SDI-12 SUBMERSIBLE PRESSURE SENSOR

Models 56-113 & 56-114

Operations & Maintenance Manual

Part No. 8800-1116
Revision A

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1. Introduction

The 56-113 SDI-12 Submersible Pressure Sensor is a solid-state pressure transducer suitable for data collection and monitoring applications. The sensor has been designed with the following features to operate in a wide range of applications:

low power consumption	standby power is 0.2mA, average power when taking measurements every 15 minutes via SDI-12 is less than 0.25 mA.
full temperature compensation	the accuracy is maintained over the temperature range of -10° to +50°C.
selectable units	the sensor can be configured to output the data in psi, feet of water, kilopascals, centimeters of water, meters of water, millimeters of water, or customer defined units.
non-volatile setup	the setup is stored in EEROM and remains even when power is removed from the sensor
wide operating voltage	the sensor operates over the voltage range of 8 to 28 VDC

Note: Long term submersion in seawater is not a recommended use for the standard unit. Contact Sutron's sales and applications department before considering long term use in sea water. See the specifications for a list of wetted materials.

2. Quick Start

The sensor comes with a setup compatible with a Sutron 8210. If you have an 8210, you are able to operate the sensor without making any changes to the setup. If you do not have an 8210, you may need to change the wiring to make it connect to your system as described in Chapter 3.

To use the sensor with the 8210 follow these simple steps:

- Connect the sensor to your Sutron 8210 Data Logger SDI-12 port.

Description	Sensor	8210 Data Recorder Connection
Battery	Red	SDI-12 +
Ground	Black	SDI-12 G
SDI Data	White	SDI-12 D

- Use the 8210 SYSTEM SETUP\ENABLE SENSOR menu to turn SDI0-1 ON. If you want to see the units indicator for the measurement, also turn SDI0-2 ON. Refer to the Sutron 8210/8200A Data Logger Operations and Maintenance Manual if you do not know how to ENABLE sensors.

- Use the 8210 VIEW\LIVE READINGS menu and select the SDI0-1 sensor.

The 8210 will now display the pressure readings from the sensor in units of feet of water.

3. Cabling

SDI-12 Wiring

The SDI-12 interface conforms to SDI-12 standard version 1.2. Only three wires are needed to use the SDI-12 interface.

Description	Sensor	Data Recorder Connection
Battery	Red	Connect to Battery or data recorder supplied voltage
Ground	Black	Connect to Ground
SDI Data	White	Connect to data recorder SDI Data line

Differential SDI-12 / RS-485 Wiring

Differential SDI-12 is not a defined standard. The differential SDI-12 / RS-485 interface is a low power modification of an RS-485 interface. It also overcomes the cable limit of SDI-12 since transmitted data is not referenced to the power supply ground. It does not utilize a power consuming termination resistor. It has transient protection built in that raises the output impedance above the level that is normally encountered in RS-485 applications. The data signaling rate and protocol conform to SDI-12 standard version 1.2. Four wires are needed to use the differential SDI-12 interface.

Description	Sensor	Data Recorder Connection
Battery	Red	Connect to Battery or data recorder supplied voltage
Ground	Black	Connect to Ground
RS485A	Blue	Connect to – Data (5 Volt idle state)
RS485B	Yellow	Connect to + Data (0 Volt idle state)

4. Setup and Operation

Introduction

This section will familiarize you with the steps and commands needed to alter the setup of the 56-113. If you will use the sensor at address 0 (the factory default) and can accept the output in units of feet of water, you will not need to use these commands. Typically, you will need to issue some of the commands, so we recommend you learn how to do so. Learning to issue commands also helps if you need to troubleshoot a sensor.

To issue commands to the SENSOR via SDI-12, you will need to connect it to a data recorder, such as a Sutron 8200, 8210, or 8400 which is capable of issuing standard and extended SDI-12 commands. Follow the instructions in Sections 2 and 3 in order to make these connections.

Nomenclature

All commands have three components: the **device address**, the **command body**, and the **command termination**.

The **device address** is a single character and is the first character of a command. In the examples that follow, it is usually the number 0 (the default address as shipped from the factory).

The **command body** and the responses are shown as a combination of upper and lower case letters. The upper case letters are the fixed portions of the command and the lower case letters are the variables or values. In the specific examples, you will see that the lower case letters are replaced with actual numbers.

All commands are shown with an exclamation point (!) as the **command terminator**.

Setting the Address

If you are using the SENSOR connected with other SDI-12 devices, you will need to change the SENSOR address. Otherwise, skip this section. The address simply lets multiple devices share the same wiring. When the data recorder needs data from a particular sensor, it requests data using an address. Only the device with the matching address will reply.

The default SDI-12 address is 0.

Using a command to Set the Address

No other SDI-12 devices connected to the system should be set to address 0 or to the desired sensor address. Hint: If you do not know the address of a particular sensor, use the unknown address command to have the sensor identify itself.

NOTE: There can only be one SDI-12 sensor connected in order for the unknown address command to work. The syntax for the unknown address command is

?!

The SDI-12 command for setting the sensor's address is the A command

0An!	Where 0 is the current address of the device, n is the new SDI-12 address (0 to 9, A to Z, a to z).

Note that the command follows the SDI-12 standard beginning with the address and ending with "!".

The sensor will issue a reply message in response to the command if the command was recognized. The message will be the new address n.

As an example, the following command would set the sensor address to 5:

0A5!

The sensor will respond with the new address which is 5.

Subsequently, the address can be set to a different address, 9 for example, by the command:

5A9!

Verifying the Address and Operation

The sensor will respond with an identifying message when it receives the *send identification* command, I. The format of the command is:

aI!	Where a is the address for the sensor.

The sensor will reply with

a12 SUTRON 113-151.0ssssssVvvv	Where:
a	SDI-12 address
12	supports SDI version 1.2 commands
SUTRON	manufacturer SUTRON
113-15	Sutron model number
1.0	hardware revision level
sssssss	sensor serial number
Vvvv	the software revision

If you do not get a reply, check the address setting for the sensor and make sure you use the proper address.

Commands (Overview)

The commands to set up and operate the sensor are those defined by the SDI-12 specifications version 1.0, version 1.1, and version 1.2 plus some extended commands defined by Sutron. Note: **ALL SENSOR COMMANDS ARE UPPER CASE**. All commands start with a single-character address and end in an exclamation point. The address is a single character with values 0 to 9, A to Z, and a to z. Values are entered in the form of a polarity sign (+ or –) followed by up to seven digits, including a decimal point. The commands are in ASCII and all the replies use printable

ASCII characters followed by <CR> <LF>. The case of the letters is important. An "A" is not the same as an "a".

The sensor replies to all SDI commands it supports. If the sensor receives a command it does not support, no reply is made. The reply will have one of three forms:

a0000	where a is the address and the 0000 indicates that there is no further message to send
or	
atttn	where a is the address, ttt is the amount of time, in seconds, the sensor needs to make the measurement or process the command and n is the number of values that can be collected. In this form the sensor will also respond with its address when the data is ready to collect if ttt is not 000. This response is called a service request.
and	
a	
or	
atttnn	where a is the address, ttt is the amount of time, in seconds, the sensor needs to make the measurement or process the command and nn is the number of values that can be collected.

If you issued the *change address* command or the *identify* command described in the previous sections, you already have some experience with using commands. There are other commands available to make measurements, set the type of output units for the measurements, perform special scaling of the measurements, do field calibration, etc. The following sections describe the commands by function.

Making a Measurement

There are two classes of measurement commands which will be referred to as M commands (Measurement Commands) and C commands (Concurrent Measurement Commands). Concurrent measurement commands are new to version 1.2 of the SDI-12 specification. In the original class of "M" measurement commands the data recorder issued the measurement command and then waited for the sensor to complete the measurement before continuing the data collection cycle. Only one sensor could be accessed at a time and a maximum of nine parameters could be returned. With version 1.2 of the specification, concurrent measurements were defined. With a concurrent measurement, the data recorder can request the sensor to take a measurement, determine how long it will be until the sensor has a reading, and then continue on making requests to other sensors on the SDI-12 bus. This way multiple sensors are taking measurements concurrent with each other. Once the measurement time for a sensor has expired the data recorder polls the sensor for the data.

Making a non-concurrent Measurement (M command)

The command to tell the sensor to make a measurement with the original measurement command is:

aM!	where a is the address character, and M is the command to make a measurement

Most data recorders will issue this command and automatically handle the reply to collect data. You can also issue the command yourself. In reply, the sensor will respond with

attt2	acknowledging it is address a and indicating that after ttt seconds are allowed for the measurement, 2 values can be collected.

When the measurement is complete, the sensor responds with a service request

a	where a is the address character

Note that you still do not have any data from the sensor. To request the data after a measurement,

aD0!	where a is the address character and D0 is the command to retrieve measured data. Note: the number zero follows D, not the letter O.

In this case, the sensor will reply with two values in the format:

avu	where a is the address, v is the data value and u indicates the units. Both v and u have the format of a polarity sign (+ or −) followed by up to seven digits, including a decimal point.

The u indicates the units of the measurement. When u is 0, the value has units of feet of water. When u is 1, the units are psi. When u is 9, the units depend on a user entered slope and offset. u can also take on additional values after a field calibration has been performed. The following table summarizes all the values of u.

0 units are feet of water
1 units are psi
2 units are kilopascals
3 units are cm of water
4 units are meters of water
5 units are mm of water
9 units depend on user-entered scale and offset.

If the field calibration offset is non-zero, then one of the following values of u will be returned:

10 units are feet of water with non-zero field calibration offset
11 units are psi with non-zero field calibration offset
12 units are kilopascals with non-zero field calibration offset
13 units are cm of water with non-zero field calibration offset
14 units are meters of water with non-zero field calibration offset
15 units are mm of water with non-zero field calibration offset
19 user units with non-zero field calibration offset
(psi + field calibration offset) ∗ user scale + user offset
set by XE or XS set by XUU set by XUU

If the unit has had its calibration modified at a standards lab other than at Sutron, then the value returned for u will have one hundred (100) added to it. In other words, if the XC command has been utilized to set the calibration scale factor to other than 1 or the calibration offset factor to other than 0 then 100 will be added to the units indicator.

In most cases, you will not set up the recorder to store this units identifier. It is provided in response to the standard measure command to eliminate confusion as to the computation used to determine the final value.

Making a Concurrent Measurement (C command)

The command to tell the sensor to make a concurrent measurement is:

aC!	where a is the address character, and C is the command to make a concurrent measurement

The concurrent measurement command was first defined in version 1.2 of the SDI-12 specification. Therefore the data recorder will have to be SDI-12 version 1.2 or higher compliant before it can be expected to issue this command and automatically handle the reply to collect data. You can also issue the command yourself. In reply, the sensor will respond with

attt02	acknowledging it is address a and indicating that after ttt seconds are allowed for the measurement, 2 values can be collected.

When the measurement is complete, the sensor does NOT issue a service request Note: this is different from the M command.

To request the data after a measurement,

aD0!	where a is the address character and D0 is the command to retrieve measured data. Note: the number zero follows D, not the letter O.

In this case, the sensor will reply with two values in the format:

avu	where a is the address, v is the data value and u indicates the units. Both v and u have the format of a polarity sign (+ or –) followed by up to seven digits, including a decimal point.

The u indicates the units of the measurement. When u is 0, the value has units of feet of water. When u is 1, the units are psi. When u is 9, the units depend on a user entered slope and offset. u can also take on additional values after a field calibration has been performed. The following table summarizes all the values of u.

0 units are feet of water
1 units are psi
2 units are kilopascals
3 units are cm of water
4 units are meters of water
5 units are mm of water
9 units depend on user-entered scale and offset.

If the field calibration offset is non-zero, then one of the following values of u will be returned:

10 units are feet of water with non-zero field calibration offset
11 units are psi with non-zero field calibration offset
12 units are kilopascals with non-zero field calibration offset
13 units are cm of water with non-zero field calibration offset
14 units are meters of water with non-zero field calibration offset
15 units are mm of water with non-zero field calibration offset
19 user units with non-zero field calibration offset
(psi + field calibration offset) ∗ user scale + user offset
set by XE or XS set by XUU set by XUU

If the unit has had its calibration modified at a standards lab other than at Sutron, then the value returned for u will have one hundred (100) added to it. In other words, if the XC command has been utilized to set the calibration scale factor to other than 1 or the calibration offset factor to other than 0 then 100 will be added to the units indicator.

In most cases, you will not set up the recorder to store this units identifier. It is provided in response to the standard measure command to eliminate confusion as to the computation used to come up with the final value.

Other Measurements

The SDI standard allows for other measurement commands such as M1, M2 etc. The sensor supports the following optional measurement commands:

aM1!	measure psi using factory calibration. Do not apply any user scaling, field calibration or offsets. This returns 1 value and the units are fixed to psi.
aM2!	measure temperature (Celsius or Fahrenheit). This returns two values: the temperature and the units. The units will be 0 for Celsius and 1 for Fahrenheit.
aM3!	measure user scale, user offset, field calibration offset. Use this if you want to view the user-entered values that can affect the value returned by the M and C commands.
aM4!	measure calibration lab scale and offset. Use this if you want to view the calibration lab values that can affect the value returned by the M and C commands.
aM5!	Measure the operating mode for the unit.

Remember to issue the aD0! command after the measurement is complete in order to retrieve the data.

Other Concurrent Measurements

The SDI standard allows for other concurrent measurement commands such as C1, C2 etc. The sensor supports the following optional concurrent measurement commands:

aC1!	measure psi using factory calibration. Do not apply any user scaling, field calibration or offsets. This returns 1 value and the units are fixed to psi.
aC2!	measure temperature (Celsius or Fahrenheit). This returns two values: the temperature and the units. The units will be 0 for Celsius and 1 for Fahrenheit.
aC3!	Measure user scale, user offset, field calibration offset. Use this if you want to view the user-entered values that can affect the value returned by the M and C commands.
aC4!	Measure calibration lab scale and offset. Use this if you want to view the calibration lab values that can affect the value returned by the M and C commands.
aC5!	Measure the operating mode for the unit.

Remember to issue the aD0! command after the measurement is complete in order to retrieve the data.

Changing the Units

As noted above, the aM! command can return the pressure in several different units. The selection of the units is made using the XUPcommand:

aXUP+n+d!	where n is one of the selections from the following table and d is the number of digits to the right of the decimal point.

n	Type Units	Comments
0	ft of water	The conversion to feet of water uses the factor 2.3073 ft per psi.
1	psi	pounds per square inch.
2	kPa	kilo-pascals
3	cm of water	The conversion formula is 70.3265 cm per psi.
4	m of water	The conversion formula is 0.703265 m per psi.
5	mm of water	The conversion formula is 703.265 m per psi.
9	user units	The value has units that depend on the values entered using the XUU command.

For example, the command

aXUP+0+2!

will specify the output to be in the default units (Feet of water) with a resolution of 2 decimal places. The second parameter (2 in the example) is optional. If omitted, the resolution is not changed.

Setting User Units

If you want the sensor to read out in units other than feet of water, psi, kPa, cm of water, m of water, or mm of water you will need to use the **XUP** command to set the units to 9, **user units**. When user units are selected, the software will use the equation:

output = psi * scale + offset
where scale and offset are values you can enter into the system.

The XUU command is used to enter the user scale and offset. The format of the command is:

aXUUso!	where s is the signed scale and o is the signed offset.

For example, the following command will set the scale to 70.32 and the offset to 0.0, which are the proper values to convert the psi to cm of water:

aXUU+70.32+0

Similarly, the slope and offset can be set to any values that will produce the desired units.

NOTE: Remember that the XUP command then the XUU command are required for the SENSOR to report in user-defined units.

Field Calibration

The sensor may have a change in the calibration over time. The most common change is a change in sensor zero (value read when the pressure is 0). The sensor has two commands that can be used to adjust for this change in zero. The XE command allows direct setting of an offset which will be added to the measurement to compensate for this drift:

aXEou!	where o is adjustment value with units u. u can have units 0=feet, 1=psi, 2=kPa, 3=cm, 4=m, 5=mm, and 9=user units.

For example, the command:

aXE+0.02+0

would set the offset pressure to 0.02 with units of feet.

The other command used to set the offset is the XS command. This command causes the sensor to make pressure readings and automatically compute a new offset. You can use this command only if you vent the sensor to the atmosphere or have a stable, known pressure on the sensor. The command has the format:

aXS! or aXSdu!	use this form only when the sensor is vented to the atmosphere use this form when the sensor is at a stable, known pressure. The d represents the desired reading and u the units.

For example, after venting the sensor to the atmosphere, the following command would cause a new offset to be computed:

0XS!

If the sensor was under pressure and stable at 4.65 feet, the following command would adjust the offset to ensure the 4.65-foot reading:

0XS+4.65+0!

If the sensor was under pressure and stable at 4.65 psi, the following command would adjust the offset to ensure the 4.65-psi reading:

0XS+4.65+1!

When the sensor is done with the self-calibration, the new offset is stored into memory. A subsequent aD0! command will display this offset in units of psi. The offset can also be displayed using the M3 command. Remember, the units for the displayed offset will be psi regardless of the units you used in the XSdu command.

Configuring the Operating Mode and Averaging Time

Setting the Operating Mode

The user can select the operating mode of the unit. The operating mode that can be enabled is background conversion. If background conversion is enabled, the sensor will keep the transducer continuously powered. Background conversions add about 7 mA to the quiescent power consumption. With background conversions disabled, the quiescent power consumption drops to about 0.25 mA. Due to the increased power consumption, the background conversions should not be enabled unless they are needed.

The form of the Command is:

aXOMm!	Where a is the address character, XOM is the extended command to set the operating mode and m represents the operating mode.

The valid values for m are:

0 Background operation disabled. (Low quiescent power consumption.)

Setting the Averaging Time

The sensor supports user selectable averaging time for SDI-12 readings. The time period in seconds is specified with the aXT+t extended command.

For example, the command

0XT+10!

will set the averaging time to 10 seconds for a sensor at address 0.

Note: The averaging time is not the same as the time till completion of a reading. When the sensor is awakened by the SDI-12 data recorder and a measurement is requested, the sensor calibrates its internal A/D converter before taking the reading. This removes any drift from the analog readings before the pressure measurement is started.

There are two speed regions. If the requested time is less than 1 second then the unit enters a higher speed mode. In the accurate mode (t >1) the noise floor of the sensor is typically 0.0002 feet of water (0.00009 PSI), in the high speed mode it increases to 0.004 feet of water (0.002 PSI). In the accurate mode there is approximately a 3 second overhead involved in the initial calibration before the sensor starts the pressure measurement averaging. With the high speed mode the overhead drops to 0.4 seconds.

Note: It is recommended that a measurement be manually initiated (an M, M1, or M2 command) after issuing the XT command to insure that the new coefficients are flushed through the measurement system. This is particularly true with units operating in the background measurement mode. Depending on when the XT command is issued with respect to the background measurement, there is the possibility that the first reading after issuing the XT command will be incorrect.

5. Command Reference

This section documents the commands supported by the 56-113 sensor. The commands are listed in alphabetical order.

	Command Description	**Command Syntax (command underlined)**	**Sensor response (underlined) "a" represents the single-character address**
	Acknowledge active	a!	a
?	Request Address	?! New in version 1.2 of SDI-12 spec. Also see X? command.	a indicating that the current address is a. **Note**: The sensor should be the only sensor on the SDI-12 bus when this command is given, otherwise there will be a communications collision when all units respond.
Ab	Set SDI-12 address	aAb! b new SDI-12 address Example: 5A9! (set address 5 to address 9, the address was previously set to 5)	b indicating that the new address is b.
C	Request Default Concurrent Pressure Measurement	aC! aD0!	attt02 ttt is the time in seconds until the measurement is ready, 2 is the number of values that can be collected axu where x is the signed pressure value and u is the signed indicator of the units. The units are set by the XUP command.
C1	Request Concurrent Pressure Measurement in psi (factory calibrated value)	aC1! aD0!	attt01 ttt is the time in seconds until the measurement is ready, 1 is the number of values that can be collected. ap where p is the signed pressure value in psi
C2	Request Concurrent Temperature Measurement	aC2! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected atu where t is the temperature and u is the units 0= Celsius and 1=Fahrenheit. Use the XUT command to set the units.

	Command Description	**Command Syntax (command underlined)**	**Sensor response (underlined) "a" represents the single-character address**
C3	Request User Scale, User Offset, and Field Calibration Offset	aC3! aD0!	a00003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected asoc where, s is the user scale and o is the user offset (psi), and c is the field calibration offset (psi).
C4	Request Standards lab Calibration Scale and Offset	aC4! aD0!	a00002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected aso where, s is the scale calibration and o is the offset calibration(psi).
D0	Request Data	aD0! **NOTE:** This command is only issued after a measurement command. It should not be issued until the measurement time has expired or a service request has been received.	av v contains the previously-requested measurement values. Example: 0 + 10.23 + 0 If the above example was received and the previous measurement command was an M, it would indicate that the water level is at 10.23 feet. NOTE: If the address is returned with no data values, this indicates that there is no data available. Either a measurement command was not issued, the command was aborted by sending a new command before the measurement time expired, or a service request was received.
I	Send Identification	aI!	a12 SUTRON 113-151.0ssssssVvvv 12 supports SDI version 1.2 commands SUTRON manufacturer 113-15 model number 1.0 hardware revision level sssssss the sensor serial number Vvvv the software revision

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
M	Request Default Pressure Measurement	aM!	attt2 ttt is the time in seconds until the measurement is ready, 2 is the number of values that can be collected
			a service request
		aD0!	axu where x is the signed pressure value and u is the signed indicator of the units. The units are set by the XUP command.
M1	Request Pressure Measurement in psi (factory calibrated value)	aM1!	attt1 ttt is the time in seconds until the measurement is ready, 1 is the number of values that can be collected.
			a service request
		aD0!	ap where p is the signed pressure value in psi
M2	Request Temperature Measurement	aM2!	attt2 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected
			a service request
		aD0!	atu where t is the temperature and u is the units 0= Celsius and 1=Fahrenheit. Use the XUT command to set the units.
M3	Request User Scale, User Offset, and Field Calibration Offset	aM3!	a0003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected
		aD0!	asoc where, s is the user scale and o is the user offset (psi), and c is the field calibration offset (psi).

	Command Description	**Command Syntax (command underlined)**	**Sensor response (underlined) "a" represents the single-character address**
M4	Request Standards lab Calibration Scale and Offset	aM4! aD0!	a0002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected aso where, s is the scale calibration and o is the offset calibration(psi).
M5	Request operating mode for the unit	aM5! aD0!	a0004 000 is the time in seconds until the measurement is ready and 4 is the number of values that can be collected astrm where, s, t, and r are reserved values, and m is the operating mode.
R0 R1 . . . R9	Request Continuous Measurement Readings	aR0! aR1! . . . aR9!	a Unit only returns its address because it **does not support continuous measurements**.
V	Initiate Verify sequence	aV! aD0!	attt5 indicating that the command will be complete in ttt seconds and 5 values can be collected. a service request arespu where r is the ROM checksum, e is the EEROM checksum, s is the number of resets since power up, p is the number of power ups, and u is the number of unexpected interrupts.
X?	Request unknown address	*X?! This command causes any Sutron 56-113 or ACCUBAR to identify it's address. If you have more than one sensor connected, the result may be garbled.	a Sensor's address.

	Command Description	**Command Syntax (command underlined)**	**Sensor response (underlined) "a" represents the single-character address**
XAD	Set SDI-12 address (non-standard version) see A command for standard version.	aXADnAn! n new SDI-12 address, repeated twice Example: 5XAD9A9! (set address 5 to address 9, the address was previously set to 5)	a0011 no response if addresses do not match **Note:** a D0 command issued to the new address after the XAD command will return the new address.
XE	Set Field Calibration offset	aXExu! where x is the pressure offset u indicates the units of the offset, 0 = feet water, 1 = psi. Example: 0XE-0.05+0 (set offset to -0.05 feet)	a0011 indicating that the command will take 1 second and 1 value can be collected. a service request **Note:** a D0 command issued after the XE command will return the offset in units of psi.
XS	Self-Cal the Field Calibration Offset	aXS! or aXSdu! where d and u are optional. When omitted, the sensor is assumed to be vented to the atmosphere. When supplied, d is the desired reading for the sensor and in the units indicated by u. The sensor will make a measurement and adjust the field offset to ensure the reading matches the value entered. Example: 0XS! (sensor is vented, adjust sensor to read 0) Example: 0XS+7.87+0 (sensor is at 7.87 feet, adjust offset to ensure this reading)	attt1 where ttt indicates the command will be complete in ttt seconds and 1 indicates one value can be collected. **Note:** a D0 command issued after XS is complete will display the new offset in units of psi. The offset can also be displayed using the M3 command.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
XT	Set Averaging Time	aXT+t! t = averaging time in seconds (0 to 240 seconds) Example: 0XT+10! (sets the averaging time to 10 seconds)	a0011 indicating the command will be complete in 1 second and 1 value can be collected **Note:** a D0 command issued after the XT will return the number of samples to be averaged during the selected time.
XUP	Set pressure units	aXUP+n+d! n = 0 feet water n = 1 psi n = 2 kPa n = 3 cm water n = 4 m of water n = 5 mm water n = 9 user units d = number of places right of the decimal (optional parameter) Example: 0XUP+9+2! select user units with 2 right digits--(make sure you use XUU command to set the scale and offset for the desired user units)	a0012 indicating the command will be complete in 1 second and 2 values can be collected **Note:** a D0 command issued after the XUP will return the value of the units that are selected and the number of digits right of the decimal point.
XUT	Set temperature units	aXUTn! n = 0 for Celsius, n = 1 for Fahrenheit Example: 0XUT1! (set temperature units to F)	a0011 indicating the command will take 1 second to complete and 1 value can be collected. **Note:** a D0 command issued after the XUT will return the value of the units that are selected.
XUU	Set User Units	aXUUso! where s is the pressure scale factor and o is the offset, User output = (psi)*scale + offset Example: 0XUU+27.63+0 (27.63 inches per psi)	a0012 **Note:** a D0 command issued after XUU will return the scale and offset. **Note**: a scale of 0 is invalid. **Note:** Be sure that the units of pressure (XUP) are set to user units (9).

6. Installation

Most installations either suspend the submersible transducer in a perforated 1½" or 2" PVC instrumentation stilling well or attach the transducer (using the optional M NPT fitting) to a rigid conduit.

In all installations care should be taken to ensure that no damage occurs to the cable as cable damage represents one of the most frequent causes of transducer failure.

Care and Handling

The submersible transducers are designed for rugged use, but they need protection from over pressure and sharp impact. When lowing the transducer into a liquid, penetrate the surface slowly and only to the depth necessary. Avoid dropping the unit from above the surface. Clean transducers by rinsing them in a mild detergent. Direct probing of the diaphragm or attempts to remove protective screens can damage the sensor.

Bending of Cable

The polyurethane jacketed cable is quite flexible. Care needs to be taken to ensure that when bending the cable to suit your installation you do not crimp the vent tube inside the cable. The smallest bend radius of the cable is 1 inch.

Cable Compression

Many users require a compression fitting to secure the polyurethane jacketed cable as it enters a junction box. Approximately 15 ft-lbs of force can be applied without damaging the cable or pinching the vent tube.

Securing Submersible Cable

Installers often use cable hangers (Chinese finger grips) that are typically used for hanging electrical cables and are readily available from most electrical supply stores. The cable hanger slides onto the cable from the bare wire end. The cable hanger can be positioned anywhere on the underwater cable by pushing the ends together. Once positioned, the cable hanger expands and provides a snug grip on the underwater cable.

When mounting the transducer in a well casing, the cable hanger can be secured to a hook on the well plate or an eyebolt may be attached to the side of the well casing. The cable hanger loop is then secured to the eyebolt by using any number of types of fasteners.

A similar technique can be used when working in stilling wells for surface water level measurement. In this case the loop end of the cable hanger can be attached directly to a screw or bolt bored into the stilling well shelf.

In cases where the sensor is hanging vertically with the cable fully extended (not looped), it is recommended to tie the kevlar strength member (yellow braid) off to the anchor point.

Moisture Protection

A vent filter and vapor trap is supplied with each submersible pressure transducer to ensure reliable operation and long life. The replaceable vent tube dehumidifier protects sensitive electronic components from mildew, corrosion, rust, and prevents the formation of a liquid column in the vent tube, which will affect calibration.

The dehumidifier connects to the vent tube via a short section of flexible tube. The acrylic drying tube is 6 inches in length and ¾ inches in diameter. Inserted in each pull-off molded polypropylene drying tube end cap is a 20 micron polypropylene filter.

The drying tube is filled with 30 grams of indicating desiccant (drying agent). The maximum flow rate through the drying tube is 300 cubic centimeters per minute, more than sufficient to allow the transducer to respond to barometric changes. As air passes through he drying tube, moisture is absorbed by the desiccant. The desiccant changes from blue to a rose red as its drying capacity becomes diminished.

NOTE: The dehumidifier has an endcap installed when shipped from the factory. This ensures that the desiccant does not become saturated during storage. Upon installation, this vent cap should be removed to allow for barometric compensation of the pressure readings.

A new 5100-0452-1 dehumidifier can be installed by unscrewing the old one from the tube and screwing on the new one.

7. Calibration

The sensors under go a rigorous screening and testing at the factory before they are shipped to ensure that they meet their accuracy specifications over temperature. Any drift in the zero of the unit can be easily checked by exposing the unit to atmosphere and performing a measurement. Any drift can be nulled out via the XS command. Note: The sensor is very sensitive. Sensor orientation can affect the zero pressure readings by up to 0.005 PSI. Perform any calibration with the sensor in the same orientation that it will be utilized.

Factory Calibration

The initial factory calibration typically includes pressure and temperature points that cover the complete temperature range and cover the complete pressure range. This ensures that the sensor meets the specifications over the complete pressure and temperature range. Sensors can be sent back to the factory for a complete calibration over temperature. Contact Sutron Customer service for more details on this service.

Metrology Lab Calibration

The sensor does have the provision for a calibration to be performed by a Metrology Lab. The calibration coefficients that can be entered by a metrology lab are a scale and an offset parameter. There is not a provision for any temperature dependent parameters. Most metrology labs would not have the capabilities to provide a calibration over temperature and pressure. To accurately calibrate a sensor requires a reference accuracy on the order of 0.01% of the Full Scale range of the sensor.

To collect data for calibration of the sensor, the M1 command should be utilize. This will ensure that field offset or old calibration coefficients do not affect the accuracy of the data collected. The command that is utilized to enter the Metrology Lab Coefficients is:

aXCosc!	where a is the address character, XC is the extended command to set the calibration coefficients, o is the offset in PSI, s is the scale factor, and c is the checksum.

The Checksum is the 8 bit sum of the 7 bit ASCII characters (parity is striped) from and including the address character through the last character of the scale factor. It does not include the checksum string nor its delimiting polarity sign. The checksum is transmitted as an ASCII string. That means that if the 8-bit sum is 236 then the value of c is +236. The command to set the offset of the unit at address 0 to 0.0000 and the scale factor to 1.0000 would be:

0XC+0+1+130!

The calibration coefficients affect the output of the M and C commands. This command does not affect the output of the M1 or C1 command. The data output by the M and C command is computed from the following equation:

Pressure = unit's offset + unit's scale * (field offset + calibration scale *(press. in PSI - calibration offset))

where:

pressure in PSI is the factory calibration pressure as returned by the M1 command.
calibration offset is entered by the XC command
calibration scale is entered by the XC command
field offset is entered by the XE or XS commands
unit's scale and unit's offset are set by the combination of the XUP and XUU commands.

Note: Calibration scale and calibration offset can be determined via the M4 command.
Note: The current value of field offset, user units offset, and user units scale can be determined via the M3 command.

8. Troubleshooting and Maintenance

Troubleshooting

The following checklist will help in troubleshooting problems:

Problem	Possible Cause
No data	Faulty wiring -- check all wiring and terminations
	No power -- check fuse in the data recorder and power at sensor. There is no fuse in the sensor itself.
	Wrong address requested -- make sure the data recorder is set up to request data at the proper address
	Wrong address set in sensor -- use the address query (?!) command to make sure the sensor is responding to the proper address. The Identify command (aI!) can be used to verify the sensor responding to a specific address.
	Command or address is wrong case -- all SDI-12 commands are capital letters, make sure address is proper case and commands are upper case.
	With RS-485, make sure that the data lines are not reversed.
Garbled data	Multiple sensors set to the same address -- check address settings of all SDI sensors. Remove all other sensors from the recorder and add them one at a time. Communication is defined to be 1200, E, 7, 1.
	Command issued to a wild card address (* or ?). Remove all other sensors from the recorder and try again.
Erroneous data	Wrong units selected -- use the M command and look at the units field. Verify that the desired units are selected.
	Erroneous offset entered -- display the field calibration offset using the M3 command and verify it. Re-calibrate the offset.
	Erroneous user scale and offset entered -- display the user scale and offset using the M3 command and verify.

Additional Troubleshooting commands

Measure Break detect time

The SDI-12 specification requires that all sensors ignore breaks less than 6.5mS and states that they must detect breaks that are at least 12mS in length. There is a command for the unit to measure its break detect time.

aXB!	where a is the address character, XB is the extended command to measure the break detect time. Returns: a0012 indicating that it will have 2 values ready in 1 second.
aD0!	Returns: adr where d is the break detect time and r is the break reset time

The break detect time should be between 6.5 and 12 milliseconds and the break reset time should be less than 1 millisecond. For the best results disable any automatic measurement commands in the data recorder when using the XB command.

Maintenance

Typical maintenance for the sensor consists of checking the wiring to make sure it is not corroded or frayed, checking the tubing to make sure it is intact and leak-free, checking the desiccant (needs to be replaced if it is rose red), and checking or setting the field calibration offset.

Maintenance should be performed at least every 6 months in order to insure that the sensor meets the accuracy specifications.

The offset can be checked by exposing the sensor to the atmosphere and taking a reading from the sensor. Note: Sensor orientation should be the same as it is when in use.

If the sensor has been subjected to more than its maximum pressure, the offset of the unit should be checked as described above.

Cleaning

Clean transducers by rinsing them in a mild detergent. Direct probing of the diaphragm or attempts to remove protective screens can damage the sensor.

9. Specifications for 56-113 SDI-12 Sensor

Body Dimensions	1.1” Diameter 28 mm Diameter
Range	**15, 25, 30, 50 psi**
Proof Pressure	2 times rated pressure
Burst Pressure	3 times rated pressure
	Operating Temp Range-10°C to +50°C
Accuracy	0.1% of Full Scale (includes non-linearity, hysteresis, non-repeatability and thermal errors
Resolution (default)	0.001psi (0.001 ft of water) - user selectable
Supply Voltage	+8 to +28VDC (reverse polarity protected)
Current Draw	
SDI-12 (active)	7mA typ., 12 mA max
Quiescent (Continuous update)	7mA typ.
Quiescent (Background disabled)	0.25mA typ.
Interfaces Supported	
	SDI-12 and SDI-12 protocol and data rates over RS-485
Units Supported	ft H_2O, cm H_2O, m H_2O, mm H_2O, psi, kPa, and user defined
Optional Pressure Connection	Ported nosepiece
Cable	Polyurethane jacketed shielded cable with vent tube and Kevlar tension members.
Wetted Materials	316 SS, Delrin, Nylon, TPE, Polyurethane, and N-Buna

Accessories

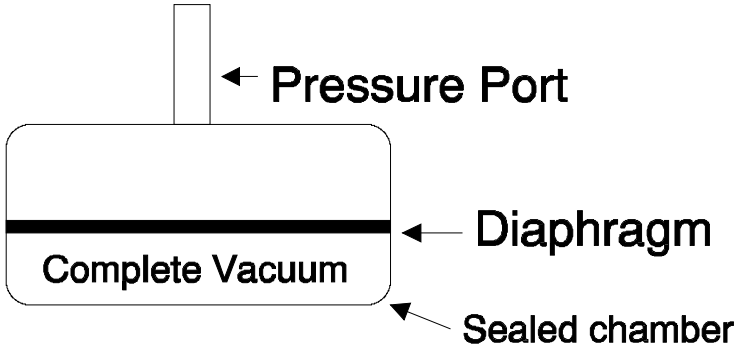
5100-0452-1 Replacement Desiccant Dehumidifier

Specifications subject to change without notice

TYPES OF PRESSURE MEASUREMENTS

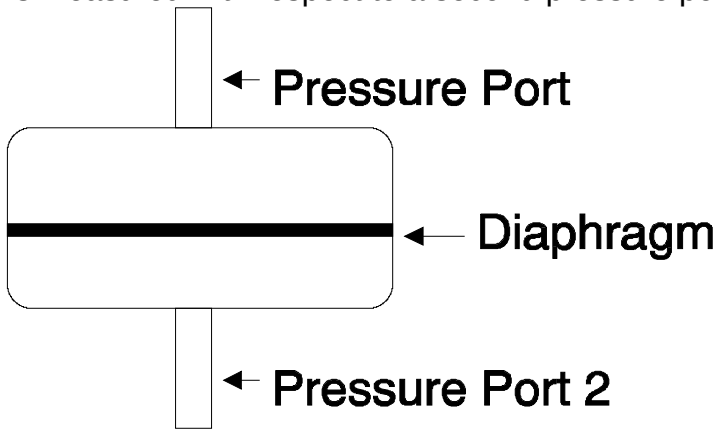
ABSOLUTE (PSIA)

Pressure is measured with respect to an absolute vacuum. This is how barometric pressure is measured.



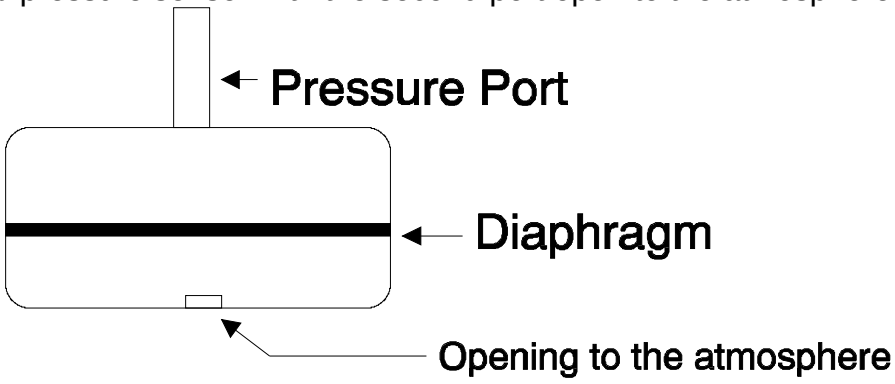
DIFFERENTIAL (PSID)

Pressure is measured with respect to a second pressure port.



GAUGE (PSIG)

Pressure is measured with respect to atmospheric pressure. Same as a differential pressure sensor with the second port open to the atmosphere.



PRESSURE UNITS

PSIG or PSI pounds per square inch
feet of water (USGS conversion factor is 2.3073 * PSI)
Meters of Water conversion based on density at 10°C

PRESSURE EQUIVALENTS

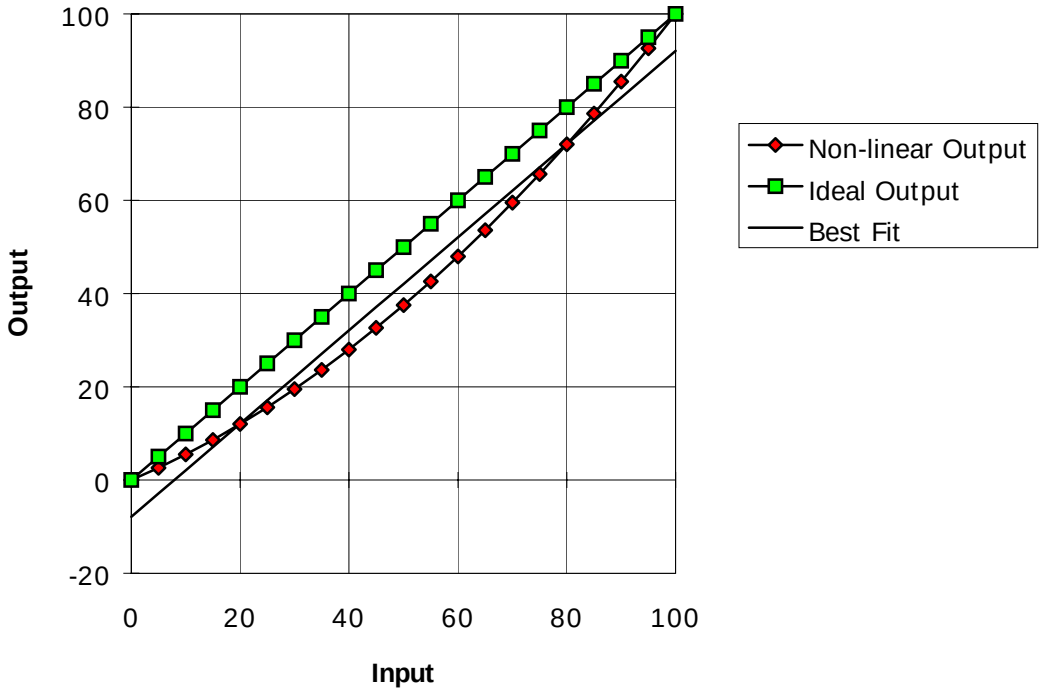
PSI	feet of Water	Meters of Water	kPa
0	0.000	0.000	0.000
5	11.537	3.516	34.474
10	23.073	7.033	68.948
15	34.610	10.549	103.421
20	46.146	14.065	137.895
22	50.761	15.472	151.685
30	69.219	21.098	206.843
35	80.756	24.614	241.317
50	115.365	35.163	344.738
100	230.730	70.327	689.476

ERROR DEFINITIONS AND EXAMPLES

Linearity:

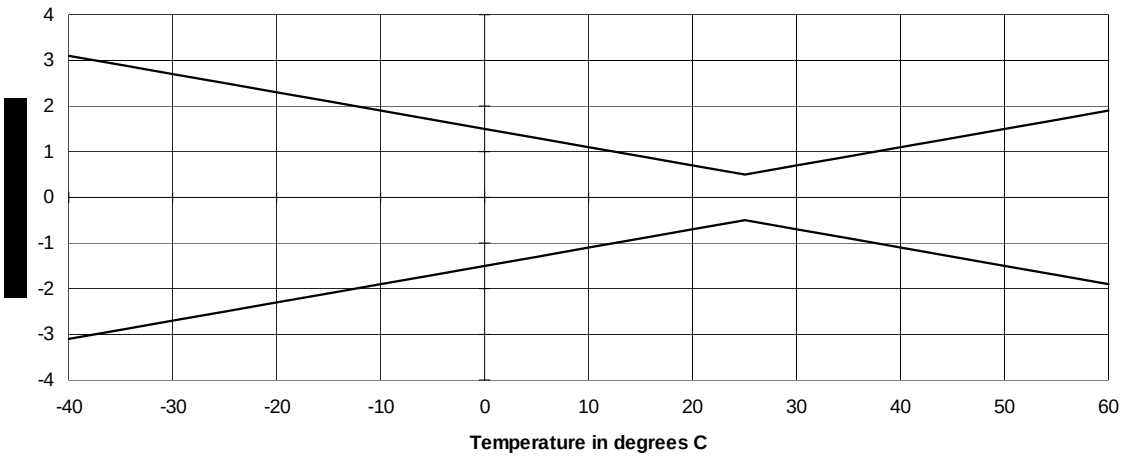
Linearity error is the deviation of the output from a straight line. Many transducers for measuring physical phenomena have outputs which do not vary linearly with the phenomena being measured. Sometimes the deviation from linear is slight and is accepted as part of the error of the device, in other cases manufacturers attempt to "linearize" the output. Usually when this done through an analog means, there will be a residual non-linearity, i.e., the non-linearity is not completely removed. The following non-linearity graph illustrates why a two point calibration (zero and full scale) is many times insufficient and ensures that the maximum error is achieved. A best fit straight line decreases the maximum error by ensuring that the errors fall evenly on both sides.

Example of Linearity Error



Temperature coefficient -- This is made up of two components, the temperature coefficient of the offset and the temperature coefficient of the slope. These can be referred to as thermal shifts, temperature dependence, and other names. The offset is sometimes referred to as zero. The slope is sometimes referred to as span, sensitivity, or scale factor. The following graph illustrates why the temperature coefficient is an important specification for remote equipment. In an indoor environment a competitor's barometer is about a 0.5 mB instrument. Over the operating temperature range of Sutron equipment, it degrades to a $\pm$3 mB instrument.

Example Temperature error of a Competitor's 0.5 mB "Accurate" Barometer



Hysteresis - This is a measure of deviation in the output when passing through an input point from two different directions. If a pressure transducer has zero pressure applied, then 10 PSI, then 22 PSI, then 10 PSI, the difference between the two 10 PSI readings would be a measure of the pressure hysteresis of the transducer. Pressure transducers can also have temperature hysteresis errors. Sometimes hysteresis is lumped in with other non-repeatability errors.

ACCURACY - Accuracy is a measure of how closely the sensor's output matches the "true" value of the parameter being sensed.

PRECISION - Precision is a measure of the repeatability of the sensor. It will most always be better than the accuracy of the sensor.

RESOLUTION - The resolution of a sensor is the smallest change in the input that is reflected in the output. For digital sensors it also refers to the smallest increment of the output. This may be greater than or less than the sensor's resolution with respect to its input. Greater resolution does not imply greater accuracy. Resolution and Accuracy are two independent variables. The advantage of resolution in excess of accuracy is that changes in the input parameter can be detected and tracked.

Appendix B -- SDI-12 with the Sutron 8200, 8200A, and 8210

Entering Extended Commands for Configuration Purposes

The Sutron 8200 family of data recorders supports the SDI-12 transparent mode. This allows the user to issue commands to the sensor via the data recorder.

From the Front Panel

Go down the menu tree till you come to:
INSPECT SYSTEM
Go right and then down until you come to:
Enter SDI-12 Cmd
Press SET and then the unit will prompt you with:
Cmd:

At this point enter the command you wish issued over the SDI-12 bus. The command is entered via the arrow keys. Remember that the address is always the first character of the command. The 8200/8210 will append the ! to the end of the command for you. When you have finished entering the command press SET and the 8200/8210 will send the command and display the response to the command.

From a PC connected to the RS-232 port

From the main menu select:
I - Inspect System
From the inspect system menu select:
E - Enter SDI-12 Commands

At this point you will be prompted to enter the command. Enter the command beginning with the unit's address and ending with an exclamation point (!). Do not forget the exclamation point. After entering the command, press ENTER to send the command out over the SDI-12 bus. The 8200/8210 will then display the response to the command.

Logging data from the M1 or M2 commands or from addresses above 9

Beginning with version 3.3 of the software for the 8200 family, SDI-12 sensors can be renamed to allow any SDI-12 address or measurement number to be specified. To remap an SDI-12 sensor from its default address and parameter number you can use the form: SENSOR7a_p where SENSOR7 is the name you wish to give the sensor (up to 7 characters), **a** is the address of the sensor "0" through "~", and **p** is the parameter number "1" through "9".

EXAMPLE:
airtempA_1
would read parameter 1 from the SDI-12 device at address "A".

If you wish to use a measurement command other than the default aM!, then you can use the form: SENS5a_pMm where SENS5 is the name you wish to give the sensor (up to 5 characters), a is the address of the sensor "0" through "~", p is the parameter number "1" through "9", and m is the measurement command to use.

EXAMPLE:
stage0_1M3
would use measurement command M3 to read parameter 1 from the SDI-12 device at address 0.

Another feature is that you can define multiple sensors for the same SDI-12 parameter which will allow you to define separate slopes, offsets, and other processing for the same parameter.

Logging Temperature data from the sensor

Temperature data is the first parameter the sensor returns from the M2 command. Unless the units of temperature have been changed from the factory defaults, the sensor will return the temperature in degrees C. To log the internal temperature of a sensor that has been installed at address 5, the following command must be issued:

5M2!

With the 8200 family the logged parameter came be named to help identify the data on future visits or upon data retrieval. To issue the 5M2! command we are limited to a 5 character name. If "temp" is chosen as the identifying name then the sensor should be named:

temp5_1M2

This name indicates that the M2 command should be issued to address 5 and the first parameter returned should be logged.

Appendix C -- Sutron Customer Service Policy

CUSTOMER SERVICE POLICY

Customer service often begins after the sale, usually when the customer has a question or problem. At Sutron we are dedicated to providing unmatched Customer service before and after the sale.

Sutron Customer Service representatives routinely handle a wide variety of questions every day. Do you have a sensor that you are not sure how to interface? Are you using a Sutron sensor with someone else's data logger and are not sure how to connect it? Which telemetry options would be the most economical, yet still provide you with the quality of data that you need?

We encourage customers to take advantage of our years of experience with equipment, systems, and services. Our Customer Service representatives are electronic technicians with field and applications experience, not just someone with a technical background. Sutron can answer most sensor or interface questions on the first call. If Sutron cannot quickly answer a question on an interface, we will work with the customer to find a solution. The solution may involve sending in the sensor for close examination by Sutron's engineers.

Sometimes a customer's problem is application specific. Although Customer Service prides itself on handling 95% of application related questions over the phone, we maintain constant contact with our Integrated Systems Division. When a customer needs an engineer to back him up, we have Computer/Electrical Engineers, as well as Hydrologist/Water resources, and Civil Engineering Services.

Of course not all problems can be fixed over the telephone. Sometimes a customer needs someone on-site who can identify site related problems or troubleshoot a telemetry network. Sutron is happy to provide these services at reasonable cost.

Training is an important part of Sutron Customer Service philosophy. Without the proper training our customers cannot take advantage of the benefits and advantages that our equipment provide. We often provide on-site introductory training at your facility for no charge. We also conduct in-house or on-site format training classes for those customers who desire it. Refer to the Services Section of the Sutron catalog for classes and call Sutron to schedule your training requirements.