ACCUBUBBLE

SELF-CONTAINED BUBBLER SYSTEM

MODEL 5600-0131-1

MODELS 5600-0131-3, -4, -5

OPERATIONS & MAINTENANCE MANUAL

Part No. 8800-1102
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1. Introduction

The 5600-0131 ACCUBUBBLE™ Self Contained Bubbler System utilizes a solid-state pressure transducer suitable for data collection and monitoring applications. The ACCUBUBBLE™ system has been designed with the following features to operate in a wide range of applications:

High silting immunity	Purges before every measurement. Prevents silt from building up over the orifice line.
low power consumption	average power when taking measurements every 15 minutes via SDI-12 is 20 mA.
high accuracy	0.0044 psi for pressures less than 4.4 psi, 0.1% of reading for pressures 4.4 to 22 psi. (0.01 ft. up to 10 ft. of water, 0.1% of reading 10 to 50 feet of water)
excellent stability	Measurement error increases by no more than 0.02% of 22 psi or 0.1% of the actual pressure, whichever is greater, for a period of 6 months.
full temperature compensation	the accuracy is maintained over the temperature range of -25° to +60°C.
selectable units	the sensor can be configured to output the data in psi, feet of water, kilopascals, centimeters 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 16 VDC

2. Initial Setup Guide

A few quick comments first. The AccuBubble utilizes the SDI-12 command syntax. This means that all commands are case sensitive and are immediately responded to if recognized. If they are not recognized, there is no response. The first character of every command is the address of the unit. By default this is 0 (zero). However, if the address is set to any alpha/numeric value other than 0, then that alpha/numeric value must be used. The first character of every response is also the address character. If the command is one which requires time to process, i.e., taking a measurement, then the AccuBubble responds immediately with the time required perform the measurement and with the number of values to be returned. For example, in response to a 0XPC! Command, the AccuBubble (at address 0) will respond with 02553. The first character is the address, the next three are the number of seconds until the measurement is ready, 255, and the last character is the number of parameters that will be returned, 3. At this point the user should wait the 255 seconds before entering the 0D0! Command. If the AccuBubble finishes the command in less than 255 seconds, it will output a service request, which just consists of its address, 0. Once the service request is received, the user can request the data with the 0D0! Command.

1. Steps 2-11 must be completed with each initial installation and anytime the orifice line has been removed from the AccuBubble. (Though not required, it is a good practice to check the commands to insure your specific setup is correct.)

2. With the orifice line attached to the AccuBubble and deployed in the water, enter the command 0XPR+60+30! (the ! is not needed if entering commands from the front panel of an 8200/8210 or 8400). This will purge the line for 60 seconds, and then wait 30 seconds before returning a value. This is done to clear the line of any water and refuge after initial orifice line installation, or after the orifice line has been open at the AccuBubble.

3. With the orifice line in water, enter the command 0XPC! (the ! is not needed if entering commands from the front panel). The unit will respond with 02553. Where 0 is the address, 255 is time in seconds before value is returned and 3 is how many values will be returned.

4. The pump sequence is a long run of 10 or more seconds, a long wait, a short pump run of pump_on length (factory default of 0.1 second), a wait, and then 0.1 second run of the pump. At this point the command is finished and the unit will respond with a 0. The 0 will not be displayed if using the 8200/8210 Inspect System/Enter SDI Commands. The total time required for this characterization is dependent upon orifice line length. It may not take the 4 ¼ minutes requested. After you see the 0, type 0D0!. If this command is used in the 8200/8210 Inspect System/Enter SDI Command, you must wait for 4 ¼ minutes or the three pump runs to issue the 0D0! Command. The unit will respond with some thing like 0+10+25+8.2, where 10 is the purge on time, 25 is the purge off time, and 8.2 is the pump off time used for averaging. IMPORTANT NOTE FOR -1 BUBBLERS: WHATEVER THE RETURNED VALUE IS IN STEP 3 (0XPC! Command), 0D0!, WRITE IT DOWN AND ENTER IT INTO THE ACCUBUBBLE IN STEP 5! For -3 and -4 Bubblers, if any of the numbers returned are negative, then the characterization is questionable and should be repeated (go back to step 3).

5. **Note: This step is only required for -1 units running software prior to version V2.0.** Enter the command 0XPT+10+25! (the ! is not needed if entering commands from the front panel of an 8200/8210 or 8400). The unit will respond with 00015. Enter the command 0D0!. You should see the values you just entered. Now the timing parameters are set.

6. To set the User Units of Pressure, enter 0XUP+0+2! (This will set the bubbler up to respond in Feet of water with 2 right digits). If meters of water with mm resolution is desired, the Command should be 0XUP+4+3!

7. Issue the 0XE+0! command to zero any offset that had previously been entered into the unit.

8. Once this is all done, enter 0M!. The bubbler pump will come on for the purge on time, then wait the purge off time. You will see a response like 00352; this means that address 0 will be ready in 035 seconds with 2 available values.

9. Using the example above, once the "035" seconds have elapsed, enter 0D0! To get the data.

10. To ensure that the system is leak free, enter 0XPL! Command. Wait the specified time, or until a service request is received, then issue a 0D0! Command. The number returned will be the amount the water level appeared to change in 30 seconds, i.e., the leak rate of the system. This should ideally be 0. If it is considerably larger than 0.01 ft, then either the water level changed or there is a leak in the tubing or fittings. For a bubbler, any bubbler, to work correctly, the system needs to be leak free. If the system has a leak, it must be repaired before accurate readings will be obtained.

11. Once the setup of the system has been completed, to take readings, issue the 0M! command, wait the specified time, then issue the 0D0! Command. Repeat this step for more readings.

12. The AccuBubble also supports entering an offset into the unit. For example, assume that the end of the office tube was installed 2.36 feet above a datum. Entering 0XE+2.36+0! will set the offset of 2.36 feet into the unit. The 2.36 is the adjustment you want to have added to the reading and 0 is the User Units of pressure you are using (0 is feet of water).

3. Cabling

5600-0131-1 Units with Circular Connectors

The 5600-0131-1 ACCUBUBBLE needs two cable connections. The first is to a 12 VDC 3 A power source to power the pump. The second cable is for the SDI-12 connection to a data recorder. The three wire SDI-12 cable does contain 12V and Ground. These are needed for the internal SDI-12 sensor, but should NOT be used to power the pump. The 12 VDC power supply for the pump needs to share a common ground with the SDI-12 data recorder collecting data from the AccuBubble.

2 Pin Circular Connector

The –1 ACCUBUBBLE comes with a 2 pin circular connector on it. The wiring of the connector is as follows:

Name	Circular Pin	Notes * The ACCUBUBBLE needs a 3 A 12 VDC supply, do not use the SDI-12 power line or SW 12 to power the unit.
Battery	A	Red wire (8 to 16VDC)
Ground	B	Black wire

SDI-12 Circular Connector

The following table contains pin descriptions for the circular connector.

Description	Circular connector	Notes
SDI Data	A	SDI-12 Data line
Battery	B	(8 to 28VDC)
Ground	C	
No connection	D	

The circular connector is a MS3102A-14S-2P. A mating connector for it is a MS3106A-14S-2S. It is also recommended that a MS3057-6AC cable clamp with a MS3420-6 bushing be used with the mating connector to provide strain relief.

NOTE: Sutron has 2 SDI-12 cables which are optional.

- Part Number 6411-1300-1 has an MS3106A-14S-2S circular connector on one end and a DB-9 (RS232 Type) connector on the other end. This cable allows for a simple connection to Sutron 8200 dataloggers
- Part Number 6411-1299-1 has an MS3106A-14S-2S circular connector on one end and 3 solder tinned wires on the other end. This cable allows for easy connection to Sutron 8210 and 8400 dataloggers. On this cable the White wire is the SDI-12 Data line, the Red wire is the Supply Voltage line (8 to 28 VDC), the Black wire is ground.

5600-0131-3 and –4 and -5 Models with Terminal Strip

The following table contains pin descriptions for the terminal block.

Description	Terminal Block	Notes
Pump Power IN Positive	1	+8 to +16 VDC (3 Amp)
Pump Power IN Ground	2	
Pressure Sensor Pwr In +	3	+8 to +28 VDC
Pressure Sensor Pwr In -	4	
SDI-12 Data	5	
Analog output (A+)	6	0-5 VDC (only on –4)
Analog ground (A-)	7	Also can be used as ground for Quad. Out
Quadrature out Phase A	8	Phase A will lead Phase B for positive change (only on –3)
Quadrature out Phase B	9	Phase A leads by going to 5V before Phase B (only on –3)

Note: Only the 5600-0131-3 supports Quadrature and only the 5600-0131-4 supports analog out. 5600-0131-5 supports SDI-12 output only.

The ACCUBUBBLE needs two power connections. The first is to a 12 VDC 3 A power source to power the pump. The second is to power the pressure sensor. It is recommended that the pressure sensor power be in common with the device reading the sensor. If the sensor is being read by an SDI-12 data recorder, then the sensor power would come from the SDI-12 data recorder (SDI-12 defines a three wire connection of data, 12V, and Ground). The SDI-12 12V should be used for the internal SDI-12 sensor, but should NOT be used to power the pump. The 12 VDC power supply for the pump needs to share a common ground with the SDI-12 data recorder collecting data from the AccuBubble.

SDI-12 Data Recorder Connection

Description	Terminal Block	Notes
Pump Power IN Positive	**1**	**+8 to +16 VDC (3 Amp)**
Pump Power IN Ground	**2**	
Sensor Pwr In +	**3**	**SDI-12 Power line**
Sensor Pwr In -	**4**	**SDI-12 Ground Line**
SDI-12 Data	**5**	**SDI-12 Data Line**
Analog output (A+)	6	
Analog ground (A-)	7	
Quadrature out Phase A	8	
Quadrature out Phase B	9	

Note: Connection to an SDI-12 data recorder does NOT preclude an additional Quadrature (-3) or Analog (-4) output connection. The 5600-0131-5 supports SDI-12 output only.

Quadrature Data Recorder Connection (Shaft Encoder Replacement) –3 only

Description	Terminal Block	Notes
Pump Power IN Positive	**1**	**+8 to +16 VDC (3 Amp)**
Pump Power IN Ground	**2**	
Sensor Pwr In +	**3**	**8-28 VDC Power connection to data recorder**
Sensor Pwr In -	**4**	**Ground Connection to Data Recorder**
SDI-12 Data	5	
Analog output (A+)	6	
Analog ground (A-)	7	
Quadrature out Phase A	**8**	**Phase A will lead Phase B for positive change (only on –3)**
Quadrature out Phase B	**9**	**Phase A leads by going to 5V before Phase B (only on –3)**

Note: The XQS command should be issued to the unit to correctly configure the quadrature output step size and rate. The XQC command can be used to synchronize the output with the quadrature recording device. The XOM command specifies whether the Quadrature output should be updated independently of SDI-12.

Analog Display or Data Recorder Connection (-4 only)

Description	Terminal Block	Notes
Pump Power IN Positive	**1**	**+8 to +16 VDC (3 Amp)**
Pump Power IN Ground	**2**	
Sensor Pwr In +	**3**	**8-28 VDC Power connection to data recorder**
Sensor Pwr In -	**4**	**Ground Connection to Data Recorder**
SDI-12 Data	5	
Analog output (A+)	**6**	**0-5 VDC (only on –4)**
Analog ground (A-)	**7**	**Output ground reference**
Quadrature out Phase A	8	
Quadrature out Phase B	9	

Note: The XAR command command can be utilized to customize the analog output range. The XOM command specifies whether the Analog output should be updated independently of SDI-12.

4. Setup and Operation

Introduction

This section will familiarize you with the steps and commands needed to alter the setup of the ACCUBUBBLE. The ACCUBUBBLE System is set to address 0 (the factory default) and the output is set to units of feet of water.

To issue commands to the ACCUBUBBLE 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.

Setting the Address

If you are using the ACCUBUBBLE connected with other SDI-12 devices, you will need to change the ACCUBUBBLE 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

In order to set the address by SDI-12 command, the DIP switch address must be set to 0 (Switches 1,2,3,4 OFF). This is the factory setting for the switches. Also, no other SDI-12 devices connected to the system should be set to address 0 or to the desired ACCUBUBBLE address. Hint: If you do not know the address of a particular ACCUBUBBLE, use the unknown address command to have the ACCUBUBBLE identify itself.

NOTE: There can only be one ACCUBUBBLE connected in order for the unknown address command to work. The syntax for the unknown address command or address query command is:

?!

The SDI-12 command for setting the ACCUBUBBLE's address is the XAD command

0XADnAn!	where 0 is the current address of the device, n is the new SDI-12 address and n is the same address repeated (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 ACCUBUBBLE will issue a reply message in response to the command if the command was recognized. The message will be 00011 which is explained in the Command Reference. If you do not get this message, try the command again and check the switches (Unit must be set to address 0 since that is the address this command trying to change from). Note: The ACCUBUBBLE will not respond if the command is invalid, i.e., there is a typing mistake in the command or the two copies of the new address do not match.

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

0XAD5A5!

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

5XAD9A9!

Beginning with version 1.9 the ACCUBUBBLE also supports an alternate version of the set Address command as specified in SDI-12 standard version 1.2.

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).

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

0A5!

The ACCUBUBBLE 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 ACCUBUBBLE 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 ACCUBUBBLE.

The ACCUBUBBLE will reply with

a13 SUTRON 0131-31.0sssssssVvvv	Where:
a	SDI-12 address
13	supports SDI version 1.3 commands
SUTRON	manufacturer SUTRON
0131-3	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 ACCUBUBBLE and make sure you use the proper address for the sensor.

Commands (Overview)

The commands to set up and operate the ACCUBUBBLE are those defined by the SDI-12 specifications version 1.0, version 1.1, version 1.2, and version 1.3 plus some extended commands defined by Sutron. 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".
Note: Some dataloggers, such as the Sutron 8400, enter the exclamation point automatically.
Note: ALL ACCUBUBBLE COMMANDS ARE UPPER CASE

The ACCUBUBBLE replies to all SDI-12 commands it supports. If the ACCUBUBBLE receives a command it does not support, no reply is made. The reply will have one of two forms:

a0000	where a is the address and the 0000 indicates that there is no further message to send
or	
atttn and a	where a is the address, ttt is the amount of time, in seconds, the ACCUBUBBLE 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.

If you issued the *change address* command or the *identify* command described in the previous sections, you already have some experience with using ACCUBUBBLE 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 four classes of measurement commands which will be referred to as M commands (Measurement Commands), C commands (Concurrent Measurement Commands), MC commands (Measurement commands with CRC-16), and CC commands (Concurrent Measurement Commands with CRC-16). Concurrent measurement commands are new to version 1.2 of the SDI-12 specification. The commands with CRC-16 are new to version 1.3 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. The CRC-16 commands that were added in version 1.3 of the specification add a 16 bit cyclic redundancy check (CRC-16) to the returned data values. This provides an additional means for the data recorder to ensure that the collected data has not been corrupted. Software support for SDI-12 version 1.3 was added in software revision V2.0.

Selecting a measurement command class

Always supported

The first requirement is that the data recorder support the command. All SDI-12 data recorders support the non-concurrent measurement M command. With the M command the data recorder collects data from the sensors one at a time.

Multiple long measurement time sensors

When collecting data from several SDI-12 sensors that have long measurement times, the complete data collection cycle can be shortened by utilizing concurrent commands. The data recorder can initiate the measurement on all the sensors and when each finishes, then collect the data from all of them. Since the measurement times overlap, the complete data collection cycle is shorter. There is no advantage to the concurrent measurement C command when there is only one sensor.

Improved data integrity checking

The measurement command classes with CRC-16 (MC and CC) offer additional data integrity checking over the non CRC-16 commands (M and C). The non CRC-16 commands offer data integrity checking in the form of parity and the SDI-12 command structure. The CRC-16 commands offer some additional data integrity through the addition of a CRC-16. Since the CRC-16 commands are brand new in SDI-12 version 1.3, not as many data recorders support them. In most applications, lack of this support on the part of the data recorder will not be missed since non CRC-16 SDI-12 commands still offer significant data integrity checking. If the data recorder supports CRC-16 commands, then it is recommended to use them when collecting data from this sensor in order to benefit from the increased noise immunity.

Making a non-concurrent Measurement (M command)

The command to tell the ACCUBUBBLE 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 ACCUBUBBLE 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 ACCUBUBBLE responds with a service request

a	where a is the address character

Note that you still do not have any data from the ACCUBUBBLE. 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 ACCUBUBBLE 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 m 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 m 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.

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.

Making a non-concurrent Measurement with CRC-16 (MC command)

The command to tell the AccuBubble to make a non-concurrent measurement with a CRC-16 check on the data is:

aMC!	where a is the address character, and MC is the command to make a non-concurrent measurement with a CRC-16

The non-concurrent measurement with CRC-16 command was first defined in version 1.3 of the SDI-12 specification. Therefore the data recorder will have to be SDI-12 version 1.3 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 AccuBubble 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 AccuBubble. 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 AccuBubble will reply with two values in the format:

avuC	where a is the address, v is the data value, u indicates the units, and C is the CRC-16 encoded into 3 ASCII characters. Both v and u have the format of a polarity sign (+ or −) followed by up to seven digits, including a decimal point. The CRC-16 is always the last three characters which are never a numeric digit.

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 with CRC-16 (CC command)

The command to tell the AccuBubble to make a concurrent measurement with CRC-16 check on the data is:

aCC!	where a is the address character, and CC is the command to make a concurrent measurement with a CRC-16 check on the returned data

The concurrent measurement with CRC-16 command was first defined in version 1.3 of the SDI-12 specification. Therefore the data recorder will have to be SDI-12 version 1.3 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 and MC commands.

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:

AvuC	where a is the address, v is the data value, u indicates the unit's units, and C is the CRC-16 encoded into 3 ASCII characters. Both v and u have the format of a polarity sign (+ or −) followed by up to seven digits, including a decimal point. The CRC-16 is always the last three characters which are never a numeric digit.

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-12 standard allows for other measurement commands such as M1, M2 etc., other current measurement commands such as C1, C2, etc., other non-concurrent measurements with CRC-16 such as MC1, MC2, etc, and other concurrent measurement with CRC-16 such as CC1, CC2, etc. This unit maintains symmetry across all four classes of commands, that is, it returns the same information to a C1 as it does to a M1 or a MC1 or a CC1. The AccuBubble supports the following optional measurement commands:

aM1! aC1! aMC1! aCC1!	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! aC2! aMC2! aCC2!	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! aC3! aMC3! aCC3!	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, C, MC, and CC commands.
aM4! aC4! aMC4! aCC4!	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, C, MC, and CC commands.
aM5! aC5! aMC5! aCC5!	measure the quadrature scale factor, quadrature threshold, quadrature step rate, and operating mode for the analog and quadrature outputs
(*Version 2.0 and higher*.) aM6! aC6! aMC6! aCC6!	Measure temperature and pressure. The output is the concatenation of the M2 and M commands. Temperature, temperature units, Pressure, Pressure units.
(*Version 2.0 and higher*.) aM7! aC7! aMC7! aCC7!	Measure psi and degrees C using factory calibration. Do not apply any user scaling, field calibration or offsets. This returns two values and the units are fixed to psi and degrees C.

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 XUP command:

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 mm 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, or cm 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 both an XUU and an XUP command are required for the ACCUBUBBLE to report in user-defined units.

Field Calibration

The ACCUBUBBLE 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 ACCUBUBBLE 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 ACCUBUBBLE is done with the self-calibration, the new offset is stored into memory. A subsequent aD0! command will display this offset in the current units of pressure. The offset can also be displayed using the M3 command.

Configuring the Quadrature Output (-3 models only)

Setting the Quadrature Scale Factor, Threshold, and Step Rate

The quadrature output tracks the pressure as returned by the M command. The units of pressure for the M command are user configurable with the XUP command. Changing the units of pressure for the M command with the XUP command also changes the units of pressure for the quadrature output. The quadrature scale factor is the number of steps the quadrature output takes per unit of change of the input pressure. As shipped from the factory the default units for the M command is feet of water. The factory default scale value is 1000. This means that the quadrature output steps 1000 times for every change in the input pressure of one foot. This means that the resolution of the quadrature output as shipped from the factory is 0.001 feet of water. This is the scale factor necessary to produce one rotation of the output shaft of the Sutron 5600-0126-1 chart drive per foot of input change. If the ACCUBUBBLE was being hooked up as a shaft encoder for a data logger, the scale factor would usually be set to 100 since most incremental shaft encoders produce 100 steps per revolution.

The threshold level is utilized to minimize excess stepping by a chart drive and therefore conserve power. If the difference between the measured pressure and the quadrature output is less than the threshold level, the quadrature output is not changed. Once the difference between the measured pressure and the quadrature output exceeds this threshold level, the quadrature output will be stepped in order to eliminate this "error". As shipped from the factory, the default value of the threshold is 0.01. This means that once the measured pressure and the quadrature output differ by 0.01 feet of water, the output will be stepped to eliminate this error.

The interface to the Sutron 5600-0126-1 operates at the 0.001 foot level. This means that if the threshold were set to zero then for every 0.001 foot of change detected by the AccuBubble, the stepper would be stepped. This would cause excessive power consumption on the stepper side because it would be attempting to track all the ripples in the water's surface. To prevent this excessive power consumption the threshold is set to the level of accuracy desired. This is usually on the order of 0.01 feet. If a particular installation was using a stepper and was not interested in any changes under 0.05 feet, then the threshold could be changed to 0.05 and a power saving would result from the decreased stepping. If the quadrature output was run directly into a data logger where there is not any penalty from the excessive stepping, then the threshold could be set to 0.

This command also supports setting the step rate for the quadrature output. The factory default for the step rate is 100 steps per second. This corresponds to the maximum step rate for the Sutron 5600-0126-1 Chart Drive. This means that if the ACCUBUBBLE detected a one foot change, then the output would be ramped at the rate of 0.1 foot per second for 10 seconds (1000 steps divided by 100 steps per second). If the ACCUBUBBLE was connected to the shaft encoder input of a data logger the user might want to increase the step rate if the data logger could track a faster rate. Likewise it can be decreased for slower devices. NOTE: Decreasing this number will result in increased power consumption for the 5600-0126-1 Chart Drive, not lower power consumption.
The format for the command is:

aXQSstr!	where a is the address character, XQS is the extended command to set the Quadrature Scale Factor s in steps per unit of change as returned by the M command, the Quadrature Threshold t, and the Quadrature Step Rate r in steps per second.

If a user wanted to setup an ACCUBUBBLE at address 3 to produce 1000 steps per foot (units of pressure are 0 for feet of water), with a 0.01 foot threshold and a step rate of 100 steps per second, the command would be:

3XQS+1000+0.01+100!

If the user wanted to connect it to a data logger that expected an incremental encoder that with a resolution of 0.01 feet and could track a rate of change of 2 feet per second then the command would be:

3XQS+100+0+200!

This represents a command to the ACCUBUBBLE at address 3 to produce 100 steps per unit of change (units of pressure, XUP command, is 0 for feet of water), no threshold, and to produce 200 steps per second (200/100 or 2 feet per second).

Setting the Quadrature Output's Reading

The Quadrature output is an incremental output. It indicates a change in the value, it does not report an absolute value. The device the ACCUBUBBLE is connected to will have some indication of what it thinks the current reading is. To facilitate synchronizing the quadrature input device with the true pressure reading of the AccuBubble, the ACCUBUBBLE has an extended command to set the quadrature output to the current reading of the quadrature input device. The XQC command causes the ACCUBUBBLE to drive the quadrature input device to match the reading of the AccuBubble.

aXQCv!	where a is the address character, XQC is the extended command to set the Quadrature Current value where v represents the quadrature value as indicated by the quadrature input device.

Once the XQC command is given, the ACCUBUBBLE knows the level as perceived by the quadrature input device. The next time the ACCUBUBBLE complete a pressure measurement, it will check and see if the difference between the input value and the measured pressure exceeds the threshold level set by the XQS command. If so, it will drive the quadrature output to update the quadrature input device.

NOTE: If the XQS command needs to be given (M5 command returns current value of Scale, Threshold, Rate, and Operating Mode parameters), it should be issued with the correct parameters before issuing an XQC command.

Use of an ACCUBUBBLE with a Sutron 5600-0126-1 Chart Drive

The 5600-0126-1 Chart Drive requires 1000 steps for one rotation of the shaft. The maximum input step rate is 100 steps per second. The higher the quadrature threshold is set, the lower the power consumption for the chart drive. The factory default settings of the ACCUBUBBLE of 1000 for the scale factor, 0.01 for the threshold, 100 for the step rate, and Feet of Water as the units for the M command will produce one shaft rotation per foot of water. To produce Clockwise rotation of the shaft as viewed from the end of the shaft for increasing water level, connect Phase A to the chart drive input labeled A, and Phase B to the chart drive input labeled B. For counter-

clockwise rotation, either reverse the connections (A to B, B to A) or enter the quadrature scale factor as -1000.

Configuring the Analog Output (-4 models only)

Analog Output Range

The 5600-0131-4 model supports an analog output. The output range is 0 to 5 volts. As shipped from the factory, this corresponds to 0 to 22 psig. The analog output is driven by a 12 bit D/A converter. This means that the output changes in discrete steps of about 1.25 mV. Analog transmission of data is less accurate than digital transmission. There are three contributors to this error: Error in the transmitted value; noise and voltage drops picked up during transmission through the cable; and conversion errors at the receiving end. For the AccuBubble, the error in the transmitted value is going to be the error in the digital value plus a voltage error of the output. For the receiving end (data recorder, logger, panel display), there is a quantization error plus an accuracy error when the analog voltage is converted to a digital value. The best resolution of a 12 bit A/D on a 0 to 5 scale is 1.25 mV. If the scale is wider or the number of bits is less, then the resolution is even coarser.

This suggests that most users will want to customize the output range to maximize the accuracy of their equipment over the range of interest. The command to set the Analog Output range is the

aXARzf!	Where a is the address character, XAR is the extended command to set the analog range, z is the pressure in psi that is to correspond to 0.000 VDC, and f is the pressure in psi that is to correspond to 5.000 VDC.

If the user wanted the output of the ACCUBUBBLE to be 5 to 10 psi then the following command would adjust the range.

0XAR+5+10!

If the user wanted the ACCUBUBBLE to output V1 volts at pressure P1 and V2 volts at pressure P2, then the following formulas would be used to determine z and f.

$$z = P1 - \frac{V1(P2 - P1)}{V2 - V1}$$

$$f = P1 + \frac{(5 - V1)(P2 - P1)}{(V2 - V1)}$$

For example, suppose we want the ACCUBUBBLE to output 2V at 20 ft of water and 4V at 40 ft of water. First we must convert feet of water to psi by dividing by 2.3073. This gives V1=2V, V2=4V, P1=8.668, P2=17.336. Therefore

z = 8.668 - (2*(17.336 - 8.668) / (4-2)) = 0

f = 8.668 + ((5-2)(17.336 - 8.668) / (4-2)) = 21.67

Our command would therefore be:

0XAR+0+21.67!

Converting Voltage to Pressure

The formula for converting the analog output voltage to pressure is:

Pressure = analog output * Slope + offset

where the slope is (5 volt pressure value - 0 volt pressure value) / 5
and the offset is the 0 volt pressure value.

For the above illustrated range of 2V at 20 feet of water and 4V at 40 feet of water the offset for reading the pressure in psi would be **z** which was 0. The slope would be (**f - z**) / 5 which is: 4.334. To compute the output in feet of water for this example, the slope would be 10 and the offset would be 0.

The slope and offset for different units when the output is configured for the factory default of 0 to 22 psi is given in the following table:

UNITS	slope	offset
psi	4.4	0
feet of water	10.152	0
kPa	30.337	0
cm of water	309.44	0

NOTE: The analog output voltage does take into account the field calibration offset (set by the XE or XS commands).

Configuring the Operating Mode, Purges, and Sample Averaging

Setting the Operating Mode

In order for the ACCUBAR to control the ACCUBUBBLE and make measurements, the operating mode ***MUST*** be set to 64 or higher.

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 Bubbler disabled. (Low quiescent power consumption mode for an AccuBubble being used as a pressure sensor.)
64 Bubbler operation. For analog (-4) units this configures the analog output to be updated only when an SDI-12 measurement is requested.
72 Bubbler with quadrature output. Quadrature output will only be updated when an SDI-12 measurement is requested. Only relevant for a –3 unit.
80 Bubbler with Analog output, self updating. SDI-12 measurements not required for the analog output to be updated. Only relevant for a -4 unit.
88 Bubbler with quadrature output, self updating. SDI-12 measurements not required for the quadrature output to be updated. Only relevant for a -3 unit.

Configuring Analog or Quadrature outputs to update independent of SDI-12

To configure a -3 unit to update the quadrature output without an SDI-12 measurement being invoked, the operating mode of the unit must be set to 88. To configure a -4 unit to update the analog output without an SDI-12 measurement being invoked, the operating mode of the unit must be set to 80. See previous paragraph on Setting the Operating Mode for instructions.

In addition to configuring the unit to update the output independent of SDI-12, the other parameter to consider is how often the output needs to be updated. The more frequent that the output is updated, the more frequent the measurements. This measurement rate is specified through the pump_cycle parameter of the pump timing command: aXPT+purge_on+purge_off+pump_on+pump_off+pump_cycle!
The pump_cycle parameter specifies the maximum time between measurements, it does not impose a fixed schedule. If the unit receives an SDI-12 measurement command, then a measurement will be invoked and outputs updated. The next measurement will occur in either pump_cycle seconds or when the next SDI-12 measurement command is received, which ever occurs first. Since pump_cycle is the 5th parameter of the XPT command, values for the other four must be known to change the 5th. The current values can be determined by issuing the aXPT! command followed by the aD0! command. The first four returned values after the address can then be used as the first four parameters when issuing the XPT command to set the pump_cycle time. Issuing the aD0! command immediately after setting the pump timing will allow verification that the parameters were entered correctly. Note: At an installed site, the XPC command can be used to automatically recalculate the off parameters.

For most installation sites, if the update interval is relatively short, there is not a requirement to do a full purge every reading. See the following paragraph on configuring purge intervals to reduce power consumption.

Configuring Purge Intervals to Reduce Power Consumption

The operating mode of all software versions prior to V2.2 was to perform a purge for every reading. Beginning with V2.2, it is possible to configure the unit to only run the pump for a short period of time for a specified number of readings between readings with a purge. The aXPR+no_purge+on_time! extended command provides this flexibility. With this command you can specify that number of no_purge measurements that occur between measurements with purges. The factory default is zero to match previous software versions. With this command the pump on_time for these no_purge measurements can also be specified with 0.1 second resolution. This on_time is dependent upon the maximum expected water level change between measurements as well as the length and I.D. of the orifice line. A starting point for determining the on_time is the following formula:

on_time = 0.1 + (0.2 + 0.001 * feet of orifice line) * feet of water level change

or

on_time = 0.1 + (0.7 + 0.01 * meters of orifice line) * meters of water level change

The above formula is based on 1/8" I.D (or 3 mm I.D) orifice line and a well charged battery. If the I.D. is not 1/8" (or 3 mm) then the 0.001 (or 0.01) needs to be scaled by the ratio of the new I.D. cross sectional area to the standard one.

To handle one foot of water level change between readings, this formula would reduce to:

on_time = 0.3 + 0.1 per 100 ft of orifice line.

For sites not capable of supplying at least 12V to the pump, the times may need to be increased or accept that when the battery is low, it may take more than one reading to track a one foot increase in water level. Having an on_time longer than necessary will not have any negative affects on reading accuracy. Having an on_time shorter than necessary to track water level increases will result in the readings lagging the water level change until the no_purge readings catch up or until a purge readings occur. *Note: This is the same phenomena demonstrated by constant flow rate bubbler systems. If the water level increases faster than a constant flow rate bubbler is set for, its readings will lag the actual water level.* If there is a leak in site installation tubing, then more air could leak out between readings than what is pumped during the on_time. If this were to occur, the readings would be seen to gradually decline between purge cycles and then have a step change back up when the purge occurred. Although this can be compensated for to some degree by increasing the on_time, the proper solution especially for substantial leaks is to eliminate the leak.

Example:
Site has 150 feet of orifice line. SDI-12 data recorder is requesting measurements every 5 minutes. We want to purge once an hour. Never expect to see anywhere near a one foot change in the 5 minutes between readings. Since there are 12 readings an hour and we want one of them to be a purge, our no_purge number will be 11. For our on_time we will round the orifice line length to 200 feet and calculate an on_time of 0.5 seconds. The command for an unit at SDI-12 address zero will be:

0XPP+11+0.5!

For this example the pump would only have 13% of the duty cycle it would have from purging every reading, an 87% reduction in its power consumption.

As can be seen from a typical on_time of 0.5 seconds versus a typical purge time of 10 seconds, substantial power savings can be achieved when frequent measurements are occurring.

Setting the Sample Averaging

The AccuBubble supports user selectable averaging time for SDI-12 readings. The number of samples to average is specified with the aXPA+nsamples+speed! extended command.

For example, the command

0XPA+10!

will set the averaging to 10 samples at the slow speed for a sensor at address 0.

There are two speed regions, slow and fast. If speed is 0 or omitted then the AccuBubble operates in the default more accurate slow mode. In the more accurate slow mode (speed = 0) the noise floor of the sensor is typically 0.0002 feet of water (0.00009 PSI), in the high speed mode (speed = 1) it increases to 0.004 feet of water (0.002 PSI).

To fully specify sample averaging also requires the use of the pump timing command: aXPT+purge_on+purge_off+pump_on+pump_off+pump_cycle!
If multiple samples have been specified via the XPA command then for one measurement the purge cycle is run and then the first sample is collected. In between that sample and each of the remaining samples the pump on/off cycle occurs.

5. Command Reference

This section documents the commands supported by the ACCUBUBBLE. The commands are listed in alphabetical order.

	Command Description	**Command Syntax (command underlined)**	**ACCUBUBBLE 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**: ACCUBUBBLE 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. **Note:** if the DIP switches are set to a non-zero address then upon power-up the address will be the dip-switch address.
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).
C5	Request Quadrature scale factor, threshold, step rate, and operating mode for the unit	aC5! aD0!	a00004 000 is the time in seconds until the measurement is ready and 04 is the number of values that can be collected astrm where, s is the Quadrature scale, t is the quadrature threshold, r is the quadrature step rate in steps per second, and m is the operating mode of the analog and quadrature outputs.
C6	Request Concurrent Temperature and Pressure Measurement (Version 2.0 and higher)	aC6! aD0!	attt04 ttt is the time in seconds until the measurement is ready and 04 is the number of values that can be collected atupv where t is the temperature, u is the temperature units, p is the pressure, and v is the pressure units. Use the XUT command to set the temperature units and the XUP command to set the pressure units.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
C7	Request Concurrent factory calibration Pressure and Temperature Measurement (Version 2.0 and higher)	aC7! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected apt where p is the pressure psi and t is the temperature in degrees Celsius.
CC	Request Default Concurrent Pressure Measurement with CRC-16 (Version 2.0 and higher)	aCC! aD0!	attt02 ttt is the time in seconds until the measurement is ready, 2 is the number of values that can be collected axuC where x is the signed pressure value, u is the signed indicator of the units, and C is the 3 character CRC. The units are set by the XUP command.
CC1	Request Concurrent Pressure Measurement in psi with CRC-16 (Version 2.0 and higher)	aCC1! aD0!	attt01 ttt is the time in seconds until the measurement is ready, 1 is the number of values that can be collected. apC where p is the signed pressure value in psi and C is the 3 character CRC
CC2	Request Concurrent Temperature Measurement with CRC-16 (Version 2.0 and higher)	aCC2! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected atuC where t is the temperature, u is the units 0= Celsius and 1=Fahrenheit, and C is the 3 character CRC. Use the XUT command to set the units.
CC3	Request User Scale, User Offset, and Field Calibration Offset with CRC-16 (Version 2.0 and higher)	aCC3! aD0!	a00003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected asocC where, s is the user scale and o is the user offset (psi), c is the field calibration offset in the current pressure units, and C is the 3 character CRC.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
CC4	Request Standards lab Calibration Scale and Offset with CRC-16 (Version 2.0 and higher)	aCC4! aD0!	a00002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected asoC where, s is the scale calibration, o is the offset calibration(psi), and C is the CRC.
CC5	Request Quadrature scale factor, threshold, step rate, and operating mode for the unit with CRC-16 (Version 2.0 and higher)	aCC5! aD0!	a0004 000 is the time in seconds until the measurement is ready and 4 is the number of values that can be collected astrmC where, s is the Quadrature scale, t is the quadrature threshold, r is the quadrature step rate in steps per second, and m is the operating mode of the analog and quadrature outputs, and C is the CRC.
CC6	Request Concurrent Temperature and Pressure Measurement with CRC-16 (Version 2.0 and higher)	aCC6! aD0!	attt04 ttt is the time in seconds until the measurement is ready and 04 is the number of values that can be collected atupvC where t is the temperature, u is the temperature units, p is the pressure, v is the pressure units, and C is the CRC. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
CC7	Request Concurrent factory calibration Pressure and Temperature Measurement with CRC-16 (Version 2.0 and higher)	aCC7! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected aptC where p is the pressure psi, t is the temperature in degrees Celsius, and C is the CRC.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
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!	a13 SUTRON 0131-31.0ssssssVvvv 13 supports SDI version 1.3 commands SUTRON manufacturer 0131-3 model number 1.0 hardware revision level sssssss the sensor serial number Vvvv the software revision
M	Request Default Pressure Measurement	aM! aD0!	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 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.

	Command Description	Command Syntax (command underlined)	ACCUBUBBLE response (underlined) "a" represents the single-character address
M1	Request Pressure Measurement in psi (factory calibrated value)	aM1! aD0!	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 ap where p is the signed pressure value in psi
M2	Request Temperature Measurement	aM2! aD0!	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 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! aD0!	a0003 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, and c is the field calibration offset in the current units.
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).

	Command Description	Command Syntax	ACCUBUBBLE response (underlined)
M5	Request Quadrature scale factor, threshold, step rate, and 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 is the Quadrature scale, t is the quadrature threshold, r is the quadrature step rate in steps per second, and m is the operating mode of the analog and quadrature outputs.
M6	Request Temperature and Pressure Measurement (Version 2.0 and higher)	aM6! aD0!	attt4 ttt is the time in seconds until the measurement is ready and 4 is the number of values that can be collected a service request atupv where t is the temperature, u is the temperature units, p is the pressure, and v is the pressure units. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
M7	Request factory calibration Pressure and Temperature Measurement (Version 2.0 and higher)	aM7! aD0!	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 apt where p is the pressure psi and t is the temperature in degrees Celsius.

	Command Description	Command Syntax	ACCUBUBBLE response (underlined)
MC	Request Default Pressure Measurement with CRC-16 (Version 2.0 and higher)	aMC! aD0!	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 axuC where x is the signed pressure value, u is the signed indicator of the units, and C is the 3 character CRC. The units are set by the XUP command.
MC1	Request Pressure Measurement in psi with CRC-16 (Version 2.0 and higher)	aMC1! aD0!	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 apC where p is the signed pressure value in psi and C is the 3 character CRC
MC2	Request Temperature Measurement with CRC-16 (Version 2.0 and higher)	aMC2! aD0!	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 atuC where t is the temperature, u is the units 0= Celsius and 1=Fahrenheit, and C is the 3 character CRC. Use the XUT command to set the units.
MC3	Request User Scale, User Offset, and Field Calibration Offset with CRC-16 (Version 2.0 and higher)	aMC3! aD0!	a0003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected asocC where, s is the user scale and o is the user offset (psi), c is the field calibration offset (current pressure units), and C is the 3 character CRC.

	Command Description	Command Syntax	Sensor response (underlined)
MC4	Request Standards lab Calibration Scale and Offset with CRC-16 (Version 2.0 and higher)	aMC4! aD0!	a0002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected asoC where, s is the scale calibration, o is the offset calibration (psi), and C is the 3 character CRC.
MC5	Request Quadrature scale factor, threshold, step rate, and operating mode for the unit with CRC-16 (Version 2.0 and higher)	aMC5! aD0!	a0004 000 is the time in seconds until the measurement is ready and 4 is the number of values that can be collected astrmC where, s is the Quadrature scale, t is the quadrature threshold, r is the quadrature step rate in steps per second, and m is the operating mode of the analog and quadrature outputs, and C is 3 character CRC.
MC6	Request Temperature and Pressure Measurement with CRC-16 (Version 2.0 and higher)	aMC6! aD0!	attt04 ttt is the time in seconds until the measurement is ready and 04 is the number of values that can be collected a service request atupvC where t is the temperature, u is the temperature units, p is the pressure, v is the pressure units, and C is the 3 character CRC. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
MC7	Request factory calibration Pressure and Temperature Measurement with CRC-16 (Version 2.0 and higher)	aMC7! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected a service request aptC where p is the pressure psi, t is the temperature in degrees Celsius, and C is 3 character CRC.

	Command Description	Command Syntax	Sensor response (underlined)
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.

Sutron AccuBubble Extended Commands

	Command Description	Command Syntax (command underlined)	ACCUBUBBLE response (underlined) "a" represents the single-character address
X?	Request unknown address	*X?! This command causes any Sutron ACCUBUBBLE to identify itself. If you have more than one ACCUBUBBLE connected, the result may be garbled. There is no guarantee that non-ACCUBUBBLE devices will respond to this command.	a ACCUBUBBLE's address.
XAD	Set SDI-12 address	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:** if the DIP switches are set to a non-zero address then upon power-up the address will be the dip-switch address. **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 for software versions before 2.0. Version 2.0 and later return the offset in the current units of pressure.
XFD	Reset to Factory defaults	aXFD! This command resets most user configurable configuration items back to the factory defaults. It does not reset the address nor does it affect metrology lab calibrations. **Note:** It is recommended that the unit be powered down and back up after use of this command.	a0101 indicating that the command will take 10 seconds and 1 value can be collected. a service request **Note:** a D0 command issued after the XFD command will return the operating mode

	Command Description	Command Syntax (command underlined)	ACCUBUBBLE response (underlined) "a" represents the single-character address
XOM	Set operating mode	aXOMm! where m is the desired operating mode. Values for m: 0 Bubbler Operation disabled 64 Bubbler operation. 72 Bubbler with quadrature output. Quadrature output will only be updated when an SDI-12 measurement is requested. Only relevant for a –3 unit. 80 Bubbler with Analog output. SDI-12 measurements not required for the analog output to be updated. 88 Bubbler with quadrature output. SDI-12 measurements not required for the quadrature output to be updated. Note: aXOM! Will cause the D0 command to return the current operating mode	attt1 indicating that the command will take ttt seconds to complete and that one (1) value can be collected **NOTE:** A D0 command issued after the XOM command will return the set operating mode.

	Command Description	Command Syntax	ACCUBUBBLE response (underlined)
XPA	Bubbler reading averaging	aXPA+nsamples+speed! Nsamples is the number of samples to average. If speed is 0 or omitted then the AccuBubble operates in the default more accurate slow mode. If speed is non-zero the AccuBubble will operate in fast mode. Preferred over the aXT command for setting up averaging when operating in a bubbler mode.	a0012 Indicating the command will be complete in 1 second, returning two values. a Service request acs Where c is the number of samples to be averaged and s indicates the speed where 0 is slow and 1 is fast.
XPC	Suggests bubbler pump and read times	aXPC+minpurge! If a value for minpurge is given, then the pump will be run for at least minpurge seconds before attempting to determine purge_off otherwise it will run for at least 10 seconds. aD0!	a2553 Indicating the command will be complete in 255 seconds, returning three values. a service request apos Where p is the purge_on time detected, o is the purge_off time detected, and s is the pump_off time detected for currently programmed pump_on time.

	Command Description	Command Syntax	ACCUBUBBLE response (underlined)
XPL	Leak test for bubbler system	aXPL+leak_check_time! Leak check time is optional. If not specified, 30 seconds will be used. Example: 0XPL! aD0! This command performs a normal reading, i.e., runs the pump for the currently specified purge_on time, waits the currently specified purge_off time, and then takes a pressure reading. The unit will then wait the specified number of seconds and then take another pressure reading. The returned value will be the pressure difference between the two readings in the default pressure units.	attt1 indicating that the command will take ttt seconds to complete and that one (1) value can be collected a Service request ad Where d is delta level change (in the default pressure units) during the leak check time. The value returned will be affected by any changes in the water level during the leak_check_time. If the water level is steady during the leak_check_time then the returned value should be less than the level of accuracy you are looking for. Ideally it should be less than 0.01 feet of water. If the number is larger than what is acceptable, and it is thought that the system is leak free, try increasing the current purge_off time specified by the XPT command.
XPP new in V2.2	Purge setup command	aXPR+no_purge+on_time! This command configures the unit to take non-purge measurements in between measurements with purges. The on_time parameter specifies the number of seconds to run the pump on a non-purge measurement and no_purge specifies the number of these measurements between measurements with purges. aD0!	attt2 indicating that the command will take ttt seconds to complete and that two (2) values can be collected a Service request ano Where n is the number of non-purge measurements and o is the pump on time for the non-purge measurements. Factory default is 0 for n and 0.5 for o.
XPR	Run Pump, i.e., Purge orifice line (turn pump on for a specified time)	aXPR+ontime+waittime! Will run the pump for the number of seconds specified by ontime and then wait waittime before returning. aD0!	attt2 indicating that the command will take ttt seconds to complete and that two (2) values can be collected a Service request aow Where o was the ontime and w was the wait time.

	Command Description	Command Syntax	ACCUBUBBLE response (underlined)
XPT	Manually set bubbler timing *Use after the aXPC command.	aXPT+purge_on+purge_off+pump_on+pump_off+pump_cycle! **Purge_on**: Initial pump run to purge the line in seconds **Purge_off**: Number of seconds to wait after the pump is run to take a reading **Pump_on**: Number of seconds to run between each reading of an average. Defaults to 0.1 second. **Pump_off**: Number of seconds to wait after pump_on before reading. **Pump_cycle**: Maximum time in seconds of updating analog or quadrature outputs when in operating mode 80 or 88. Maximum value of 90 minutes (5400 seconds) Note: aXPT! Will return the programmed values	a0015 indicating that the command will take one seconds to complete and that five values can be collected a Service request arwpoc Where r is purge time, w is wait time after purge, p is pump time between readings, o is pump off time before readings, c maximum output update cycle time.
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 ACCUBUBBLE 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 for software versions prior to 2.0. Version 2.0 and later return the offset in the current units of pressure. The offset can also be displayed using the M3 command..

	Command Description	Command Syntax	ACCUBUBBLE response (underlined)
XT	Set Averaging Time (**See XPA command**)	aXT+t! t = averaging time in seconds (0 to 240 seconds) Example: 0XT+10! (sets the averaging time to 10 seconds if bubbler operation disabled)	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 meters 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).

Additional commands for Quadrature output units (-3)

	Command Description	Command Syntax (command underlined)	ACCUBUBBLE response (underlined) "a" represents the single-character address
XOM	Set operating mode	aXOMm! Where m is the desired operating mode. Values for m: 0 **Bubbler Operation disabled**. Quadrature output disabled. (Low power consumption for Accububbles being used as a pressure sensor.) 64 Bubbler operation enabled. 72 Bubbler with quadrature output. Quadrature output will only be updated when an SDI-12 measurement is requested. Default mode for a –3 unit. 88 Bubbler with quadrature output. SDI-12 measurements not required for the quadrature output to be updated. All input values are standard SDI-12 values with polarity sign	attt1 indicating that the command will take ttt seconds to complete and that one (1) value can be collected **NOTE:** A D0 command issued after the XOM command will return the set operating mode.
XQC	Set Quadrature Output's Current Value	aXQCv! where v is the value currently indicated by the quadrature input device All input values are standard SDI-12 values with polarity sign	a0011 indicating that the command will take one (1) second to complete and that one (1) value can be collected **NOTE:** A D0 command issued after the XQC command will return the specified value.
XQS	Set Quadrature Scale factors	aXQSstr! where s is the number of steps to be output per a full unit of pressure change as set by the units of pressure (XUP command) t is error threshold which must be exceeded before the unit will start stepping. r is the step rate expressed in steps per second. (optional) All input values are standard SDI-12 values with polarity sign.	a0013 indicating the command will be complete in one (1) second and that three (3) values can be collected. **NOTE:** A D0 command issued after the XQS will return three (3) values representing the quadrature scale parameters the user has selected. The rate will be expressed as number of 2μS time ticks between each step. Use the M5 command to see the value in terms of a rate.

Additional commands for Analog output units (-4)

	Command Description	Command Syntax (command underlined)	ACCUBUBBLE response (underlined) "a" represents the single-character address
XAR	Set Analog Output range	aXARzf! Where z is the pressure in psi to be represented by 0.000 VDC f is pressure in psi to be represented by 5.000 VDC All input values are standard SDI-12 values with polarity sign.	a0012 indicating the command will be complete in one (1) second and that two (2) values can be collected. **NOTE:** A D0 command issued after the XAR will return two (2) values representing the pressure range that the user has selected.
XAO	Set Analog Output to a fixed voltage	aXAOv! where v is the required output in VDC All input values are standard SDI-12 values with polarity sign	a0011 indicating that the command will take one (1) second to complete and that one (1) value can be collected **NOTE:** A D0 command issued after the XAO command will return the D/A value corresponding to the requested voltage. The unit's output will not act as a pressure sensor again until this same command is given with a negative voltage request.
XOM	Set operating mode	aXOMm! where m is the desired operating mode. values for m 0 **Bubbler Operation disabled**. Quadrature output disabled. (Low power consumption for Accububbles being used as a pressure sensor.) 64 Bubbler operation enabled. 80 Bubbler operation enabled. SDI-12 measurements not required for the analog output to be updated. **NOTE:** When selecting mode 80, also review the pump cycle time set with the XPT command. All input values are standard SDI-12 values with polarity sign	attt1 indicating that the command will take ttt seconds to complete and that one (1) value can be collected **NOTE:** A D0 command issued after the XOM command will return the set operating mode.

6. Installation

The ACCUBUBBLE will return accurate and reliable pressure data. It must be mounted vertically, meaning that the circular connectors and orifice line connection should point down. This is so that the sensor with the tubing connector and cable connector points downward. This will prevent any moisture from following the cable or tubing into the ACCUBAR sensor.

The ACCUBUBBLE mounts to a panel or surface through four holes that are accessible in the corners of the fiberglass enclosure

The ACCUBUBBLE pressure fitting accommodates an 3/8" OD tubing.

Orifice installation:

Ensure that the orifice line is installed with a continuous downward slope to the water. If there are low points in the line and moisture collects there, you may get erroneous readings. The maximum length of orifice line to use with the ACCUBUBBLE is 500 ft. If longer lengths of orifice line is required, call Sutron Customer Service at 703-406-2800 for details on how to do this.

Electrical connections:

Refer to Chapter 3 on Cabling for a description of the electrical connections.

AccuBubble Setup

Expected Initial setup steps for unit at address 0.
0XFD! To eliminate any unexpected configuration in the unit and reset it to factory defaults.
0XPR+60+30! To ensure that the line is completely purged.
0XPC! A **0D0!** Will return the computed values. If any of the numbers are negative, then repeat step. If the software version is before V2.0, then use the **0XPT** to enter the values returned by the 0D0!
0XPL! to check the system for leaks and check the 0XPT timing parameters
See chapter 2 for an in-depth explanation of these steps.

Leak Checking The System

It is important to check for leaks when installing the sensor. To check for leaks, use the following command.
aXPL+leak_check_time! Note: The leak check time parameter is optional.
This command will perform a normal reading, i.e., run the pump for the currently specified purge_on time, wait the currently specified purge_off time, and then take a pressure reading. The unit will then wait the specified number of seconds (30 seconds if nothing is specified) and then take another pressure reading. The returned value will be the pressure difference between the two readings in the default pressure units. The value returned will be affected by any changes in the water level during the leak_check_time. If the water level is steady during the leak_check_time then the returned value should be less than the level of accuracy you are looking for. Ideally it should be less than 0.01 feet of water. If the number is larger than what is acceptable, and it is thought that the system is leak free, try increasing the current purge_off time specified by the XPT command.

Note: There may be small fluctuations due to thermal and other effects. A leak would be indicated by a significant and continual decrease in pressure.

7. Calibration

The ACCUBUBBLEs under go a rigorous screening and testing at the factory before they are shipped to ensure that they meet their accuracy specifications over temperature and that they are stable both in zero and span and will continue to be accurate over time. Any drift in the zero of the unit can be easily checked by opening the input to atmosphere and performing a measurement. Any drift can be nulled out via the XS command. Span drift is much more difficult to determine. The span drift of the ACCUBUBBLE in the field is typically less than 0.01% per six months. This is a small fraction of the stated accuracy of the ACCUBUBBLE. The stated accuracy of the ACCUBUBBLE at its full scale reading is 0.1% of reading, although typically it is much better. Even though it would typically take over 5 years for the ACCUBUBBLE to drift as much as 0.1%, it is recommended that the ACCUBUBBLE, like all precision measurement instruments, be placed on a periodic calibration schedule.

Factory Calibration

The initial factory calibration of the pressure sensor typically includes over 1000 different pressure temperature points that cover the complete temperature range from -40 to +60 degrees C and cover the complete pressure range from 0 to 22 PSI. This ensures that the ACCUBUBBLE meets the specifications over the complete pressure and temperature range. A calibration verification encompasses nearly 200 points over the complete temperature and pressure range. ACCUBUBBLEs can be sent back to the factory for a complete calibration over temperature. The Sutron Part number for this calibration service is: 8700-0005

Metrology Lab Calibration

The ACCUBUBBLE 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 an ACCUBUBBLE requires a reference accuracy on the order of 0.001 PSI (8 Pa).

To collect data for calibration of the ACCUBUBBLE, 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 or 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 command, the analog output, and the quadrature output. This command does not affect the output of the M1 command. The data output by the M command is computed from the following equation:

Pressure = units offset + units scale * (field offset + calibration scale *(press. in PSI - calibration offset))

where:

press. 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
units scale and units 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 identify command to make sure the sensor is responding to the proper address, if not double check internal address dip switches since on power-up they override any address set by the software.
	Command or address is wrong case – all ACCUBUBBLE commands are capital letters, make sure address is proper case and commands are upper case.
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.
	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.
	High unstable readings when bubbler is utilized – Unit has not been configured for use at the site. Use the XPC and XPT commands as described in Chapter 6 – Installation to configure the unit for the site.
	High unstable readings when bubbler is utilized – Water in the orifice line. Use 0XPR+240! To purge line for four minutes.
	Low readings when bubbler is utilized – Check for leaks in the system by using the XPL command.
	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.

CAUTION: Do not remove the microprocessor from the ACCUBUBBLE for any reason. If there is a problem with the processor, please notify Sutron Customer Service at (703) 406-2800. Only factory-trained personnel with specialized tools can remove the microprocessor without damaging the unit and the processor.

Also note that each microprocessor has been characterized for the specific unit in which it is placed; THEY ARE NOT INTERCHANGEABLE.

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, 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 venting the sensor to the atmosphere and taking a reading from the sensor.

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

9. Specifications for 5600-0131 ACCUBUBBLE

Electrical	
Power Required	8-16VDC
Current Use	~25ma/24hrs avg.
* Above based on	10 sec. Pump on, 15 min. log, with a 10 foot head of water
Pump on current	3 Amp max.
Quiescent current	<1 mA (operating mode 64)
Outputs	SDI-12, Quadrature (-3 only), and Analog (-4 only)
Pneumatic	
Pressure Range	0-22 psi
Accuracy FSO	0.0044 psi for pressures less than 4.4 psi, 0.1% of reading for pressures 4.4 to 22 psi. (0.01 ft. up to 10 ft. of water, 0.1% of reading 10 to 50 feet of water)
Resolution	0.0001 psi
Purge Pressure	35 psi max.
Bubble Rate	Purge before each reading
Compressor Type	Piston and cylinder compressor
Mechanical	
Enclosure	NEMA-4 Fiberglass
Dimensions	12” x 15” x 7.5”
Pressure Outlet	3/8” Tube fitting
Environmental	
Temperature	-25°C to +60°C
Humidity	0-95% Non-condensing

10. Accessories

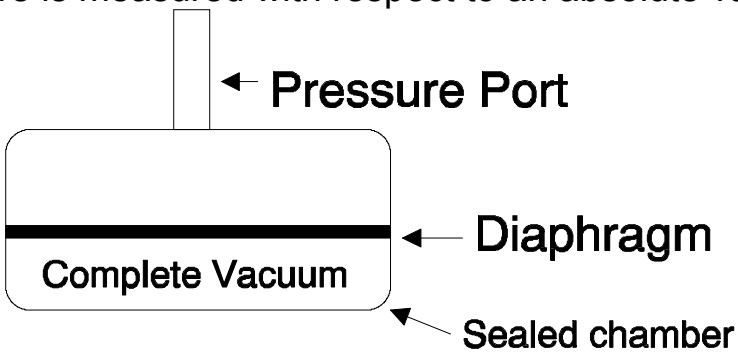
6411-1299-1 SDI-12 cable for use with 8210 or 8400 and a 5600-0131-1 (Not used for the –3 or –4 or -5)
6411-1300-1 SDI-12 cable for use with 8200 and a 5600-0131-1 (Not used for the –3 or –4 or -5)
2911-1183 Black polyethylene tubing, 3/8" O.D. X 1/8" I.D.
2911-1184 Replacement desiccant canister full
7191-1003 Refill for 2911-1184

Specifications subject to change without notice

TYPES OF PRESSURE MEASUREMENTS

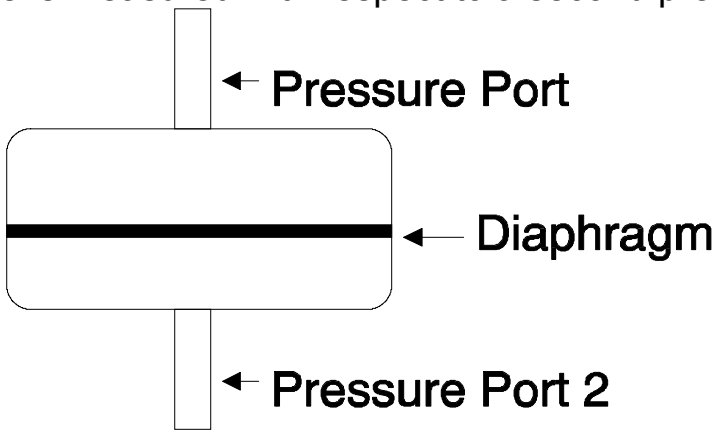
ABSOLUTE (PSIA)

Pressure is measured with respect to an absolute vacuum.



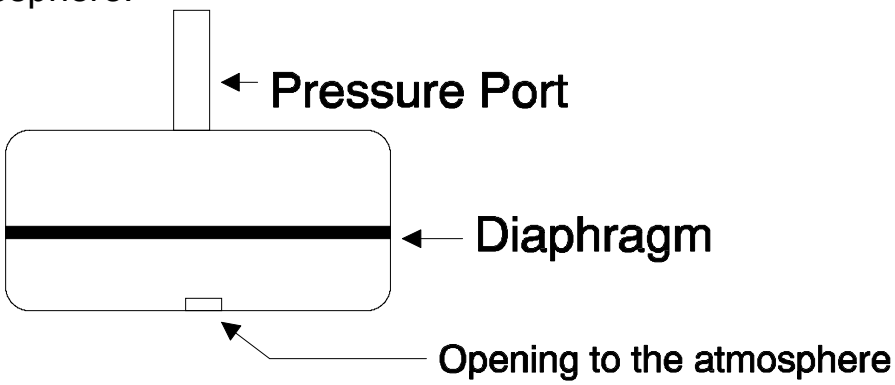
DIFFERENTIAL (PSID)

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

GAUGE

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

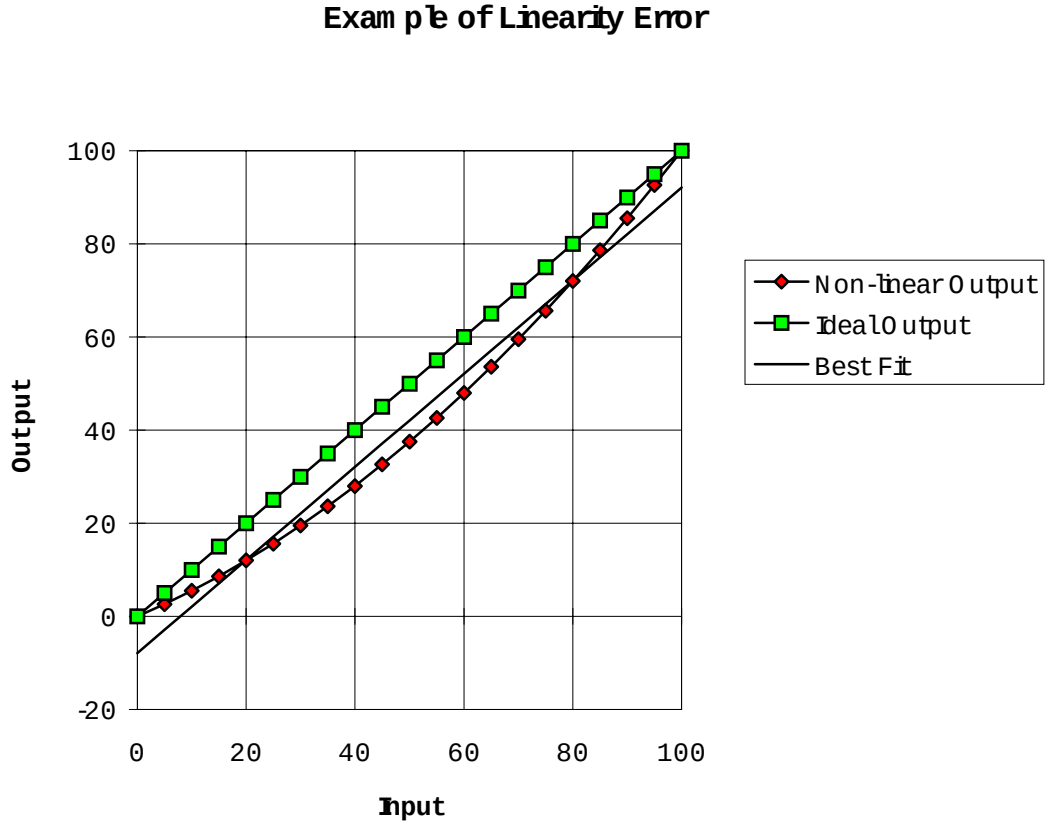
PRESSURE EQUIVALENTS

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

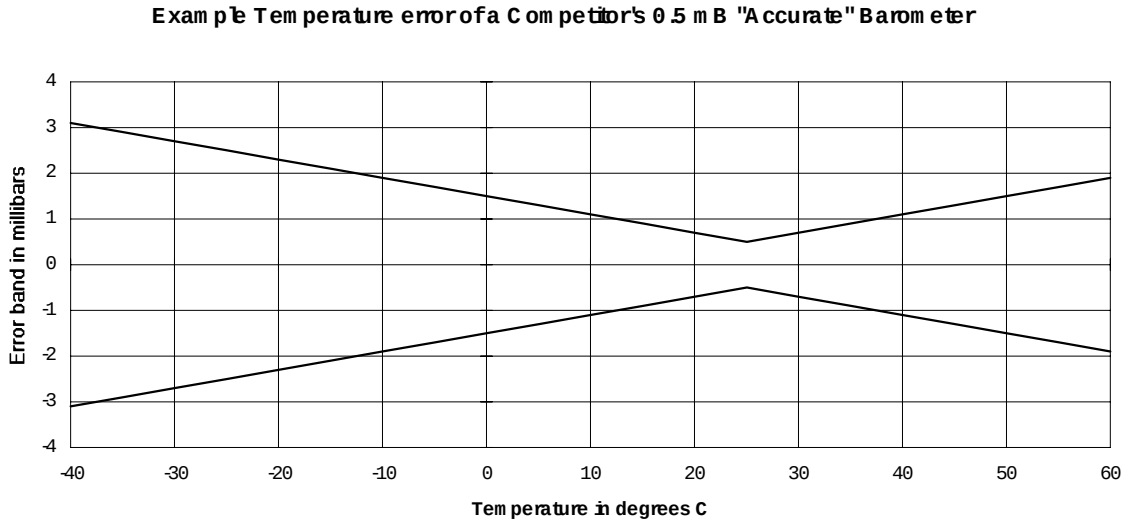
ERROR DEFINITIONS AND EXAMPLES

Linearity:

Linearity error is the deviation of the output from a straight line. Many transducers for measuring physical phenomena have outputs that 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.



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 ±3 mB instrument.



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 will append the ! to the end of the command for you. When you have finished entering the command press SET and the 8200 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 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 ACCUBUBBLE

Temperature data is the first parameter the ACCUBUBBLE returns from the M2 command. Unless the units of temperature have been changed from the factory defaults, the ACCUBUBBLE will return the temperature in degrees C. To log the internal temperature of an ACCUBUBBLE 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.