INSTRUCTION MANUAL

MEMS VERTICAL IPI SERIAL SENSORS

Model PISA-M

This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.

Tel.: 1.450.465.1113 • 1.877.ROCTEST (Canada, USA) • 33.1.64.06.40.80 (France) • 41.91.610.1800 (Switzerland)

www.roctest.com

E10350-161101

TABLE OF CONTENTS

1 INTRODUCTION

1.1 VERTICAL IN-PLACE INCLINOMETERS

The in-place inclinometer system consists of the inclinometer casing and a string of in-place inclinometer sensors (please see Figure 2 on next page).

The inclinometer casing provides access for subsurface measurements, controls the orientation of the sensors, and moves with the surrounding ground.

In vertical installations, the casing is installed in a borehole that passes through a suspected zone of movement into stable ground below. One set of grooves in the casing is aligned with the expected direction of movement, as shown below.

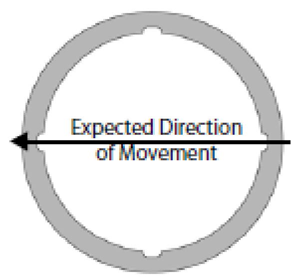


Figure 1

Casing should be installed with one set of grooves aligned with the expected direction of movement. The wheels of the sensors are inserted in these grooves.

The grooves in the casing control the orientation of the in-place inclinometer sensors. A stainless steel cable keeps the sensors at the required depth.

The sensors measure inclination from vertical. As ground movement occurs, the casing moves with it, changing the inclination of the sensors inside the casing.

The inclination measurements are then processed to provide displacement readings in mm or inches.

In most applications, sensors are connected to a data acquisition system and data processing is completed by a computer program.

1.2 SENSOR COMPONENTS

In-place sensors can be installed as a single sensor or as a string of linked sensors. Figure 3 shows both.

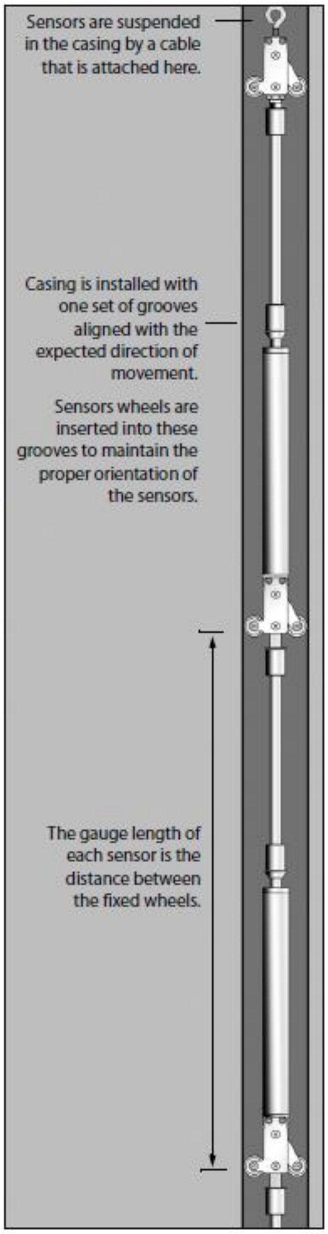


Figure 2

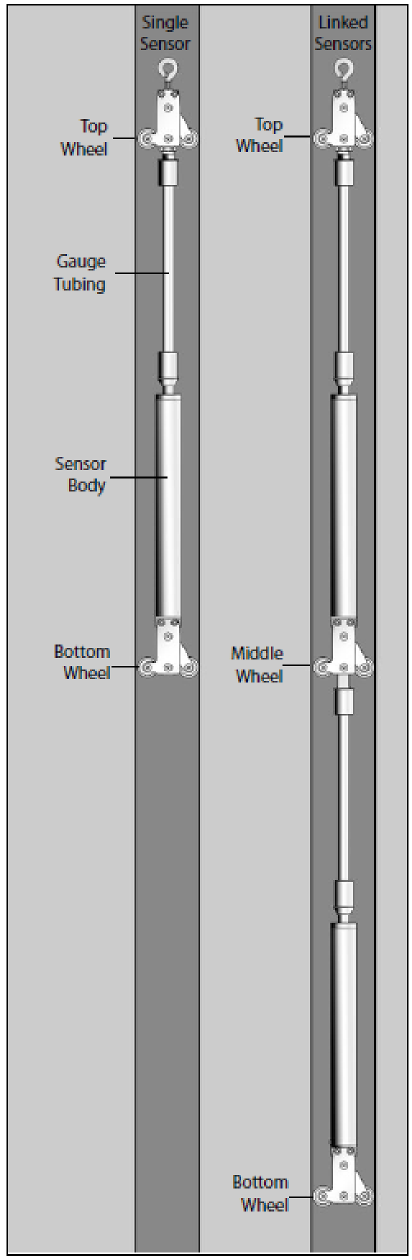


Figure 3

An individual sensor includes a sensor body, a gauge tube, a top wheel, and a bottom wheel.

A string of linked sensors includes *n* sensor bodies, *n* gauge tubes, a top wheel, a bottom wheel, and *n*-1 middle wheels.

Sensor bodies can contain uniaxial or biaxial sensors, both look the same.

Gauge tubes are sized to make gauge lengths of 1, 2, or 3 m when joined to a sensor body and wheels.

Top wheels have an eyelet for attaching a stainless steel suspension cable. They also have a socket for connecting to a gauge tube.

Bottom wheels attach directly to the bottom of the sensor. They have no socket.

Middle wheels are used to link sensors. The middle wheel attaches directly to the bottom of the sensor and has a socket for connecting to the gauge tube from the sensor below.

1.3 SERIAL SENSOR CABLE CONNECTIONS

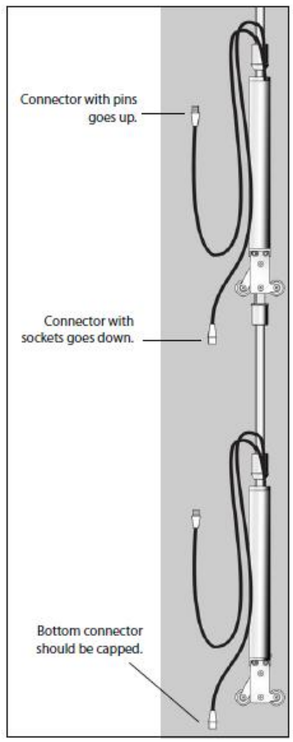


Figure 4

1.4 OTHER COMPONENTS

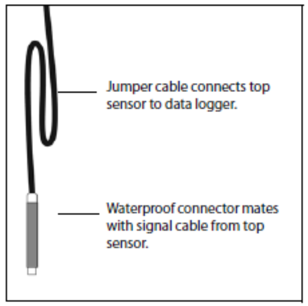


Figure 5

1.5 SUSPENSION KITS

Top suspension kit is used to suspend the IPI sensors from the top of the casing, as shown on Figure 6. Stainless steel cable is ordered separately.

In-line suspension kit is used to suspend a string of deeper sensors from a string of shallower sensors. This allows economical monitoring of two or more separate zones of interest. Please refer to Figure 6.

Safety cable (not shown) is sometimes attached to the bottom sensor and used to prevent loss of sensors downhole during installation. A safety cable is also helpful when sensors are withdrawn from the casing.

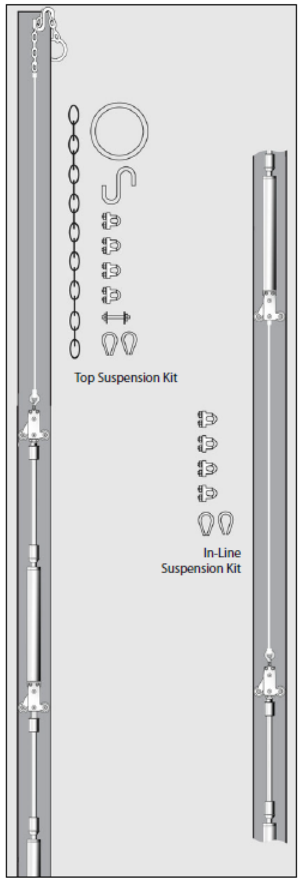


Figure 6

2 PREPARATION FOR INSTALLATION

2.1 CHECK SENSORS

1. Check each sensor.
2. Identify the bottom sensor for each string. The bottom sensor will require a plug for the bottom connector.
3. Make a note of the serial number of each sensor and its intended depth of installation.
4. Mark sensors for order of installation.
5. Check length of jumper cable to make sure it will run from the top sensor to the datalogger.

2.2 PREPARE SUSPENSION CABLE

1. Check project specifications for intended depth of top sensor.
2. Determine the required depth of the top wheels of the top sensor.

3. Determine the distance between the top wheels and the top of the casing. Cut the stainless steel suspension cable to this length.
4. Connect suspension cable to top wheel as shown in Figure 7.
5. Connect suspension cable to the chain as shown in Figure 7.

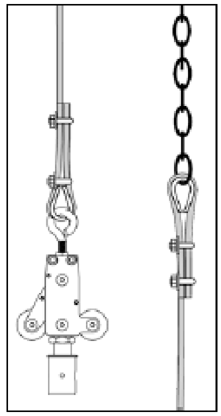


Figure 7

2.3 ATTACH GAUGE TUBING

1. Remove screw from socket.
2. Align hole in gauge tube with hole in socket, then insert gauge tube into socket.
3. Insert screw and tighten to secure the gauge tube.
4. No further pre-assembly is recommended.

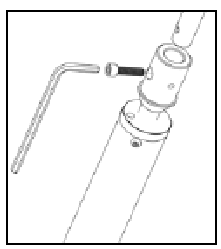


Figure 8

2.4 GATHER TOOLS

- Vise-grips (clamping pliers) for holding gauge tubing while connecting adjacent sensors.
- Allen wrench for screws that secure gauge tubing.
- Cable ties or vinyl tape to secure cable gauge tubing.
- Optional: safety cable connected to bottom sensor to prevent loss of sensors down hole. The safety cable is also helpful when the sensors are withdrawn from the casing.

3 INSTALLATION

3.1 INSTALLATION OVERVIEW

1. Lay out sensors in the order of installation.
2. Insert the first sensor into the preferred set of grooves.
3. Lower the sensor into the casing. Using the vise-grip, clamp the top of the gauge tube to hold the sensor while you connect the next sensor.
4. Align the next sensor with the preferred set of grooves as in step 2, and connect it to the gauge tubing of the downhole sensor.
5. Lower the two sensors. Repeat steps 4 and 5 until all sensors have been installed.
6. Connect the top wheel and suspension kit and lower the sensors to their final elevation.

3.2 GATHER TOOLS

1. Vice grips (Clamping pliers) for holding gauge tubing while connecting adjacent sensors.
2. Allen wrench for screws that securing gauge tubing.
3. Cable ties or vinyl tape to secure cable to gauge tubing.
4. Optional: safety cable connected to bottom sensor to prevent loss of sensors down hole. The safety cable is also helpful when the sensors are withdrawn from the casing.

3.3 INSTALL THE FIRST SENSOR

1. Check that bottom connector of first sensor is capped.
2. Optional: Attach safety cable to wheel assembly.
3. Insert first sensor in selected set of grooves. The fixed wheel should point to the expected direction of movement, as shown on Figure 9.
4. Secure signal cable to gauge tubing and then lower sensor into casing. Clamp the top of gauge tubing to hold it at the top of the casing.

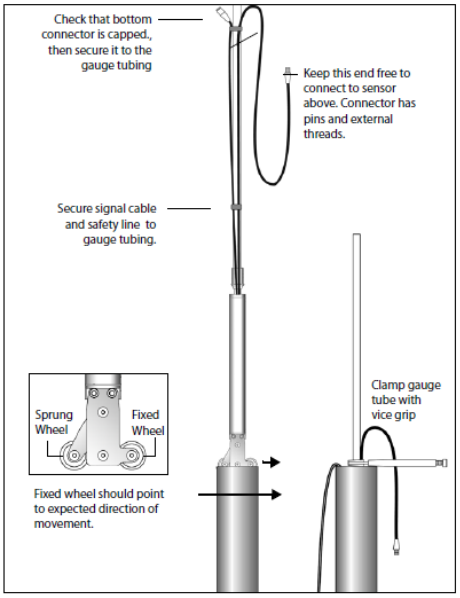


Figure 9

3.4 INSTALL ADDITIONAL SENSORS

1. Connect next sensor to the gauge tubing of the sensor below. Always check that fixed wheel points to expected direction of movement, as shown on Figure 10
2. Check that connectors are clean, and then connect the cables. Secure excess cable to the gauge tubing with tape or a cable ties.
3. Continue adding sensors until the sensor string is complete.

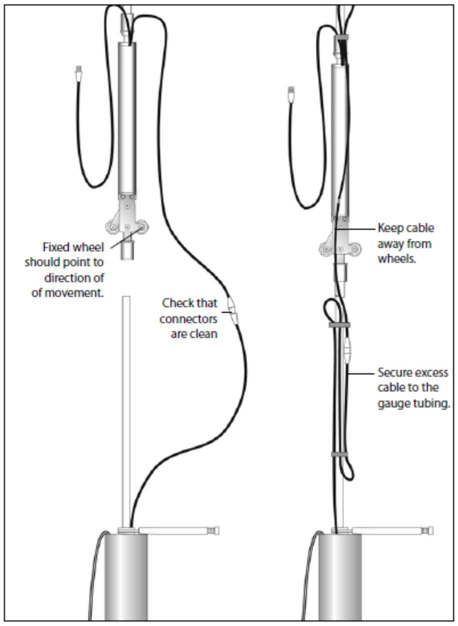


Figure 10

3.5 INSTALL THE TOP WHEEL

1. Connect the data cable to top sensor. Cable runs from top sensor to data logger (see Figure 11).
2. Connect top wheel to gauge tube.

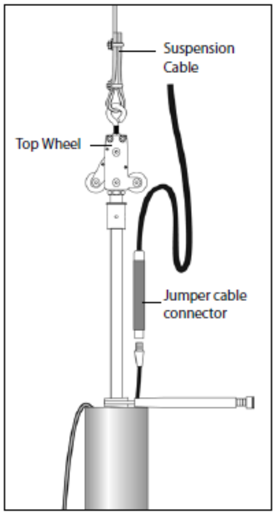


Figure 11

3.6 SUSPEND THE SENSORS

1. Check that suspension cable is securely clamped.
2. Use the chain and S-hook to make fine adjustments to the final depth of the sensor (see Figure 12).

Figure 12

3.7 NOTE ON RETRIEVING SENSORS

Withdraw the sensors one by one rather than trying to pull out the entire chain. If you try to extract the entire chain at once, you will bend the gauge tubes and the wheels.

1. Draw each sensor upwards.
2. Clamp the gauge tube of the sensor below.
3. Disconnect the sensor, and repeat. If you intend to reinstall the sensors, check that they are still numbered for order of installation.

4 DATA REDUCTION

4.1 INTRODUCTION

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

In this section, we explain the sensor calibration sheet and provide an example of converting a single reading in volts to tilt in mm per meter and tilt in degrees.

4.2 CALIBRATION SHEET

A calibration sheet is provided with each sensor. Use sensor serial numbers to match sensors with their calibrations. Calibrations are unique for each sensor.

Factors for tilt are C0, C1, C2, C3, C4 and C5. A-axis factors have an A prefix: AC0, AC1, AC2, AC3, AC4, AC5 and B-axis factors have a B prefix.

4.3 CONVERTING VOLTS TO TILT

To convert a reading in volts to tilt, use the following formula.

$$\textbf{Tilt (mm/m)=C5*Volts}^{2}\textbf{+C4*Volts+C3+C2*TdegC+C1*TdegC}^{2}\textbf{+C0*Volts*TdegC}$$

Where

C5…C0 are factors for A-axis or B-axis

Volts is the sensor reading in volts

TdegC is the temperature reading in degrees Centigrade

4.4 CALCULATING TILT IN MM/M

For example, Sensor *14384* gives an A-axis reading of 0.4137 V at 6.7°C. The calibration sheet lists these factors for tilt in mm/m:

AC5 = -3.3789E-3
AC4 = 7.9648E1
AC3 = 5.4138
AC2 = -2.9838E-2
AC1 = -2.5159E-4
AC0 = 9.8415E-3

$$\text{Tilt=C5*Volts}^{2}\text{+C4*Volts+C3+C2*TdegC+C1*TdegC}^{2}\text{+C0*Volts*TdegC}$$

Tilt = 38.1797 mm/m

4.5 CALCULATING TILT IN DEGREES

For example, Sensor *14384* gives an A-axis reading of 0.4137 V at 6.7°C. Then to convert the tilt in mm/m in degree, following formula must be applied.

Tilt (degrees) = arcsin($Tilt_{mm/m}$ /1000)

With previous reading

Tilt (degrees) = arcsin(38.1797/1000)

Tilt = 2.188°

4.6 CALCULATING DEVIATION

To calculate deviation over the gauge length of the sensor, use either formula below:

$Deviation_{mm}$ = $Tilt_{mm/m}$ * $gauge\_length_m$
or
$Deviation_{mm}$ = sin($Tilt_{deg}$) * $gauge\_length_{mm}$

For example, Sensor 14384 has a gauge length of 2 meters. The examples below use the temperature corrected tilt values.

$Deviation_{mm}$ = 38.1797 mm/m * 2 m
$Deviation_{mm}$ = 76.3594
$Deviation_{mm}$ = sin(2.188) * 2000 mm
$Deviation_{mm}$ = 76.357

4.7 CALCULATING DISPLACEMENT

Displacement (movement) is the change in deviation:

Displacement = $Deviation_{current}$ - $Deviation_{initial}$

4.8 DIRECTION OF TILT AND DISPLACEMENT

Uniaxial sensors respond to tilt in the plane parallel to the wheels of the sensor. This plane is called the A axis. A-axis readings may be positive or negative. Positive readings indicate that the sensor is tilted in the direction of the fixed wheel. Negative readings indicate that the sensor is tilted in the direction of the sprung wheel. Please refer to Figure 13.

Biaxial sensors respond to tilt in the plane of the wheels (A-axis) and the plane rotated

90 degrees to the wheels (B-axis). Positive A-axis readings show tilt in the direction of the fixed wheels. Positive B-axis readings show tilt in the direction rotated 90 degrees clockwise. Displacement directions follow the same convention. In the Figure 14, the sensor is viewed from the top.

Figure 13

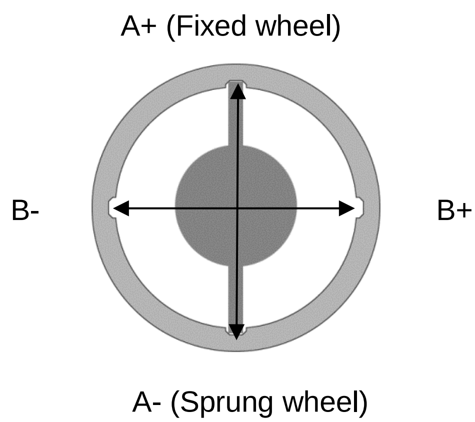


Figure 14

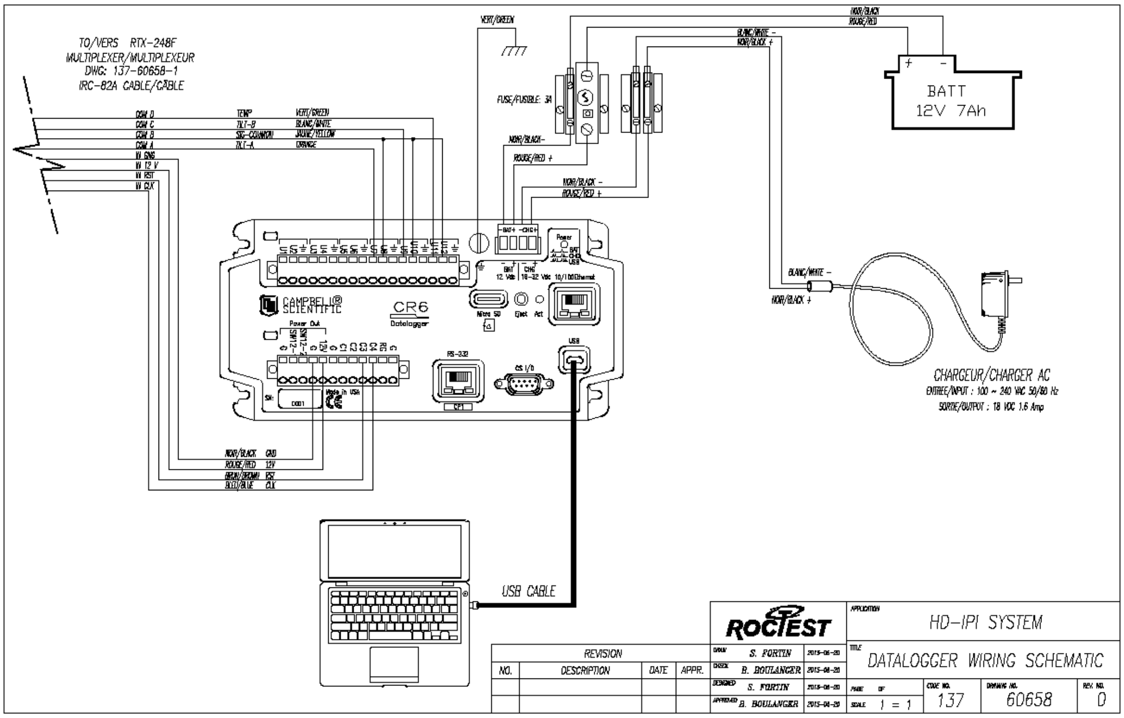
5 CONNECTION TO DATALOGGERS

5.1 CAMPBELL SCIENTIFIC CR6

These instructions provide information needed for reading uniaxial and biaxial Pisa-M with the Campbell Scientific CR6 datalogger system.

Wiring diagrams: The wiring diagram below shows how to connect serial Pisa-M to the Campbell Scientific CR6 datalogger. Uniaxial and biaxial connections are identical.

5.2 WIRING DIAGRAM



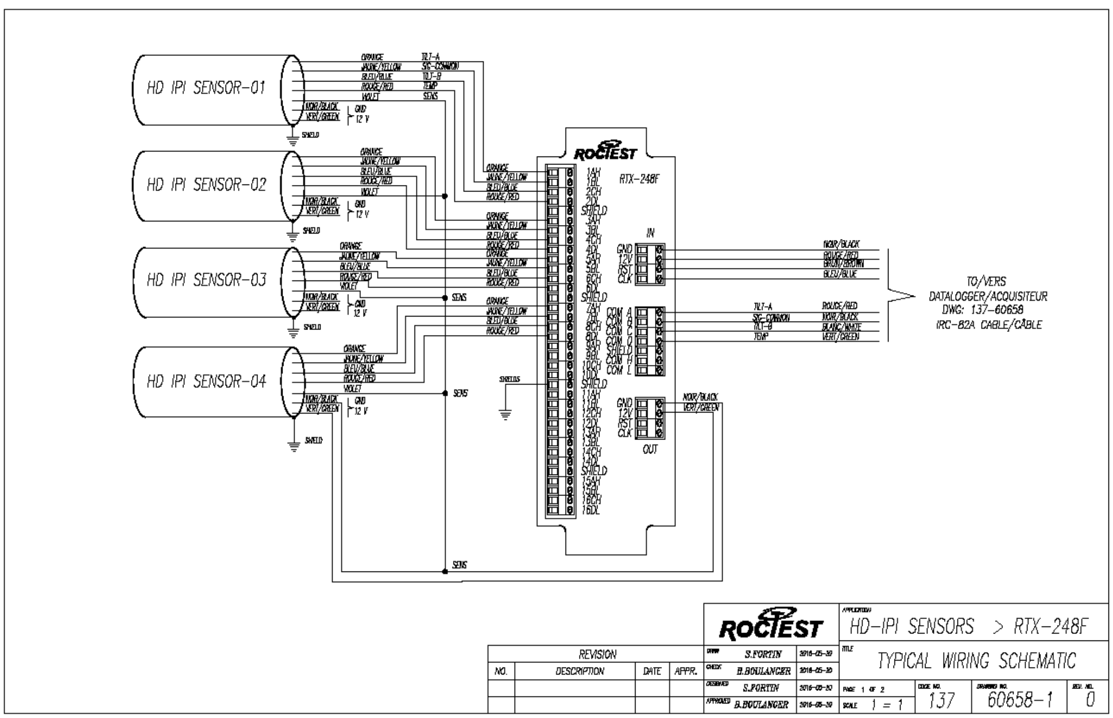


Figure 15

5.3 LIMITATIONS

The list below shows nominal limits for chain of serial sensors. The following table assumes that the logger supplies 12 volts:

Cable Length of jumper cable	Limit of sensors in the chain
40 m	50 sensors
92 m	40 sensors
165 m	30 sensors
258 m	20 sensors
375 m	10 sensors