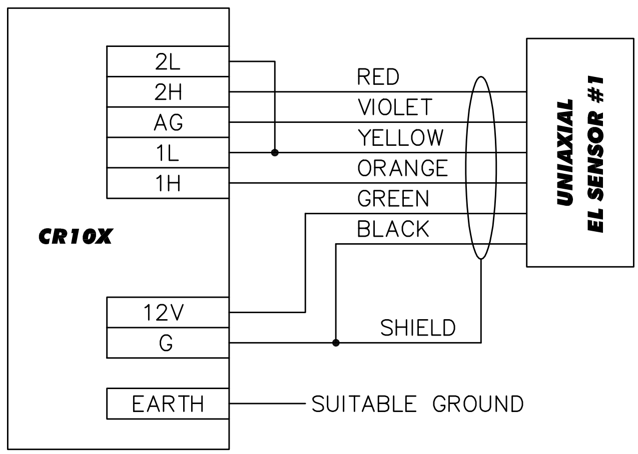
Data Logging

Introduction

We recommend using the Campbell Scientific CR10X data logger for reading EL sled sensors. We provide two wiring diagrams below. A sample monitoring program is available at Slope Indicator's website. Go to www.slopeindicator.com - support - tech notes. Look at the data logger technotes to find a link for sample programs that you can download.

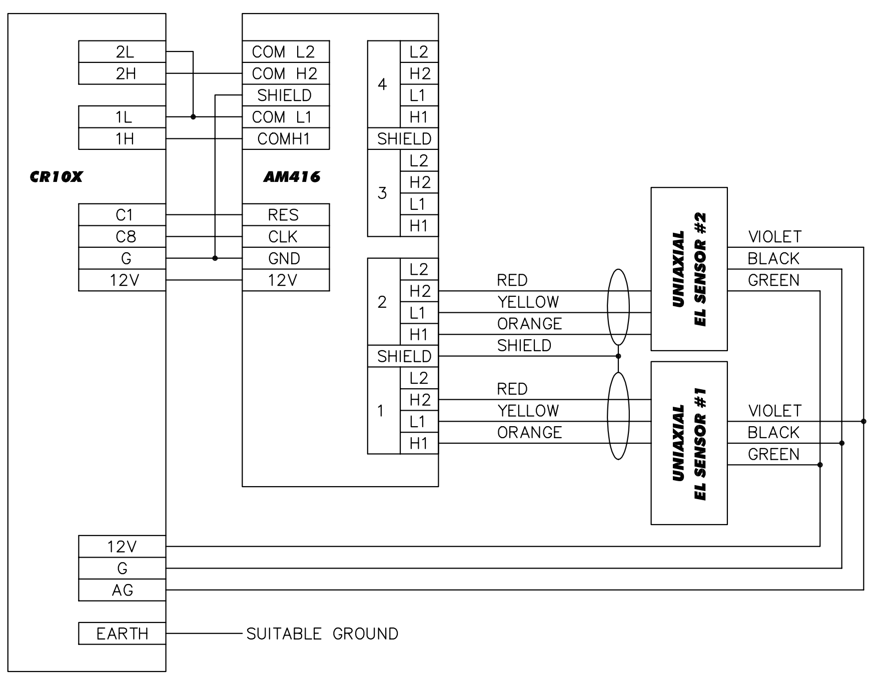
Wiring Diagram 1

Connecting a uniaxial sensor directly to the CR10X



Wiring Diagram 2

Connecting uniaxial sensors to an AM416 multiplexer



Data Reduction

Introduction

Data reduction is usually automated because it involves a large number of readings and a large number of calculations.

Here, we explain how to use the sensor calibration record and provide an example of converting a single reading from voltage to mm of deviation.

Once you have deviations, you can calculate displacements (movements) by subtracting the initial deviation from the current deviation.

Calibration Record

A calibration record is provided with each sensor. Note that calibrations are unique for each sensor, so use sensor serial numbers to match sensors with their calibrations.

The sensor calibration record lists three sets of factors for each axis of the sensor and one factor for the temperature sensor. The table at right shows factors for sensor serial number 10001. Your sensors will have different factors.

C0	-7.0311
C1	73.878
C2	-0.22265
C3	-0.33079
C4	0.019426
C5	0.020221
S0	1
S1	0.00059828
S2	0.0000068117
F0	00012125
F1	0.016273
F2	0.00096919
Toffset	0.19
Tnom	12

C0 to C5: Use these factors to convert a reading in volts to mm per meter of gauge length.

S0 to S2: Use these factors to adjust the mm/m value above for temperature-related changes in sensor sensitivity.

F0 to F2: Use these factors to adjust the mm/meter value for temperature-related changes in the offset of the sensor.

Toffset: Use this factor in the equation to convert a thermistor reading in volts to degrees C.

Tnom: Tnom is normally 12 degrees C. However, the value shown on the sensor calibration record may be higher or lower if your sensors were calibrated over a custom range of temperatures.

Applying Calibration Factors

Suppose you obtain a reading of 570 millivolts (0.57V) from sensor 10001, which has a gauge length of 2 meters. How do you convert the voltage reading to mm of deviation?

Converting sensor reading to mm per meter

Apply the C factors to the voltage reading as shown below. EL represents a reading in volts. C5 through C0 are factors that appear on the sensor calibration record. The result of the calculation is a value in mm per meter.

mm/meter = $C5 \cdot EL^5 + C4 \cdot EL^4 + C3 \cdot EL^3 + C2 \cdot EL^2 + C1 \cdot EL + C0$

	C Factor	EL Reading	Value
C0	-7.0311		-70311
C1	73.878	0.57	42.11046
C2	-0.22265	0.57^2	-0.07234
C3	-0.33079	0.57^3	-0.06126
C4	0.19426	0.57^4	0.002051
C5	0.020221	0.57^5	0.001217
	mm per meter deviation =		34.94903

Calculating deviation in mm

To calculate deviation for a particular gauge, multiply the mm/meter value by the gauge length of the sensor.

deviation in mm = mm/meter value • gauge length of sensor

In this example, the gauge length is 2 meters, so the deviation would be about 70 mm.

Temperature Readings

The CR10 delivers thermistor readings in volts. The equation below shows how to convert the volt reading to degrees C. The factors in the equation are optimized for temperatures between -15 and 85 degrees C. ET is the volt reading. Toffset is taken from the sensor calibration sheet.

$$DegC = (9.3219 \times ET^5) + (-54.3038 \times ET^4) + (131.165 \times ET^3) + (-161.2568 \times ET^2) + (137.7711 \times ET) + (-37.7705) - Toffset$$

Correcting for Temperature

Changes in temperature affect both the sensitivity and the offset of the sensor. In the instructions below, the sensitivity temperature correction is called SENSTC. The offset temperature correction is called OFFSTC.

1. Find the change in temperature from Tnom, which is a value on the sensor calibration sheet.

   DeltaT = DegC - Tnom

   For our example, DegC is 19.3 and Tnom is 12 degrees C, so DeltaT, the change in temperature, is 7.3 degrees C.

2. Calculate the sensitivity correction:

   SENSTC = S2•DeltaT^2 + S1•DeltaT + S0

	S Factor	DeltaT	Value
S0	1		1
S1	0.00059828	7.3	0.004367
S2	0.0000068117	7.3^2	0.000363
		SENSTC =	1.00473

3. Calculate the offset correction:

   OFFSTC = F2•DeltaT^2 + F1•DeltaT + F0

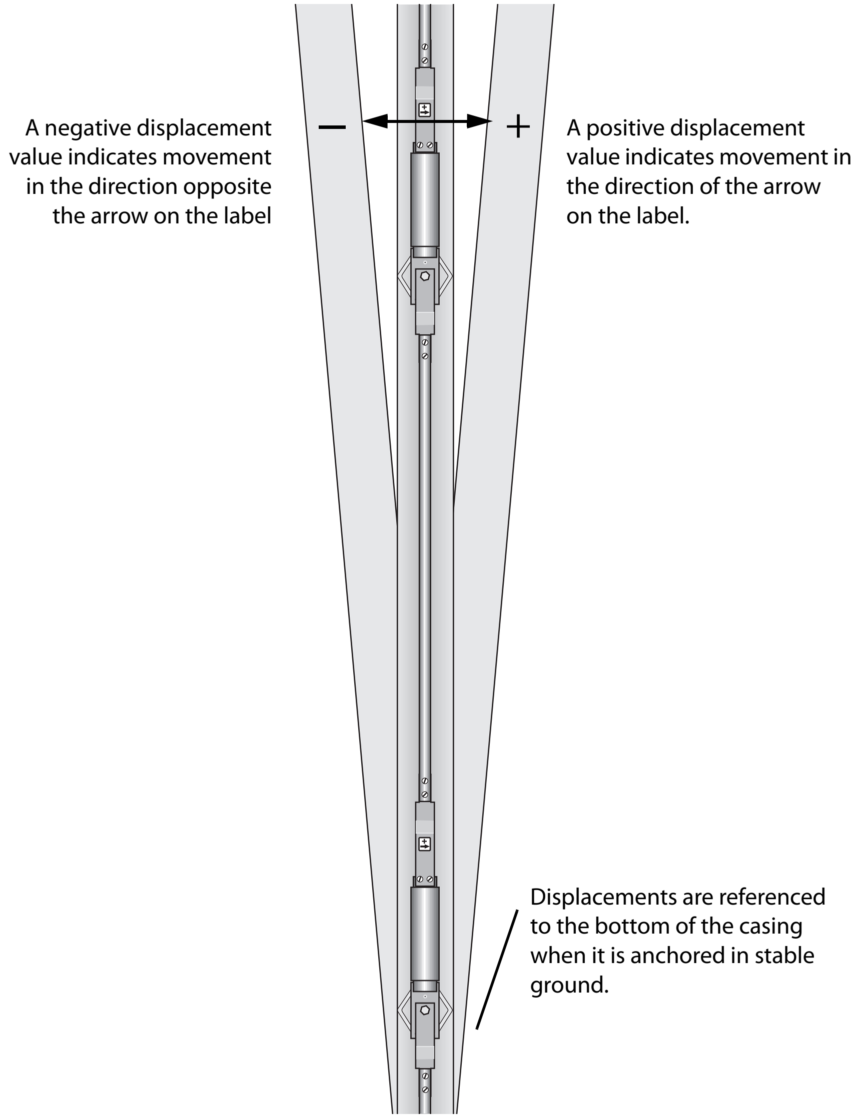
	F Factor	DeltaT	Value
F0	0.00012125		.000121
F1	0.016273	7.3	0.118793
F2	0.00096919	7.3^2	0.051648
		OFFSTC =	0.170562

4. Apply the corrections:

   corrected value = (mm/meter value • SENSTC) + OFFSTC
   = (34.94903 • 1.00473) + 0.170562
   = 35.28491

Direction of Movement for Vertical Inclinometers

Displacement data from vertical inclinometers are usually referenced to the bottom of the casing, as shown below.

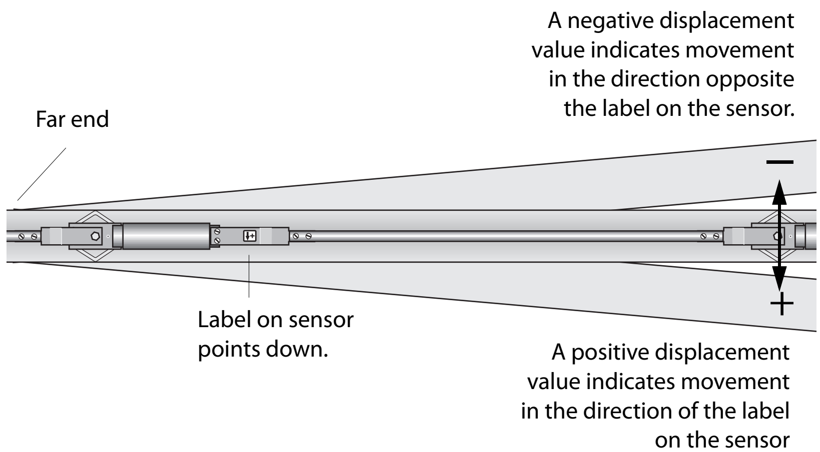


Direction of Movement Horizontal Sensor

Horizontal inclinometer casing is installed with one set of grooves oriented to the vertical plane. The sensors are installed with the label pointing down.

Far-End Reference

The drawing below shows direction of movement when the far end of the casing is used as reference:



Near-End Reference

The drawing below shows the direction of movement when the near-end of the casing is used as reference.