EXTREME ENVIRONMENTS. EXTREMELY RELIABLE.

Bubbler

User Manual

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Chapter 1 GENERAL

1.1 INTRODUCTION

The FTS Bubbler is an SDI-12 user configurable system for accurately measuring water stage in streams and reservoirs using pressure differentials. It is a self-contained, sealed system that includes an air compressor, control electronics and a high accuracy pressure sensor for measuring water levels. It must be used with a desiccator (see section 2.5) and can be connected to any SDI-12 capable data logger or data collection platform (DCP) using the SDI-12 Data Terminal Block for data logging capability. The FTS Bubbler also has the option to output the level value as a 4-20mA signal.

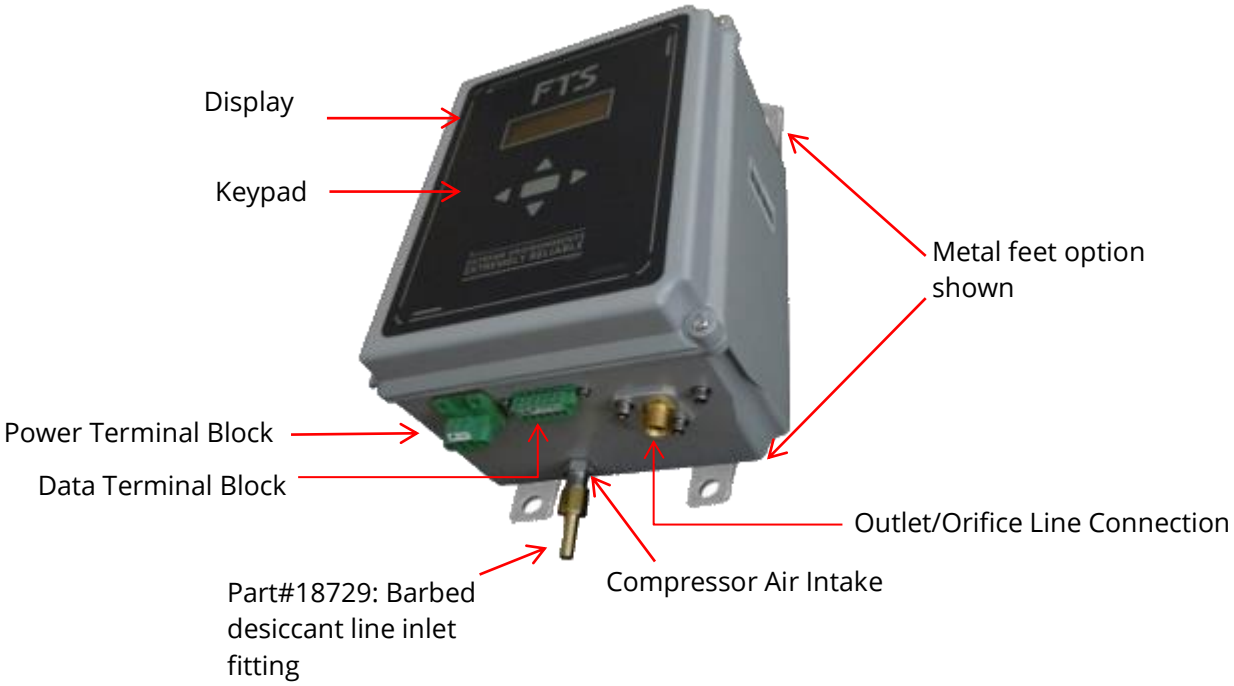


Figure 1-1: Bubbler components

The system forces air at a continuous rate through an orifice line, the end of which is mounted at a known, fixed position. A sensor measures the pressure required to maintain the air flow down the orifice line such that bubbles emerge from its end, compares that to atmospheric pressure, and computes the stage level (water depth). Any change in water level causes the air pressure in the orifice line to vary resulting in updated stage levels.

FTS' proprietary design allows for a larger orifice (18 times larger than the standard metering valve orifice of 0.035mm). Not only does this minimize fouling of the manifold but it also allows the purge to flush particulates throughout the entire system from the compressor valve to the orifice line end fitting. The purge is achieved without bypassing a portion of the system, as systems which use a metering valve must do. This results in highly accurate readings, even in environments with high humidity or containing airborne particulates.

1.2 COMPLIANCE INFORMATION

FC	This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. *Le présent appareil est conforme à la partie 15 des règlements de la FCC. L'exploitation est autorisée aux deux conditions suivantes :* *(1) l'appareil ne doit pas produire de brouillage, et* *(2) il doit accepter toute interférence reçue, notamment celles pouvant entraîner un dysfonctionnement.* This equipment may be operated in the USA and Canada.
	This device complies with Australian and New Zealand requirements specific to EMC, telecommunications and electrical safety.

1.3 DEFAULT VALUES

The Bubbler is shipped with the following default values:

SDI-12 address	0
Bubble rate (per minute)	60
Purge Pressure	90 psi
Stage Units	Feet
Sample period	8 seconds
Temperature	▪ F
4mA (min)	0 feet
20mA (max)	69.2 feet

1.4 BUBBLER RESPONSE TIMES TO STAGE CHANGES

The following table shows the response time for the Bubbler to recover from a stage change at different bubble rates. Note that response time may vary slightly under different conditions (battery charge levels, extreme ambient temperatures, etc.)

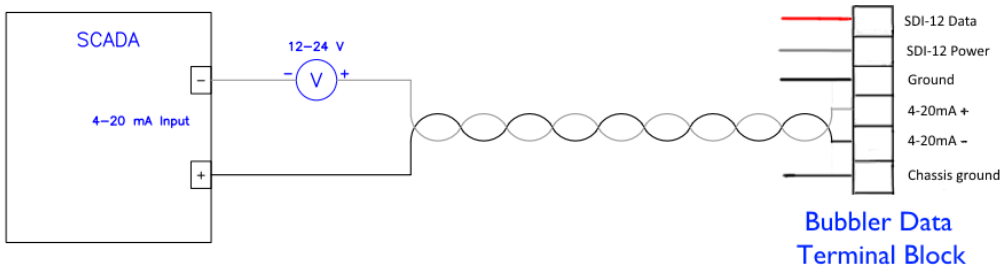
Bubbler Rate	**Response time (3 ft rise)**
30 bubbles/min	28 seconds
45 bubbles/min	15 seconds
50 bubbles/min	14 seconds
60 bubbles/min	11 seconds
120 bubbles/min	7 seconds

1.5 4-20mA OPTION

The Bubbler has an optional 4-20mA output with a resolution of 0.37 µA. A measurement scale is determined by inputting the minimum and maximum water levels which correspond to 4mA and 20 mA outputs respectively. The measured current signal is translated into a level measurement based on the linear relationship between the minimum and maximum levels and the corresponding current output. The process variable that appears on the 4-20 mA output is the average stage value calculated by the Bubbler.

> Example:
> The Minimum level is 10 feet (4mA); the maximum level is 30 feet (20 mA). A signal output of 12mA (half way between 4 mA and 20 mA) would correspond to a level measurement of 20 feet.

Because the relationship between the level variable and the 4-20mA signal is scaled based on the range of the minimum and maximum levels, the smaller the range the more precise the level measurement will be.
The 4-20mA output can be connected to a 4-20mA input on a SCADA system, PLC or chart plotter. The output from the Bubbler is connected to the SCADA equipment as shown in the following diagram. The output is isolated from the SDI-12 power supply and relies on current loop to provide power to the output circuitry.



The 4-20mA output can be validated using a DMM or the SCADA equipment to measure the output current. It is recommended to use a 6 ½ digit multi-meter for best results.

The expected output current can be determined using the following equation:

Analog Output (mA) = (Analog Slope * Stage) + Analog Offset

New values for the analog slope and analog offset can be determined using the following equations:

Analog Slope = 16/(Max Stage – Min Stage)
Analog Offset = 4 – (Analog Slope * Min Stage)

In which:

Max Stage is the maximum stage expected at the site, represented by a 20mA output.

Min Stage is the minimum stage expected at the site, represented by a 4mA output.

Minimum and Maximum stage

1.5.1 4-20mA MINIMUM/MAXIMUM, DEFAULT VALUES, AND UNITS OF MEASUREMENT

The minimum and maximum default values are:

4mA	0 feet
20mA	69.2 feet

These defaults can be adjusted from the Bubbler's front panel (section 3.6) or using SDI-12 X Commands (section 5.2.4) to modify the analog offset and analog slope respectively.

If the units of measurement are changed, either through the Bubbler's front panel or using SDI-12 commands, the minimum and maximum values will be automatically converted to the new unit of measurement (e.g. the initial unit of measurement was feet with a minimum and maximum levels of 5 and 20. Units of measurement were changed to meters. The minimum and maximum levels will automatically be changed to 1.52 and 6.09).

1.5.2 SETTING UP AUTOMATIC PERIODIC 4-20mA LOOP UPDATES

The Bubbler is able to be configured to take periodic stage measurements and update the Bubbler's 4-20mA output without being triggered by an SDI-12 command. This provides the flexibility to operate the Bubbler stand-alone or connected to a SCADA system.

This function is configured through an SDI-12 command, so the Bubbler must be connected to a datalogger initially. Once configured, the Bubbler can be disconnected from the datalogger.

Automatic, periodic stage samples are configured using the SDI-12 extended command, aXSI*P*!, which sets the interval between successive stage samples. The Bubbler will still respond to any incoming SDI-12 measurement requests, but can also operate without an attached SDI-12 datalogger. See Section 5.2.3 for details of the aXSI*P*! Command.

An unusable configuration results if both the sample period (averaging duration) and the automatic periodic stage sample interval are set to 60 seconds. There needs to be a minimum of 10 seconds between the sample period (**aXSP*P*!**) and the periodic stage sample interval (**aXSI<interval>!**).

Acceptable configurations:

1) Sample period = 60 seconds
   Periodic stage sample interval = 70 seconds (minimum)
2) Sample period = 50 seconds
   Periodic stage sample interval = 60 seconds

NOTES:

- If an SDI-12 measurement command is received while an automatic, periodic reading is in progress, the SDI-12 response will wait for the measurement in progress. Otherwise, the SDI-12 request will trigger a new stage reading.

- When an SDI-12 measurement request is received (or a measurement is triggered on-site from the Bubbler's screen), the next 4-20mA update will be shifted to occur <interval> seconds later.

1.6 SD CARD

The Bubbler has an FTS supplied internal SD card which is used for service and factory logs. This SD card has been tested to work in the environmental conditions in which the Bubbler is designed to operate. Replacing it with a non-FTS approved, standard SD card can cause reduced or lost data in the service and factory logs.

The Bubbler's SD card stores data independently from the data logger and as such, is timestamped by the Bubbler. Transmitted data will be timestamped in accordance with the data logger's clock. SD card log entries will only be timestamped if the Bubbler's date and time are set using the "*Set date and Time* X-command (see section 5.2.2).

> IMPORTANT! The Bubbler's timestamp is cleared if the Bubbler has been powered off and must be reset once power is restored.

1.7 MAINTENANCE

The Bubbler itself requires little maintenance. During site visits, inspect the Bubbler, all power and hose fittings and periphery equipment for signs of damage and to ensure the station setup has maintained its integrity. Inspect the colour of the desiccant in the desiccator and replace if it is saturated. Details of the FTS supplied desiccator and desiccant are found in section 2.5. If using a different desiccator, refer to its operating instructions. It is recommended to bring extra desiccant on site visits. Should the Bubbler not be operating as expected, contact FTS Support for assistance and guidance. FTS suggests Bubbler maintenance should be conducted by factory trained personnel.

1.8 SHIPPING THE BUBBLER

Prior to shipping the Bubbler, bleed the compressor tank (Section 3.4.2) and remove the desiccant line inlet fitting (Part # 18729). See Figure 1-1 and Section 2.5.

1.9 DISPLAY AND KEYPAD

The front panel has a display and keypad which is used to view information and perform specific actions (purge, set stage, setup, and diagnostics). The display will normally be off in power save mode. Pressing any key will display the status screen. The arrow keys are used to navigate through the different functions and configuration parameters. Refer to Chapter 3 for details of menu items.

The front panel allows the user to do the following:

- Set purge pressure
- Conduct a manual purge
- Manually bleed the tank
- Set stage
- Set stage units
- Set minimum and maximum 4-20 mA values
- Set bubble rate
- Set averaging duration
- Set temperature units
- Set the SDI-12 address

1.10 CONFIGURING THE BUBBLER

The Bubbler can be configured through its front panel using the **Set Stage** and **Setup** sub-menus (Chapter 3) or through a data logger. The Bubbler will retain the last input configuration whether set through the Bubbler or the data logger. However, changes made using the Bubbler's interface will not be reflected in the data logger, unless it is an FTS Axiom Datalogger.

If using an FTS Axiom Datalogger, configuration can be done through the Axiom using the Bubbler sensor extension. Configuration changes using the Bubbler's screen will also be valid. See Chapter 4 for details.
Note that certain features, those which require a real time clock, can only be set through a data logger. Refer to Table 1-1.

Table 1-1: Configuration using Bubbler vs data logger

FUNCTION	BUBBLER	DATA LOGGER
Set stage	●	●
Set stage units	●	●
Set bubble rate	●	●
Set temperature units	●	●
Set averaging duration	●	●
Perform manual purge	●	●
Set scheduled purge		●
Set scheduled stage collection		●
Set date and time[1]		●
Set automatic periodic stage samples		●

1.11 FIRMWARE UPDATES

Periodically, the Bubbler's firmware may need to be updated. In that event, FTS will issue a notification with instructions on how to conduct the update.

[1] This sets the Bubbler's date and time which is used on the time stamp of the Bubbler's SD card. It does not affect the time stamp of sent data or the timing of scheduled events as those are controlled by the data logger and the telemetry in use.

Chapter 2 INSTALLATION

2.1 PRIOR TO PROCEEDING TO THE SITE

2.1.1 EQUIPMENT

Unpack the Bubbler and conduct a visual inspection for any signs of shipping damage. If any damage is found, contact FTS Service and Support immediately. Retain the shipping container to transport the Bubbler to the site or to return the unit to FTS should damage have occurred during shipping.

For the Bubbler	For mounting the air dryer
• 3/32" flathead screwdriver (for the terminal block screws) • 11/16 open-ended wrench • 5/8 open-ended wrench • Teflon tape • Additional tools and hardware for mounting the Bubbler in accordance with your site characteristics.	• Drill with bits • 9/16 open-ended wrench • Flathead screwdriver • Teflon tape

2.2 SITE SELECTION

The Bubbler should be mounted adjacent to the body of water to be measured, typically in a hydrology shack or gauging house. The position of the Bubbler should allow for a continuous downward run of the orifice line to its final termination point. The water should be relatively calm and where sediment accumulations are not likely to block the orifice.

The orifice line with a terminating orifice should be laid out into the water so that the stream ward end will remain in a fixed position and at a depth that will not be exposed at low stage. Should the orifice line need to be installed in an area with high currents, it should be installed in a static tube.[2]

2.3 MOUNTING

When mounting the Bubbler these guidelines should be followed:

- The Bubbler should be firmly bolted to a sturdy, even vertical surface

  NOTE: The bubbler comes with one of two mounting options:

  1) Metal feet: Attach the metal feet to the back of the Bubbler with the supplied hardware. Securely bolt all four feet to a sturdy vertical surface.
  2) Keyway mounting plate: The shoulder bolts align with the FTS keyway plate. Secure the keyway plate to a sturdy vertical surface. Align the shoulder bolts with the slots and firmly slide the Bubbler down ensuring all four shoulder bolts are properly seated.

- Do not mount the Bubbler so that it rests on a horizontal surface such as a tabletop or shelf as this can bend the orifice line permitting moisture to accumulate and preventing the correct operation of the device

[2] Refer to USGS publications TM3-A7 Stage Measurement at Gaging Stations http://pubs.usgs.gov/tm/tm3-a7/pdf/tm3-a7.pdf and TWRI_8-A2 "Installation and Service Manual for U.S. Geological Survey Meters" http://pubs.usgs.gov/twri/twri8a2/html/pdf.html

- The Bubbler must have a dedicated desiccator and air intake path: do not use one desiccator for multiple Bubblers (this can cause spikes in the data).
- Do not use check valves on the desiccator's air intake.
- Ensure there are no kinks or blockages along the length of the air intake path (from the desiccator's air intake to the Bubbler's air intake fitting).
- The bottom of the Bubbler should be free of obstruction so that the orifice line has a free downward run.
- Ensure the orifice line is not bent or crimped.

2.4 CONNECTORS AND WIRING

When installing the Bubbler connections, do not apply power until all other connections are made.

The following connections should be made:

1. Data connections (SDI-12)
2. Desiccant assembly
3. Orifice line
4. Power

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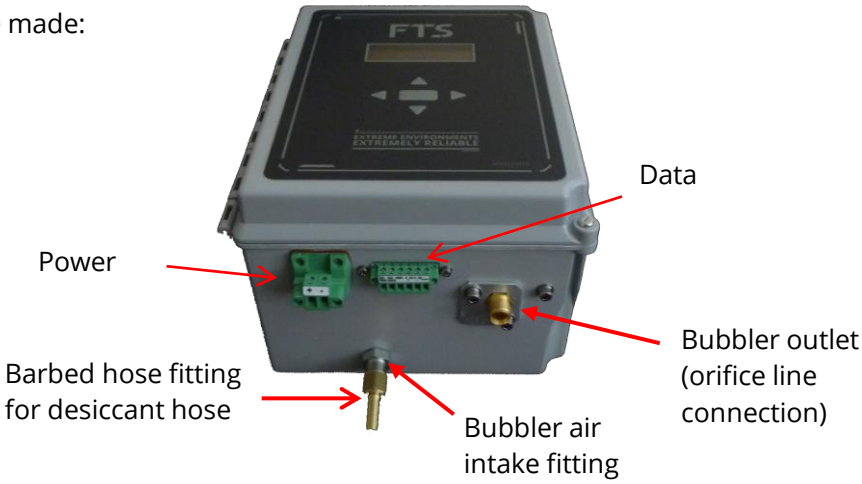

Figure 2-1: Bubbler Connections

2.4.1 DATA LOGGER CONNECTIONS

The Bubbler's interface allows for SDI-12 or 4-20mA connections to a data collection platform (DCP) in accordance with the DCP's capabilities. These connections are made using the removable data terminal block on the bottom of the Bubbler.

Connect the leads to the data logger in accordance with the manufacturer's directions. Connect the flying leads from the data logger to the Bubbler's data terminal strip as shown.

Insert the terminal block into the Bubbler's connector port and secure.

SDI-12 Connections			**4-20mA Connections**	
Pin	Description		Pin	Description
1	12 VDC		3	Ground
2	Serial data		4	4-20mA positive
3	Ground		5	4-20mA negative
6	Chassis ground		6	Chassis ground

1	2	3	4	5	6
PINS					

Figure 2-2: SDI-12 Connections

2.5 DESICCATOR

An external desiccator must be connected to prevent the accumulation of moisture in the compressor manifold and throughout the system. Moist air drawn into the Bubbler will degrade the measurement accuracy and damage the compressor and manifold. Desiccant air dryers and mounting brackets are available from FTS (see Appendix D for part numbers) and mounting/maintenance details are found in Sections 2.5.1 and 2.5.2 respectively. For other desiccators, follow the manufacturer's directions with respect to handling, mounting, maintenance, and disposal of the desiccator and desiccant.

The desiccator should be mounted close to the Bubbler to minimize the length of the output hose. Ensure there are no kinks or bends in the output hose.

A barbed hose fitting for the desiccant hose is shipped with the Bubbler and must be attached to the Bubbler's air intake fitting (see Figure 2-1). Wrap Teflon tape around the Bubbler's air intake fitting, and then screw on the barbed hose fitting finger tight. While holding the Bubbler's air intake fitting steady with the 11/16 wrench, use the 5/8 wrench to tighten the barbed hose fitting (about 2 turns). Do not turn or apply torque to the Bubbler's air intake fitting.

> IMPORTANT! Applying torque to the Bubbler's air intake fitting can displace the O-ring resulting in the possibility of moisture entering the manifold.

2.5.1 DESICCANT HANDLING SAFETY PRECAUTIONS

The desiccant supplied with the FTS supplied air dryer is blue silica gel. When handling observe the following recommended safety precautions:

	**CAUTION:** • Inhalation may irritate the respiratory tract. • Avoid breathing of the dust or prolonged contact with the skin. • Use adequate ventilation.
HANDLING	• Wear gloves. • Wear a NIOSH/MSHA approved dust mask. • Wear long sleeved clothing. • If transferring material into flammable solvents, use proper grounding to avoid static electrical sparks.
FIRST AID	• If material gets into the eyes, hold eyelids apart and flush with water for a least 15 minutes. • If material gets onto the skin, wash with soap and water. • If inhaled remove to fresh air and seek medical attention for any difficulty breathing. • If swallowed, administer plenty of water and seek medical attention.
REGENERATION	• It is NOT recommended to regenerate/reheat BLUE SILICA GEL
DISPOSAL	• Comply with local regulations for disposal. • Store in an airtight, moisture-proof container in a cool dry place until disposal.

2.5.2 MOUNTING THE FTS SUPPLIED DESICCANT AIR DRYER

Refer to the manufacturer's instructions for important details and safety information about the air dryer and desiccant.

You will need the following tools to mount the air dryer:

- Drill with bits
- 9/16 wrench
- Flathead screwdriver
- Teflon tape

IMPORTANT INSTALLATION POINTS:

- Observe the safety precautions when using the blue silica gel desiccant (section 2.5.1)
- Each Bubbler must have a dedicated desiccator and air intake path; do not use one desiccator for multiple Bubblers (this can cause spikes in the data);
- The entire air intake path from the desiccator's air intake line to the Bubbler's air intake fitting should have no restrictions (e.g. check valves) as this can cause spikes in the data;
- The air dryer should be installed as close as possible to the Bubbler's air intake with the air flow going in the direction of the arrow (see Figure 2-4);
- There should be no kinks or tight bends in the desiccant hose;
- There should be no obstruction above the mounting bracket to permit the insertion and removal of the air dryer.

1) Using the supplied screws, mount the bracket.
2) Depress the release button on the clamp ring and rotate the housing to remove the protective metal bowl.
3) Maintain a firm grip on the bowl and separate the top housing from the bowl.
4) Keep the central tube covered to prevent silica gel from entering it. Fill the bowl with desiccant to 1/8" below the inner step of the bowl. Shake or tap the bowl to settle the desiccant and add more desiccant if required. Refer to Figure 2-3.

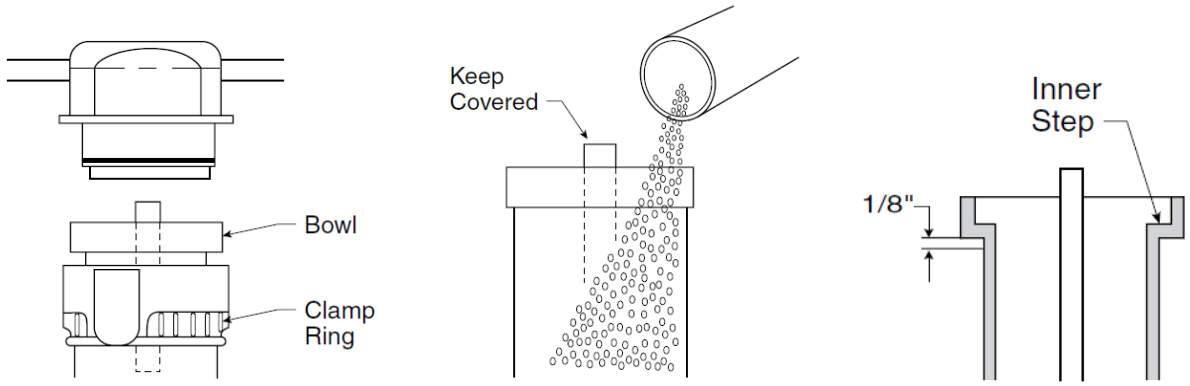

Figure 2-3: Filling the bowl with desiccant

5) Firmly replace the top housing ensuring the bowl is evenly and fully seated. Do not tip the bowl during this step. If any silica gel pellets lodge in the gaskets, they can prevent the bowl from seating properly or forming a seal.

6) Wrap Teflon tape around the threads of the barbed desiccant adaptor fitting.

7) Remove the shipping plugs from the inlet and outlet sockets.

8) Screw the desiccant adaptor (part# 19469) into the air dryer's outflow socket. Screw in finger tight and then tighten two turns with a wrench.

9) Insert the inlet vent (part # 20625), tighten finger tight and turn 1 full turn with a screwdriver.

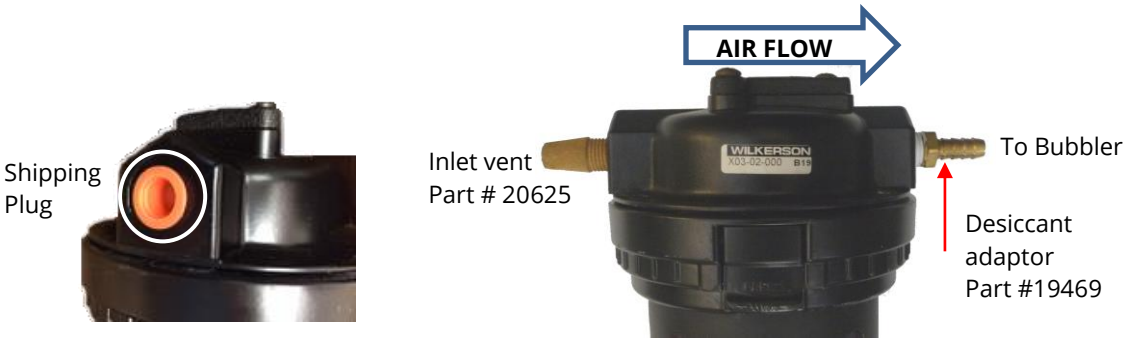

Figure 2-4: Air dryer with inlet vent and desiccant adaptor in place

IMPORTANT! **DO NOT** use a check valve at the desiccator's air intake.

Restrictions on air flow can cause spiky data. See Troubleshooting Section B3.

10) Place the desiccant dryer in the mounting bracket.

11) Push the desiccant tubing firmly onto the dryer's barbed desiccant adaptor fitting, ensuring a tight seal.

12) Attach the desiccant hose to the barbed hose fitting on the Bubbler's air intake (see Figure 2-2).

2.5.3 REPLACING THE DESICCANT

Observe the silica gel safety handling precautions (section 2.5.1). The silica gel desiccant, visible through the clear polycarbonate plastic bowl, contains a colour indicator: blue indicates it is dry, and pink indicates it is wet and needs to be replaced. The frequency of changing the desiccant is dictated by the individual characteristics of each site and levels of humidity.

Before replacing the desiccant, the Bubbler must be powered off. You may need to remove the desiccant hose from the air dryer in order to manipulate the top housing.

1) Remove the air dryer from the mounting bracket

2) Open the bowl following steps 2 and 3 in the preceding section.

3) Cover the tube to ensure no pellets can enter, and tip the desiccant out into a clean, sealable container.

4) Refill and replace the bowl following steps 4 and 5 in the preceding section.

5) Replace the air dryer in the mounting bracket and replace the desiccant hose, if it had been removed.

6) Supply power to the Bubbler.

2.6 CONNECTING AND INSTALLING THE ORIFICE LINE[3]

The orifice line should be black polyethylene 3/8" outer diameter, 1/8" inner diameter USGS approved. Maximum recommended length is 1000 feet (304.8 metres).

The orifice line should be enclosed in a protective conduit to prevent damage from foot traffic, animals, debris, etc. The run should be as straight as possible in a continuous downward path to minimize moisture collection in catenaries. No part of the line should be lower than the line exit in the water. The run should terminate in a calm area, ideally in the same pool as the outside gauge, and secured so that the stream ward end with the line outlet will remain in a fixed position and at a depth that will not be exposed at low stage. The stream ward end should be positioned perpendicular to the direction of the flow at a slight downward angle.

The use of an orifice fitting on the terminal end of the orifice line is recommended to aid in securing the line in a fixed position. There are a variety of orifice options available to the consumer depending on site characteristics and specific agency requirements. FTS offers the USGS Standard Orifice Fitting (Part #19063) as an accessory.
If the area has high currents, the orifice line should be installed in a static tube. If the waters are turbulent, a muffler should be used.

Once the orifice line run is securely laid out, connect the orifice line to the Bubbler outlet (refer to Figure 2-5) and secure it with the provided Swagelok® fitting.

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[3] For a detailed explanation of the installation of an orifice line and static tube, refer to USGS publications:

TWRI_8-A2: Craig, J.D, 1983, "Installation and service manual for U. S. Geological Survey manometers": U.S. Geological Survey Techniques of Water-Resources Investigations, book 8, chap. A2. http://pubs.usgs.gov/twri/twri8a2/html/pdf.html

TM3-a7: Sauer, V.B. and Turnipseed, D.P., 2010 "Stage Measurement at Gaging Stations": U.S. Geological Survey Techniques and Methods, book 3, chap 7, sect A http://pubs.usgs.gov/tm/tm3-a7/pdf/tm3-a7.pdf

DO:

- Use new ferrules (Part# 19864) with the Swagelok fitting each time it is assembled (see 2.6.1).
- Use only USGS approved line
- Encase the orifice line in a conduit
- Ensure the line's run is continuously downward with no dips or swells and no part of the line's run is lower than the line outlet
- Place the line outlet in calm water (when possible)
- Ensure the line outlet is secured in place and has a slight downwards tilt
- Install the line outlet perpendicular to the flow in flowing water
- Use a muffler if water is turbulent

DO NOT:

- Splice the orifice line
- Face the stream ward end of the orifice line facing upstream, downstream or upwards in flowing water
- Mount the line outlet in the wake of an obstruction (boulder, bridge footing etc.)

2.6.1 USING THE SWAGELOK® FITTING[4]

IMPORTANT: The brass ferrules (Part # 19864) are single use. New ferrules MUST be used each time the fitting is assembled. Failure to replace the ferrules will result in a seal failure at the orifice line connection.

ASSEMBLY:

1) Place the nut and ferrules on the line as shown in Figure 2-5 and fully insert the line into the Bubbler outlet.

IMPORTANT! Ensure the Swagelok fitting ferrules are oriented as shown

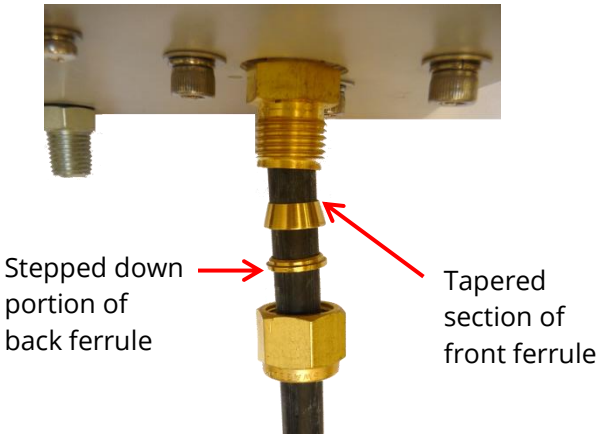
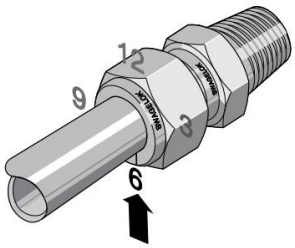


Figure 2-5: Swagelok fitting orientation

[4] For a detailed explanation of installing Swagelok fittings refer to "An Installer's Pocket Guide for Swagelok Tube Fittings" on the Swagelok website. https://www.swagelok.com/downloads/webcatalogs/en/ms-13-151.pdf

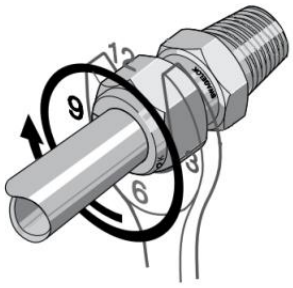
2) Screw the nut on until finger tight.

3) Mark the nut at the 6 o'clock position.



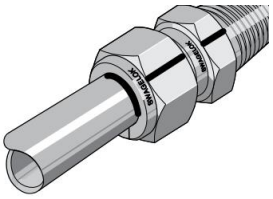
4) Use a wrench to tighten the nut one and a quarter turns (pass the 6 o'clock position once and stop at the 9 o'clock position).

> DO NOT twist the Bubbler outlet. Only turn the nut.



DISASSEMBLY

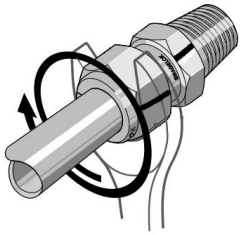
1) Mark a line along the back of the nut and Bubbler outlet. These marks will be used to return the nut to this position.



2) Use a wrench to loosen the nut.

3) Once maintenance is complete, replace the nuts and ferrules, and re-insert the line as shown in Step 1 of the assembly instructions.

4) Tighten the nut to the marked position. At this point, resistance will increase. Tighten the nut slightly.



2.7 POWER CONNECTIONS

The Bubbler requires a dedicated +12VDC power source to operate. This is normally supplied by an external lead-acid battery. Although the Datalogger supplies some power through the SDI port, it is only enough to view and operate the Bubbler's screen. It is insufficient to run the compressor.

If the Bubbler is sharing an external battery source with other equipment, the combined power draw will need to be considered when calculating the site's power budget and power requirements.

IMPORTANT! If not using an FTS supplied power cable (Part #18945) between the battery and the Bubbler, an equivalent power cable should be used. The power cable should be 14 AWG to a maximum of 8 ft with an integrated 20A slow blow fuse.

To connect the power cable:

1) Remove the power terminal block from the port
2) Secure the power wires to the appropriate pins (positive and negative – see Figure 2-4).
3) Connect the power cable to the power source (positive to positive, negative to negative).
4) Re-insert and secure the power terminal block.

Figure 2-6: Power Connections

Chapter 3 BUBBLER INTERFACE AND MENUS

The front panel has a display and keypad which is used to configure the Bubbler. When power is supplied, the start-up screen will display for about 5 seconds before the Status Screen is displayed. After three minutes of inactivity, the display will enter low power mode and blank out. Pressing any button on the keypad will display the status screen.

3.1 KEYPAD

The keypad consists of the following buttons used to navigate through the different screens and menu items:

The keypad consists of the following buttons used to navigate through the different screens and menu items:

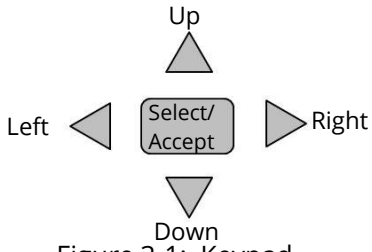
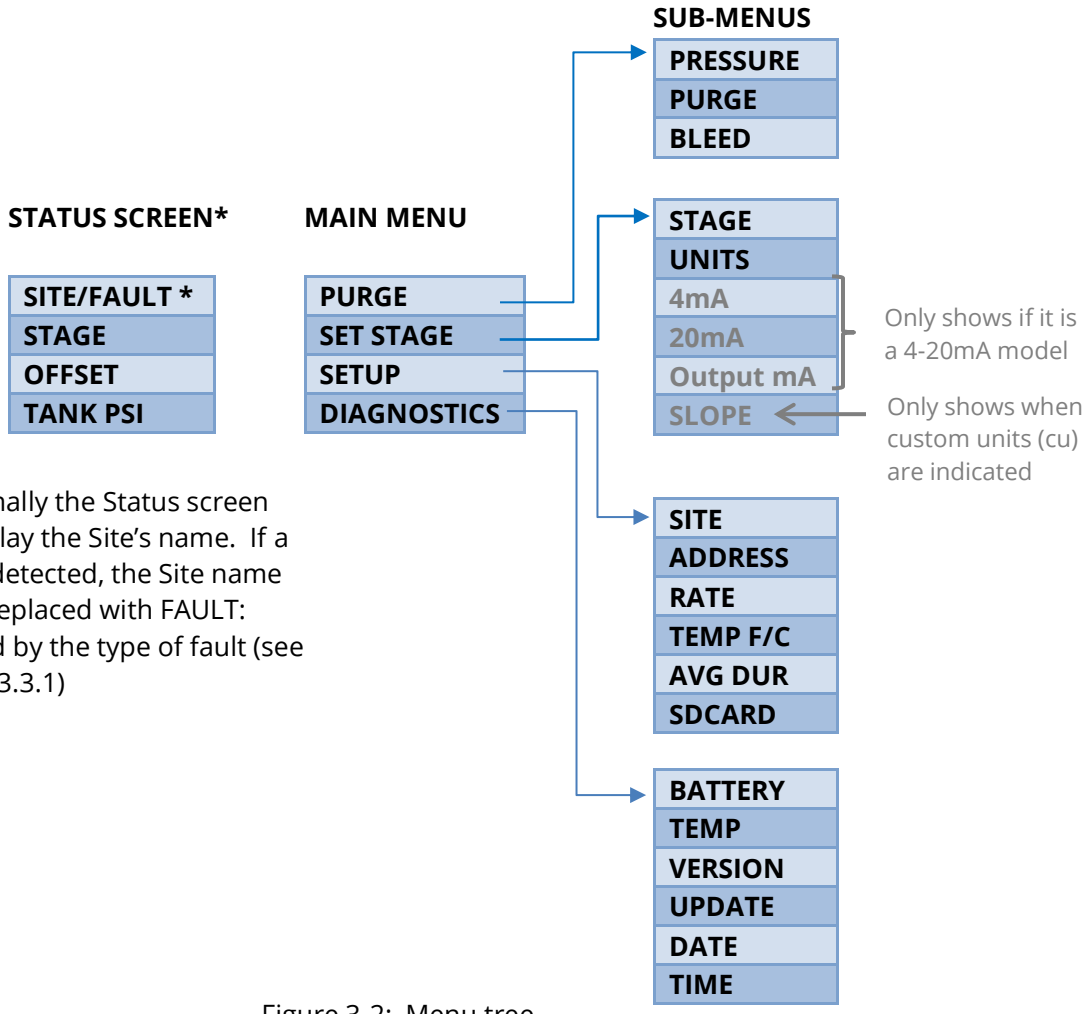


Figure 3-1: Keypad

3.2 SCREENS, MENUS AND OPERATING THE USER INTERFACE

The following diagram illustrates the different screens and menus.



* Normally the Status screen will display the Site's name. If a fault is detected, the Site name will be replaced with FAULT: followed by the type of fault (see Section 3.3.1)

Figure 3-2: Menu tree

- To display the Main Menu press the Select button.
- Use the up and down arrows to move the double arrow symbol to the desired menu item.
- Press the right arrow to bring up the sub-menu.
- Use the up and down arrows to scroll through the sub-menu items
- Press the left arrow to return to the previous menu.

Note that only four lines of the menu can be displayed on the screen, so you must use the up and down arrows to view all items in longer menus.

3.2.1 EDITING A MENU ITEM

Navigate to the item you wish to edit. It will be indicated by the double arrow symbol. Press the Select/Accept button. The field that can be edited will flash. Use the up and down arrows to input the desired number, symbol or letter. The right and left arrows will move the cursor to the next field to be edited. Press the Select/Accept to save the changes.

3.3 STATUS SCREEN

The Bubbler's status screen will display the site identification or any faults, the latest stage measurement, the calculated offset and the tank psi. The Bubbler's display will always show the latest stage measurement whether triggered by SDI-12 command, manual request from the front panel, or the automatic scheduled 4-20mA output function. The screen will show Pending... for ~10s and then display the updated stage value in the configured units. Note that if a custom slope was used to calculate the stage, the displayed unit of measurement will be "cu" (to designate custom).

When the status screen is displayed, pressing the right arrow on the keypad will initiate a fresh stage reading. See section 3.6 for details of setting stage.

3.3.1 OFFSET

Offset is calculated by the Bubbler when the stage is set and is displayed in the same units as stage.

3.3.2 FAULT

The FAULT display line can only show a single fault. Possible faults are prioritized, with the understanding that a higher priority fault is normally the cause of lower priority faults (e.g. an apparent compressor fault is caused by a battery fault). The priority of faults (highest to lowest) is:

- BATTERY
- VOLTAGE_LOW
- TEMPERATURE
- COMPRESSOR
- LINE_HIGH[5]
- TANK_LEAK

[5] Indicates a blocked line. If the block is due to tank pressure >35 PSI during a purge – refer to section 3.4 for Bubbler behaviour

- SYSTEM
- PUMP CYCLE

For fault details and troubleshooting, refer to Appendix B – Section B2.

3.4 CONDUCTING A MANUAL PURGE

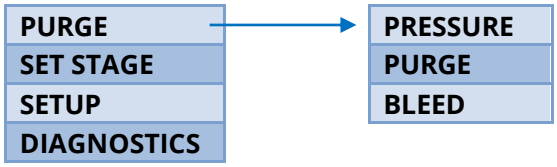


Figure 3-3: Purge sub-menus

If the line becomes obstructed by silt, dirt or other debris, or water has accumulated in the line, the line must be cleared. This is done by conducting a purge. No readings can be taken during the purge.

Input the desired pressure for the purge. The pressure range is 20-90 psi; the default setting is 90 psi. The set purge pressure must be greater than the running tank pressure for the purge to take place.

During a purge, the pump increases to the set purge pressure. Once the input purge pressure is reached, the outlet valve is opened and the air is forced out until the tank pressure has dropped to 9 psi greater than the tank pressure was prior to purge. This prevents the ingress of water into the line. Once the purge is complete, the tank pressure will equalize to the line pressure, and the bubble rate will return to the settings prior to the purge.

To conduct a purge, select **PURGE: START**. Once the purge starts the screen will display **PURGE: STOP**. The purge can be stopped during the process by selecting the **PURGE: STOP** option.

If **PURGE: STOP** is selected, the pump will stop, the tank pressure will decrease, and operations will resume at previously configured settings. The increased pressure may cause the bubble size to increase briefly until the tank pressure drops to the correct value.

3.4.1 FAILED PURGE

A purge failure is likely caused by a blockage and the LINE_BLOCK message will be displayed on the bubbler screen. Follow the steps in Section B.4 to correct.

3.4.2 BLEEDING THE TANK

The tank pressure must be bled prior to shipping, conducting some maintenance such as removing the orifice line or swapping the bubbler. Once started, bleeding can be stopped by selecting the

BLEED: STOP option. If **BLEED: STOP** is selected, the compressor will recharge the tank and operations will recommence.

Once the tank is bled, the power connector to the Bubbler should be removed until maintenance is completed. Once maintenance is completed and power is re-established, operations will recommence. However, if power is not disconnected after the tank is bled and no further actions are taken, operations will resume after 24 hours.

Normal Tank Bleed Procedure:

1) Start Bleed (bleeding will stop once the tank is empty)
2) Disconnect Power connector
3) Conduct maintenance
4) Replace power connector

3.5 CONFIGURING THE BUBBLER USING THE BUBBLER INTERFACE

The **Set Stage** and **Setup** menus are used to configure the Bubbler.

IMPORTANT! After configuring, issue a set date and time X-command to the Bubbler (see section 5.2.3). The Bubbler's time is used to timestamp the data stored on the SD card. Transmitted data will be timestamped in accordance with the data logger's clock.

The following variables can be set using either the Bubbler's interface or through the data logger. The Bubbler will retain the last input configuration regardless of which method is used.

- Set stage
- Stage units
- Rate
- Temperature units
- Averaging Duration

3.6 SETTING THE STAGE

When the stage is set using the front panel, the Bubbler will determine and store the offset. Offset is determined as the difference between the Bubbler's measured depth and the input stage. The offset is displayed on the Status Screen

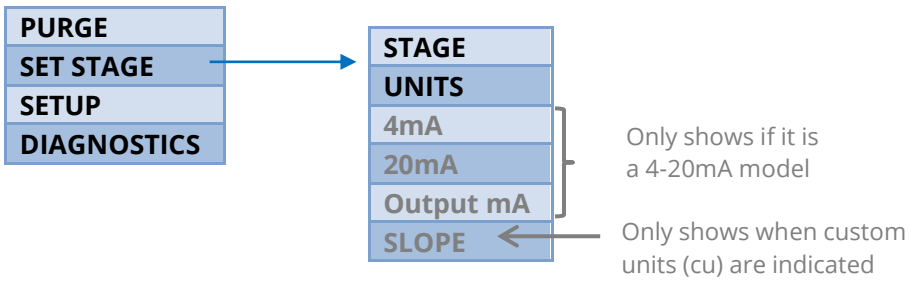


Figure 3-4: Set Stage sub-menu

Stage – Use the arrows to input the stage height. The Bubbler will use this value to calculate the offset which will be displayed on the Status Screen.

Units – Use the up and down arrows to select the measurement units. The displayed Stage value will automatically be converted to the equivalent stage value in the newly entered measurement unit.

> HINT: When initially setting the Stage, enter the units of measurement first, and then the desired stage value to prevent inadvertently leaving an erroneous stage height.

MEASUREMENT UNITS

- in (Inches)
- ft (feet)
- mm (millimeters)
- cm (centimeters)
- m (meters)
- cu (custom)

Explanation:

The desired stage measurement is 3.0 m. The currently entered stage measurement unit is in feet (ft). When you enter Stage Height 3.0, the Bubbler now recognizes 3.0 ft as the stage height. If you subsequently change the units to the desired meters (m), the stage height will be converted to 0.914 (3.0 ft = 0.914 m).

If you do not return to the Stage function and re-enter the correct stage height, the input stage value will remain as 0.914 m as opposed to the desired 3.0 m.

Slope – Displays the slope. Only appears if units are custom (cu). Insert the desired slope. Note that the Stage units on the Status screen will be displayed as "cu" not in the unit of measurement used in the slope calculation.

3.6.1 USING THE 4-20 MA OPTION TO CONFIGURE STAGE

When setting the minimum and maximum values for the 4 and 20 mA outputs, the smaller the range the more precise the measurements will be, so input minimum and maximum values that are realistic but which bracket the expected minimum and maximums. For example, if the change in depth is expected to vary between 10 feet and 25 feet, do not input a range of 0 – 50. A range of 5-30 would be more desirable.

Note that if the units of measurement are changed, the values previously input for 4mA and 20mA will be automatically converted to the equivalent value in the new unit of measurement.

For example:

	Initial values	New Units:
Units	Feet	Meters
4mA	5	1.52
20mA	25	7.62

} These values are automatically converted to the equivalent value in the new unit of measurement

4mA – input the desired minimum depth value for the selected units
20mA – input the desired maximum depth value for the selected units
Output mA – the actual output mA which the Bubbler will convert to the level measurement value

3.7 SETUP MENU

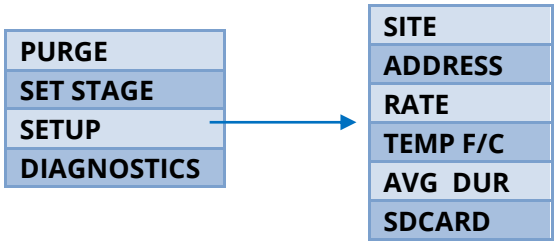


Figure 3-5: Setup sub-menu

Site: The site name can be input and is displayed here.

Address: This displays the Bubbler's SDI-12 address. The Bubbler will be shipped with the default address of zero. The address can also be set in this screen.

> IMPORTANT! Changes made to the SDI-12 address with a data logger (using SDI-12 commands) will be reflected in the Bubbler. However, changes made to the SDI-12 address using the Bubbler's Setup menu, will NOT be reflected in the data logger.

If the address is changed after the Bubbler has been configured with the data logger, you must ensure the data logger configuration is also changed to recognize the new address. If this is not done, the data logger will not be able to communicate with the Bubbler resulting in data loss.

Rate (Bubble Rate): Sets and displays the number of bubbles released per minute.

> NOTE: There will be a pause in the bubble release when a measurement is being taken.

Temperature: Select the temperature units used to display the Bubbler's internal temperature readings (· C or · F).

AVGDUR (Averaging Duration): The period of time over which the samples taken will be used to calculate the displayed stage value. The stage value is an average of the number of samples taken over the specified averaging duration. It takes approximately 2 seconds to take a sample. The average duration range is from 2-60 seconds. The default is 8 seconds.

SD Card: The SD card is used for service and factory logs. If no SD card is inserted the SDCARD option screen will display a dash. If an SD card is inserted the SDCARD option will display EJECT. This should always be selected prior to removing the SD card.

3.8 DIAGNOSTICS

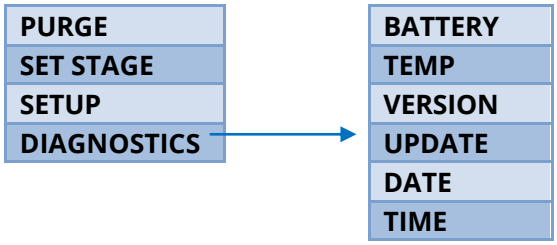


Figure 3-6: Diagnostics Sub-menu

The diagnostics sub-menu is read only, with the exception of the Update function, and displays the current state of the following items:

- Battery: displays the current voltage
- Temp: displays the internal temperature of the Bubbler
- Version: displays the current firmware version
- Update: used to update firmware
- Date: displays the date (set using X command aXDT*YYYYMMDD,HHMMSS*! (See section 5.3)
- Time: displays the time (set using X command aXDT*YYYYMMDD,HHMMSS*! (See section 5.3)

3.8.1 UPDATING FIRMWARE

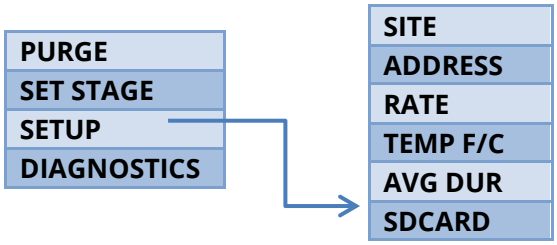
If there is a firmware update required, a notice shall be posted on the FTS Support Website with instructions.

> **IMPORTANT!** The Bubbler should be opened in a protected environment free from moisture, dust and other airborne debris which may enter the enclosure.

Copy the update (it will be a ".bin" file) to a blank, formatted SD card.

> NOTE: The only file on the SD card should be the firmware file.

1) From the Bubbler's Main Menu, select SETUP and scroll down until the SDCARD window is displayed.



2) If an SD card is inserted, the SDCARD window will indicate EJECT. Select EJECT. If no SD card is inserted a dash will be displayed. Go to Step 4.

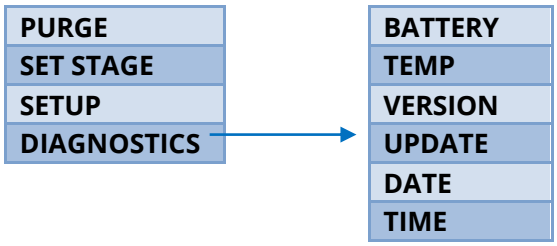
3) Open the Bubbler case and remove the SD card (if present). The SD card slot is found on the board on the interior of the Bubbler case lid.

IMPORTANT! The Bubbler should be opened in a protected environment free from moisture, dust and other airborne debris which may enter the enclosure

5) Insert the SD card with the Firmware update into the SD card slot.

6) Close the Bubbler (it is not necessary to secure the lid). and go to the Diagnostics sub-menu and select UPDATE. It will display the firmware version.

It is good practice to compare the VERSION and UPDATE displays to ensure the update is to a higher version.



7) Press the "Select/Accept" button to initiate the download. The process normally takes less than one minute.

IMPORTANT! DO NOT power cycle the Bubbler while the update is in progress[6].

The display will flash while the update is downloading. When the display stops flashing, the download is complete and the Bubbler will reset.

[6] If the Bubbler is power cycled during the download process, it will revert to the previous firmware version and the firmware update must be re-initiated

8) Return to the SETUP menu, SDCARD and select EJECT (refer to Step 2)

9) Remove the update SD card and replace the factory diagnostic SD card (if it was present).

10) Close and secure the Bubbler case lid.

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Chapter 4 CONFIGURING WITH THE AXIOM DATALOGGER[7]

The information in this chapter is specific to operating the Bubbler with an FTS Axiom Datalogger. To operate the Bubbler with other data loggers, refer to their operator's manuals. SDI-12 commands for the Bubbler are found in Chapter 5.

The Bubbler is designed to work with Axiom Dataloggers in that the Bubbler can be configured using either the Datalogger or the Bubbler's interface and changes made through one unit will be registered in the other: there is no master – slave relationship as with other data loggers.

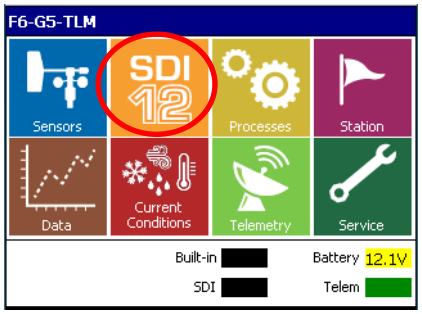
However, note that changes made on the Bubbler's interface will not be reflected in the Datalogger's screens (and *vice versa*) until after the Datalogger has sent the SDI-12 command relating to the specific variable. Prior to sending a measurement command, the Datalogger sends a configuration query. If there was a change the configuration will be updated prior to the measurement command being sent at which point the Datalogger will update its configuration.

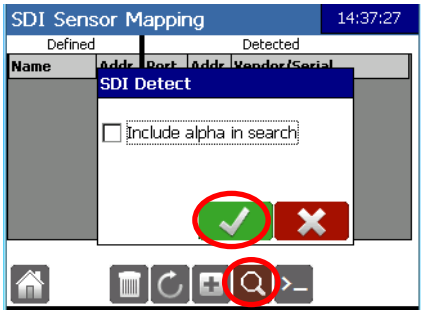
> **IMPORTANT!** Specific variables can be configured using the Bubbler's user interface or through the Axiom's Bubbler sensor extension. The Bubbler and Datalogger will retain the last input configuration regardless of which method is used.

The following variables can be set using either the Bubbler's interface or through the data logger

- Set stage
- Stage units
- Bubble rate
- Temperature units
- Averaging Duration

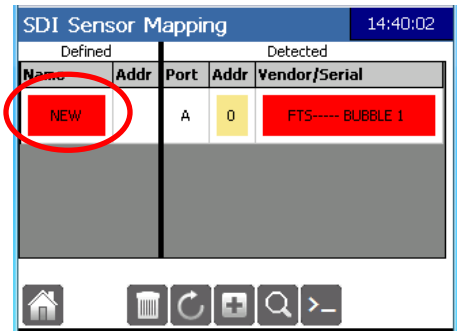
From the Datalogger's Home screen, select the SDI-12 icon and then the Search icon. Select OK on the SDI Detect screen. DO NOT check the "Include alpha in search" box.

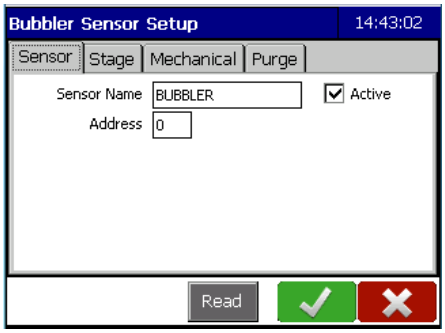




The following screen will be displayed. Note that the Address displayed will be the address set in the Bubbler. In this example it is the default address of zero (0). Tap on the "New" field to bring you to the Bubbler Sensor Setup.

[7] Refer to the Axiom Operator's Manual (700-Axiom-Man) for complete configuration details and the Axiom Telemetry Reference (700-Axiom-Telem) for detailed instructions on setting up messages.





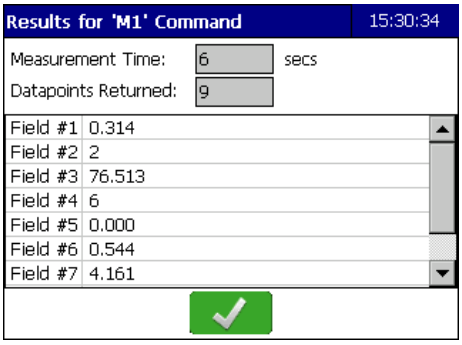
4.1 SETUP GENERAL INFORMATION

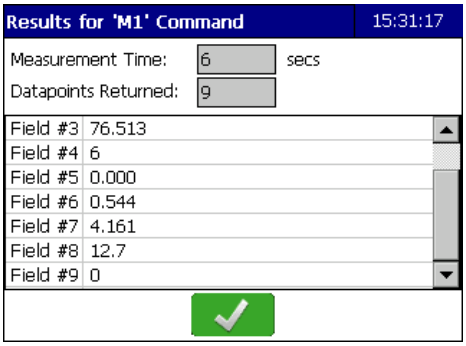
Each of the field names created in the Bubbler Sensor Setup tabs responds to a data point which will be displayed on the Bubbler's summary screen. Once a data point is created it will be available for other functions such as Logging, Current Conditions, Processes, etc.

Default names: Most fields have default names which can be edited if desired by selecting the field and then inputting the desired name using the pop-up keyboard.

In Edit mode, three icons are displayed on the bottom banner and are present in all tabs.

Read: This will send the M1 command[8] and trigger a sensor reading. It will return the Measurement Time, number of data points returned with the values taken.





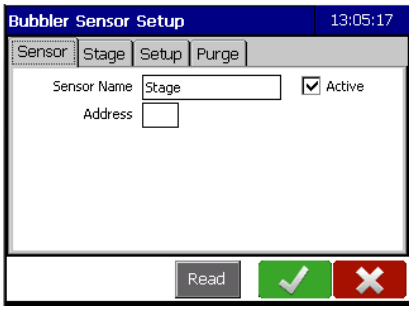
OK (green checkmark): This accepts changes in ALL the tabs. Input all desired changes in all the tabs prior to selecting OK. Once selected it saves the changes and then displays the Sensor screen.

Cancel (red X): This will cancel all the changes made in all the tabs. Tabs will revert to the previous inputs.

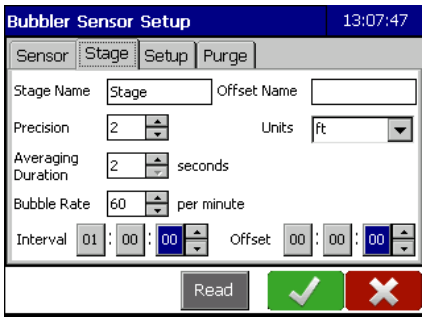
[8] Details of the M Commands can be found in Chapter 5.

4.2 SENSOR TAB

Displays the default sensor name and Address of the Bubbler.



4.3 STAGE TAB



Stage Name: This is the name of the data point. Stage is the default name and can be changed if desired.

Offset Name: Input the desired name for the Stage Offset data point. The offset is calculated automatically by the Datalogger but will only be displayed on the main Bubbler Sensor screen if the Offset Name field is populated. See section 4.6.

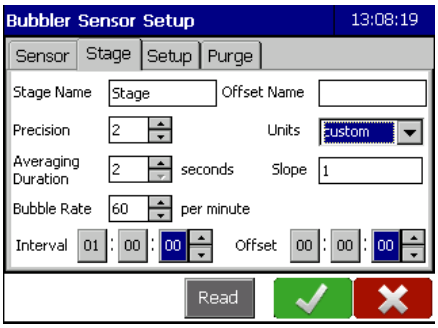
Precision: This indicates the number of decimal places to which the reading will be displayed. The maximum number is three.

Units: Select the desired units of measurement using the drop-down menu. The choices are

- m (metres)
- mm (millimetres)
- cm (centimetres)
- ft (feet)
- in (inches)
- cu

Setting Custom Unit (Slope)

Select Custom to input a slope. Once Custom is selected in the drop-down menu, a blank field will appear in which the desired slope can be input.



Averaging Duration: The period of time over which the samples taken. This will be used to calculate the displayed stage value. It takes approximately 2 seconds to take a sample. The average duration range is from 2-60 seconds.

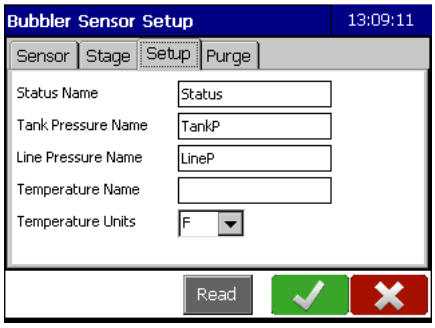
Bubble Rate: This determines the number of bubbles per minute which will be released. The rate can be set from 30-120 bubbles per minute.

Interval: This is how often a measurement will be taken. It is in HH:mm:ss format.

Offset: This determines the starting time the measurement will be taken based on time after midnight.

For example: An interval of 01:00:00 and an offset of 00:15:00 means a measurement will be taken every hour commencing at 15 minutes after midnight (00:15:00, 01:15:00, 02:15:00, etc.).

4.4 SETUP TAB



Status Name: The default name is Status and can be changed if desired.

Tank Pressure Name: The default name is TankP and can be changed if desired. Units are in psi.

Line Pressure Name: The default name is LineP and can be changed if desired. Units are in psi.

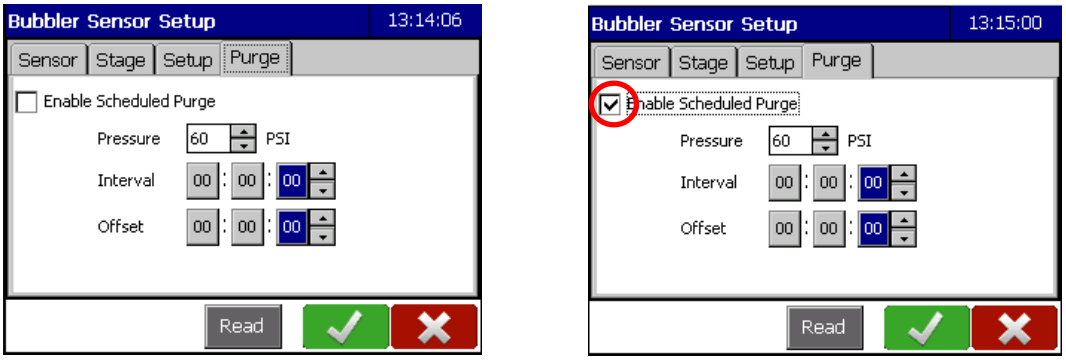
Temperature Name: Insert the desired name for the temperature variable.

Temperature Units: Select either C (Celsius) or F (Fahrenheit).

4.5 PURGE TAB

The Datalogger can initiate purges on a regular schedule to clear the hose outlet of silt or debris which may be blocking it. The frequency of the purges and the psi used to conduct them are dependent on the environment and conditions of the site. ,

> IMPORTANT! The Enable Scheduled Purge box must be selected for scheduled purges to take place. The default is to have scheduled purges disabled.



Purge Tab – default

Purge Tab showing Scheduled Purge selected

Figure 4-1: Purge tab options

Scheduled Purge

For a scheduled purge, select the **Enable Scheduled Purge** checkbox.

Select the desired pressure at which to conduct the purge. The pressure range is from 20-90 psi. The default value is 60 psi.

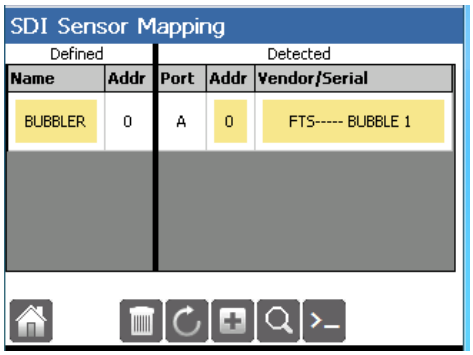
Interval: The interval is how often the purge will occur and is in HH:mm:ss format. The minimum purge interval is 10 minutes (00:10:00).

Offset: Optional. This determines the starting time the purge will commence based on time after midnight.

For example: An interval of 24:00:00 and an offset of 10:15:00 means the purge will take place daily (every 24 hours) at 10:15 a.m.

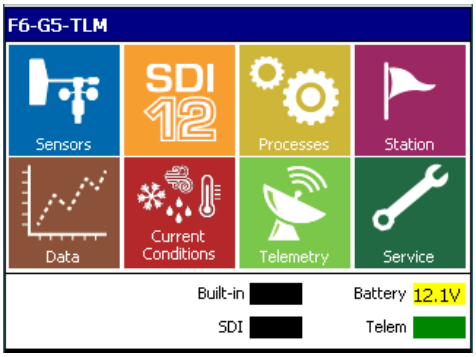
4.6 SAVE CONFIGURATION

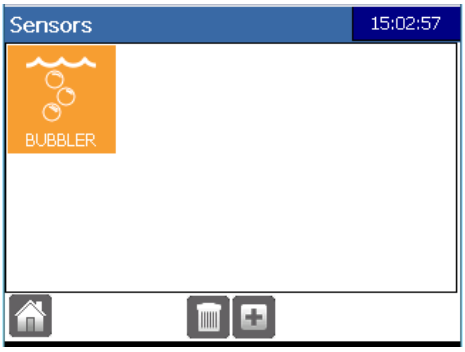
Once all tabs have been completed, select the OK checkmark on any tab. The SDI Sensor Mapping screen should display and indicate the sensor is mapped. View the Bubbler Sensor Screen and confirm configuration (see section 4.7).



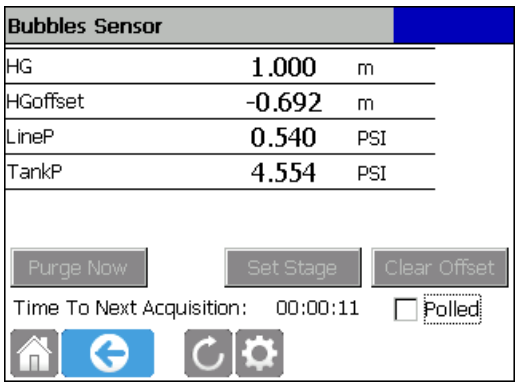
4.7 BUBBLER SENSOR SCREEN

From the home screen select the Sensors icon and then the Bubbler icon. Note that the name on the icon will be the same as the Sensor Name input on the Sensor tab. This example retains the default name.



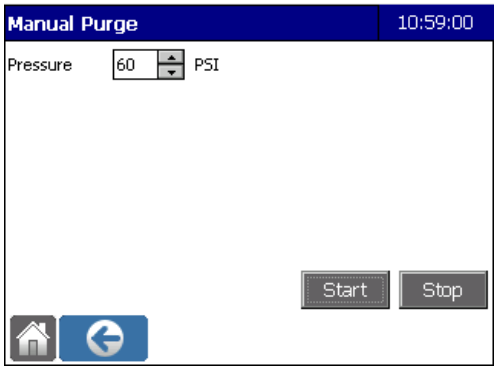


All defined data points defined in the Bubbler Sensor Setup tabs will be displayed with the latest measured values. Use the setup cog to display and edit the Bubbler Sensor Setup screen.

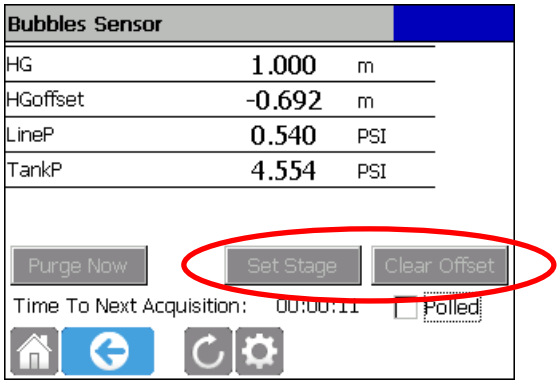


4.7.1 CONDUCT A MANUAL PURGE

Purge Now: Select this to conduct a purge. Input the desired pressure. The Purge PSI will remain at this value until changed.



4.7.2 SET STAGE AND CALCULATE/CLEAR OFFSET



Set Stage and **Clear Offset** enable the user to set and clear the stage offset value. They are present when a Stage variable is configured on the **Stage** tab. Once the stage is set, the Datalogger will automatically calculate the Stage Offset. The Stage Offset will be displayed as a data point if the Offset Name field was populated in the Stage Tab.

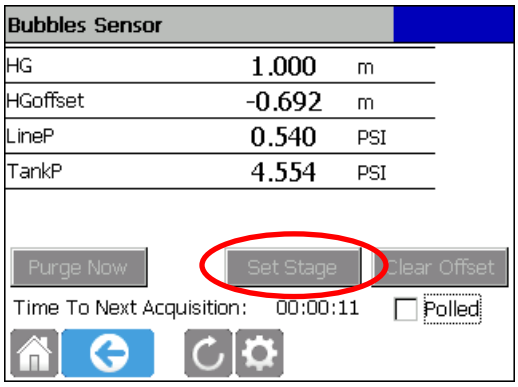
Set Stage

Once the sensor has been configured and is operating, the Set Stage and Clear Offset buttons can be used. They are present only if a stage variable has been configured on the Stage tab.

There are two methods available for setting the stage offset in the Datalogger depending on if the staff gauge reading is known or not. If it is known use the **Set Stage** button. If it is not known, use the **Polled** feature.

Staff Gauge Reading Known

If the staff gauge reading is known, press **Set Stage**, enter the staff gauge value, and confirm the changes.



The Datalogger calculates the appropriate stage offset from the current stage sensor reading.

Polling

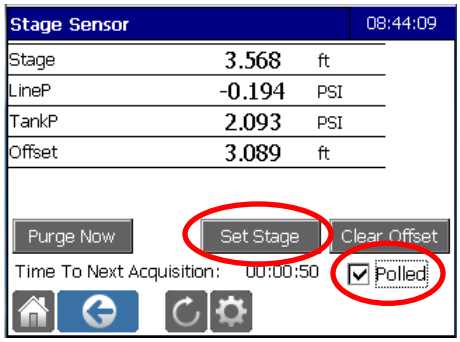
The polling option is meant as a temporary measure to confirm Bubbler operations and any data collected during the polling will not be recorded by the Datalogger. It will also not affect the Bubbler Setup values. That is to say, once polling is stopped, interval values will revert to those originally input in the Bubbler Setup Screen.

The user can select the **Polled** checkbox and then press **Set Stage** to begin a series of Bubbler readings while the user checks the staff gauge reading. After checking the staff gauge reading and returning to the Datalogger, the user can select the appropriate time stamped Bubbler reading and then enter the staff gauge value so that the Datalogger can calculate the appropriate stage offset.

The stage reported on the Display screen and on the Stage Offset Tool screen will use the units that the user has selected during the setup process.

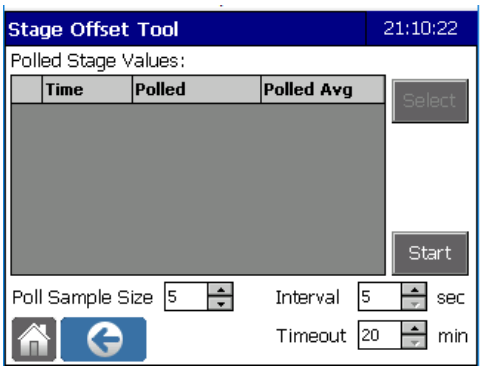
The steps to set up polling follow:

1. Tap the **Polled** box, and then select **Set Stage**.



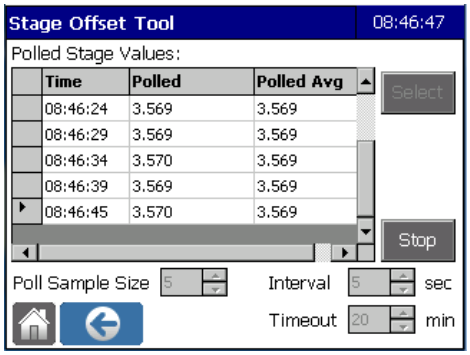
2. The **Stage Offset Tool** screen is displayed. Enter the desired **Interval** and **Timeout** times.

   Interval is the polling interval and Timeout is the period of time over which polling will take place. The **Poll Sample Size** refers to how many readings will be averaged per interval.



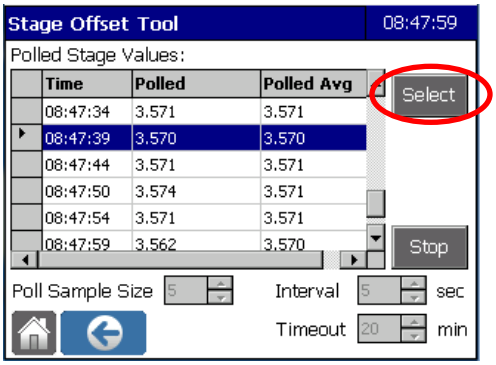
3. Synchronize your timepiece to the Datalogger and select **Start**.

   The screen is displayed in view only mode and polling commences. Polling values will be displayed until the **Stop** button is selected.

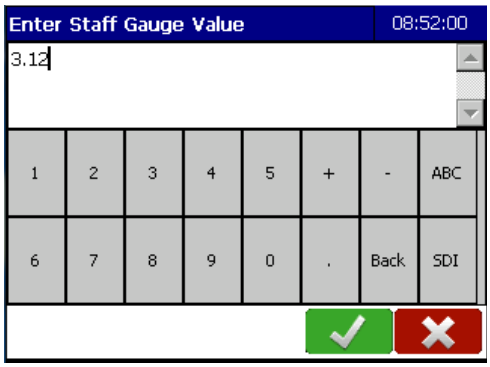


4. Go read the staff gauge. Note the time (hour, minute and second) and the observed value.

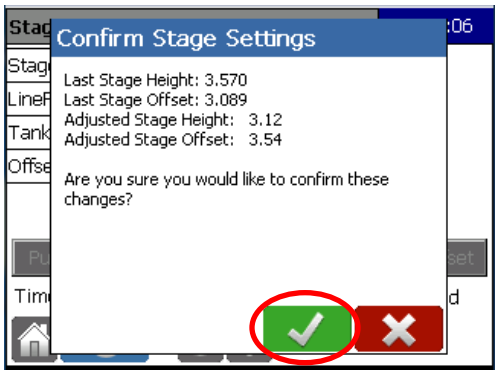
5. When you return to the Datalogger select STOP, scroll through the stage sensor readings and tap on the time that corresponds to your reading of the staff gauge. Press **Select**.



6. The **Enter Staff Gauge Value** screen appears. Enter the observed value and confirm.

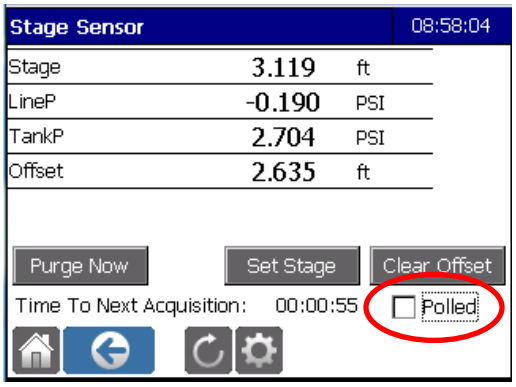


7. Confirm the new Stage Settings



8. De-select the **Polled** box. The new Stage Offset will be calculated.

IMPORTANT! You MUST de-select the polled box for the stage calculation to be implemented.



4.8 SETTING THE BUBBLER'S TIME

On power cycle, the Bubbler's date and time will be set automatically by the Axiom Datalogger. Should the Datalogger and Bubbler's times fall out of synchronization, the Bubbler's date and time can be reset using the XDT command (see section 5.2.3)

NOTE: The Bubbler's time is used to timestamp the service and log entries stored on the SD card. Transmitted data will be timestamped in accordance with the Datalogger's clock.

4.9 TRANSPARENT MODE

Entering transparent mode allows the user to send SDI-12 commands to the Bubbler through the Datalogger's SDI-12 ports. Transparent mode is used to issue those SDI-12 commands which are not incorporated into the Bubbler's sensor screen. Chapter 5 contains the complete list of the Bubbler's SDI-12 commands.

To go to transparent mode, select the SDI-12 button from the Datalogger's home screen to bring up the SDI Sensor Mapping screen. Select the transparent mode icon on the bottom of the screen. Select the port the bubbler is on and use the keyboard to type the desired commands.
See figure 4-2. Refer to the Axiom Manual for a detailed explanation of transparent mode.

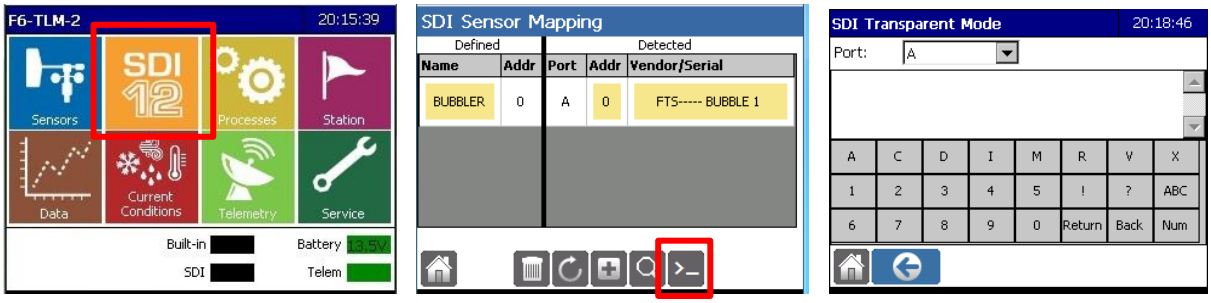


Figure 4-2: Transparent Mode

Chapter 5 SDI-12 COMMANDS

5.1 STANDARD SDI-12 MEASUREMENT COMMANDS

The Bubbler uses the standard SDI -12 Commands and protocols[9] which makes it compatible for use with DCP's or transmitters. If using an Axiom datalogger, SDI-12 commands can be entered using Transparent Mode (see Section 4.9).

The Bubbler's specific measurement commands follow.

Note the following:

- the "a" in each command should be replaced with the sensor address number
- every command must terminate with an exclamation mark (!)
- the CRC is added at the end of the message for commands with CRC
- the measurement command must be followed by a Send Data command (**aD0!**) to view the data

The format of the response to a Measurement command is ***atttn***: in which:

a	the sensor address
ttt	the specified time, in seconds, until the sensor will have the measurement(s) ready
n	the number of measurement values the sensor will make and return in one or more subsequent D commands; n is a single digit integer with a valid range of 0 to 9

Measurement response examples:

1) M Command followed by the Get Data Command:

   0M!00043

   Bubbler at address 0, measurements ready in 4 seconds, and 3 fields will be returned.

   0D0!+5.23+0+0

   Data returned is: stage (5.23), units of stage code (feet) and health status code (0).

2) M1 Command followed by the Get Data Command:

   0M1!00049

   Bubbler at address 0, measurements ready in 4 seconds, and 9 fields will be returned.

   0D0! 0+13.078+0+74.398+6+0.000

   Data returned from sensor at address 0 (first 5 fields): Stage (13.078), units of stage (feet), temperature (74.398), units of temperature (F), Offset (0.000)

   0D1!0+5.348+9.087+13.6+3

   Data returned from sensor at address 0 (last 4 fields): line pressure (5.348 psi), tank pressure (9.087 psi), Battery Voltage (13.6), health status code (3)

[9] In accordance with SDI-12 Specification, version1.3 http://www.sdi-12.org

COMMAND(S)	RESULTS
aM! aC! aMC! aCC!	Measures: • Stage • Units of stage* • Status * The status bits will only be reset if the data logger performs an XCON command or XDT for the SW_SYNC_TIME. Some HW bits can be reset.
aM1! aC1! aMC1! aCC1!	Measures: • Stage • Units of stage* • Temperature • Units of Temperature* • Offset (Units same as Stage) • Low Accuracy Line Pressure (psi)† • Tank Pressure (psi) • Battery Voltage (volts) • Status * † This is not the same line pressure source which is used to calculate stage. Stage measurements are determined using a high accuracy transducer. The low accuracy transducer should only be used as a troubleshooting tool as it provides insight into the pressure status of the system.
aM2! aC2! aMC2! aCC2!	Measures: • Purge state* • Pump on time • Pump on-off count • Pump fault count • Uncompensated stage • Status *
aM7! aC7! aMC7! aCC7!	Measures: • Purge state* • Purge pressure • Tank pressure • Status* See section 5.1.2 for details of purge actions using the M7 command. Use XPR to set purge pressure (default = 90 psi)

*See Section 5.1.1 for measurement codes and meanings

5.1.1 SDI -12 MEASUREMENT COMMAND CODES

The following codes will be returned for units of stage, temperature, purge codes and status.

UNITS OF STAGE	
Code	**Measurement Unit**
0	Feet (ft)
1	Inches (in)
2	Metres (m)
3	Centimetres (cm)
4	Millimetres (mm)
5	Custom slope

PURGE CODES	
Code	**Meaning**
0	Purge enabled
1	Purging
2	Purge disabled

TEMPERATURE	
Code	**Measurement Unit**
6	Degrees Fahrenheit (F)
7	Degrees Celsius (C)

STATUS CODES				
Value	**Meaning**	**Value**	**Meaning**	**NOTE**
0	No error detected	1024	Compressor fault	A value other than one which appears in the table means more than one status code was detected. In that case, the returned value is the sum of the status codes detected.
1	DL & Bubbler out of sync	2048	Line blocked	
2	Has rebooted	4096	Line pressure high	
4	Needs date & time set	8192	Tank leak	
256	Battery out of range	16384	System Error	
512	Temperature out of range	32768	Voltage Low	

Multiple Status Code example: Status code =7 means codes 1,2, and 4 triggered

Refer to the Troubleshooting Guide (Appendix B) for details on determining the specific indicators when multiple indicators are detected and rectifying faults.

5.1.2 CONDUCTING A PURGE USING THE M7 COMMAND

The M7 command will initiate a purge using the configured purge pressure (the default is 90 psi and can be changed with the XPR command if desired). The measurement is complete when the sensor has returned to normal operation – i.e. bubbling at the configured bubble rate.

Prior to commencing the purge, the M7 command completes a regular stage measurement and caches the value because once the purge process has started, there is a period during which the line pressure is too high to take stage measurements. Any measurement requests received before the line pressure has normalized will use this cached value.

The M7 command always responds with a fixed wait time of 300 seconds. This is well beyond the expected worst-case time required (60 seconds to charge, 60 seconds to discharge). The Bubbler will send the service request to the logger once the purging is complete, typically 80 or 90 seconds when purging at 90 psi.

5.2 EXTENDED (X) COMMANDS

In addition to the standard set of commands, the FTS Bubbler has an extension of custom SDI -12 commands called X commands that access specific features of the sensor.

The format of X commands follows the requirement for standard SDI-12 commands in that the first character of every command must be a sensor address which is then followed by the X command and terminated by an exclamation mark. Likewise, the first character of a response is also the address character.

Some commands can be used to either view a parameter ("get") or input a parameter ("set"). Set commands use an optional parameter ***P*** or a float parameter ***P.p.*** To "set" a value, the ***P*** or ***P.p*** should be replaced with the desired numeral(s). If the optional parameter is not used, it is a "get" command and will return the previously set value.

5.2.1 Required Formatting Elements

In order for X commands to be valid, the following format conditions must be met:

- the commands start with an address plus X and terminate with !
- the X command elements must be capitalized (as shown in the following table);
- there must be no spaces within the command
- in "set" commands, the '***P*** or ***P.p'*** or should be replaced with the desired numerals.

5.2.2 SETTING THE BUBBLER'S DATE AND TIME

The Bubbler's SD card stores data independently from the data logger and as such, is timestamped by the Bubbler. Transmitted data will be timestamped in accordance with the data logger's clock.

> IMPORTANT! The Bubbler's time and date MUST be input using the *Set date and Time* X-command for a timestamp to be present on the log entries. Additionally, the Bubbler's timestamp is cleared if the Bubbler has been powered off and must be reset once power is restored.

Should the data logger and Bubbler's times fall out of synchronization, the Bubbler's date and time can be adjusted using the XDT command.

5.2.3 X Commands List

X Command	Definition	Comments
aXBLD! **aXBLD*P*!**	Begin tank bleed End tank bleed	If ***P*** is empty or ***P***=B ***P***=E Bubbler needs to be power-cycled after this command in order to return to normal operations.
aXBR! **aXBR*P*!**	Get bubble rate Set bubble rate	Bubbles per minute. Minimum value is 30 and max value is 120, default is 60. To set bubble rate, replace ***P*** with desired bubble rate
aXBVI! **aXBVI*P.p*!**	Get battery voltage idle Set battery voltage idle	***P.p*** is the minimum voltage that will trigger a voltage fault, Default = 10.8.
aXBVL! **aXBVL*P.p*!**	Get battery voltage low Set battery voltage low	***P.p*** is the minimum voltage that will trigger a battery fault, Default = 8.0
aXBVH! **a XBVH*P.p*!**	Get battery voltage high Set battery voltage high	***P.p*** is the maximum voltage that will trigger a battery fault. Default = 16.5
aXCON!	Configuration change	Reset the configuration change flag indicating the settings are in sync with the data logger.
aXDOC!	Get date of calibration	Returns in YYYYMMDD format.
aXDOM!	Get date of manufacture	Returns in YYYYMMDD format.
aXDT!	Get date and time	Returns date and time in YYYYMMDD,HHMMSS format.
aXDT*YYYYMMDD, HHMMSS*!	Set date and time	aXDTYYYYMMDD,HHMMSS! Example: a20170125,130000! Sets the Bubbler's date to 2017 January 25 1 p.m. Date range is from 20170101 – 21050101 (Jan 1, 2017 to Jan 1, 2105) Time range is from 000000 to 235959

X Command	Definition	Comments
aXFSN!	Get serial number	Example: 123456
aXI!	Get firmware version and build date	Example: 1.0.65,2017-06-21 17:19:29 UTC
aXID! **aXID*P*!**	Get site ID Set site ID	Site ID is an alphanumeric string of maximum 10 characters. aXID!abubbler1 (gets Site ID of "bubbler1") aXIDbubbler1! (sets Site ID to bubbler 1) There is no error checking for symbols. Symbols can be entered but are not supported on the Bubbler's display.
aXIMIN! **aXIMIN*P*!**	Get 4-20 mA minimum Set 4-20 mA minimum	Returns the set minimum value Replace ***P*** with desired value to set minimum Default = 0.0 The minimum and maximum values must differ by 0.2 psi (6 inches). Stored in psi
aXIMAX! **aXIMAX*P*!**	Get 4-20 mA maximum Set 4-20 mA maximum	Returns the set maximum value Replace ***P*** with desired value to set maximum value Default = 0.0 The minimum and maximum values must differ by 0.2 psi (6 inches). Stored in psi
aXPCB!	Get hardware revision	This is derived by a resistor set in the hardware.
aXPUMP! **aXPUMP*P*!**	Get pump (compressor) statistics Set pump (compressor) statistics	Returns on-time, on-off count, fault count, and ***** pump idle time fault count. ***** this field is displayed in models with FW ver 1.5.273 and later (manufactured after1 July 2022) ***P*=**Z then statistics are zeroed
aXPR_!	Get purge pressure	Return purge pressure setting in psi
aXPR_*P*_!	Begin/end purge or Set purge pressure	If ***P*** is B = begin purge mode If ***P*** is E = end purge mode. Replace ***P*** with desired purge pressure (in psi) Example: aXPR90! (set purge pressure at 90 psi) Valid range is 20 to 90. Default :90

X Command	Definition	Comments
aXSH!	Get stage height value	Stage can be checked by issuing an M command. Returns the value in current units.
aXSH*P*!	Set stage height value	If ***P***=nnn.n stage value is set to the input number aXSH10!a If ***P***=Z the stage offset is set to zero (does not zero the stage reading, only the offset).
aXSI!	Get the interval between automatic, periodic stage samples	Get interval: aXSI!a300 Interval is 300 seconds This command is intended to support periodic 4-20mA loop updates without an SDI-12 command in order to operate the Bubbler stand-alone or connected to a SCADA system. See section 1.5.2 for use and details of this feature.
aXSI*P*!	Set the interval between automatic, periodic stage samples	***P*** = nn In which nn is the periodic sampling interval in seconds Interval range: 60 - 86400 seconds (1 minute – 24 hours) Default sampling interval = 0 Setting the interval to 0 disables any automatic, recurring stage measurements. **IMPORTANT!** An unusable configuration results if both the sample period (averaging duration - **aXSP*P*!)** and this stage sample interval are set to 60 seconds. There needs to be a minimum of 10 seconds between the sample period and the periodic stage sample interval. Acceptable configurations: 1) Sample period = 60 seconds Periodic stage sample interval = 70 seconds 2) Sample period = 50 seconds Periodic stage sample interval = 60 seconds Every stage measurement will update the [optional] 4-20mA output. See Section 1.5.2 for use and details of this feature.
aXSL!	Get slope	Get slope: aXSL!a2.786

X Command	Definition	Comments
aXSL*P*!	Set slope	Set slope: aXSL2.786!a The value range ***P*** is from 0.100 to 999.999 (inclusive). Once the slope is set using this command, the units are considered "custom" and the Bubbler's screen will display "cu" in the Units field of the Set Stage screen. This is useful when the site requires the slope to be a non-standard value. See X command **aXSU*P*!** for the built-in list of options.
aXSO! **aXSO*P!***	Get stage offset in psi Set stage offset in psi	These commands are used when swapping a Bubbler and it is desired for the new installation to use the previously set offset. Before swapping the Bubbler, use the "get offset" command and ensure the response is recorded. Once the Bubbler is swapped, use the "Set Stage Offset" command. Replace ***P*** with the value returned from the "Get Stage Offset" command from the previous Bubbler. Note that, although this command uses psi, the offset displayed on the Bubbler's screen and returned as part of an M command will be in the selected measurement units, not psi. Appendix C contains a table of useful conversions from depth to psi for reference.
aXSP!	Get period for samples in seconds	Returns sample period (averaging duration). The stage value is an average of the number of samples taken over the specified sample period (averaging duration). Each sample takes approximately 2 seconds. The sample period range is from 2 – 60 seconds. The default setting is 8s.
aXSP*P*!	Set period for samples in seconds	***P*** = nn aXSP30! Sets sample period to 30 seconds The min value is 2 and max value is 60 seconds. Default: 8
aXSU!	Get stage units	Returns the code (0-5) for stage units (see list below in "Set stage units") 5 = *Custom Units(Cu)* – this indicates a slope was manually set using the '**aXSL*P*!**' command

X Command	Definition	Comments
aXSU*P*!	Set stage units	***P*** = 0 sets units to *ft (feet) (slope=2.307)* = 1 sets units to *in (inches)* (slope=27.680) = 2 sets units to *m (meters) (slope=0.703)* = 3 sets units to *cm (centimeters) (slope=70.3250)* = 4 sets units to *mm (millimeters) (slope=703.250)* =.5* sets units to *psi (slope=1.0)* * This is the default custom unit setting. Any other slope entered using the "Set slope (**aXSLP!)** command will result in an indication of 5 (custom units). The user must be aware of the units associated with the input slope value.
aXTU! **aXTU*P*!**	Get temperature units Set temperature units	Returns either 6 (for ·F) or 7 (for ·C) If ***P*** = 6 temperature is Fahrenheit If ***P*** = 7 temperature is Celsius aXTU6!a (set to ·F) aXTU!a6 (get command confirms ·F)

Appendix A SPECIFICATIONS

PERFORMANCE DATA	
Accuracy	3mm (0.01ft) or 0.1% of the effective stage, whichever is greater
Operating Pressure (Depth)	0 to 30 psi (0 to 21m) (0 to 70ft)
Purge Pressure	20 to 90 psi (user selectable)
Gas Delivery	Constant flow bubbler with user programmable bubble rate. 30 to 120 bubbles per minute
Drift	Combined zero drift and span drift ≤ 0.1% FS/year
AMBIENT CONDITIONS	
Operating Temperature	-40°C to +60°C (-40°F to +158°F)
Storage Temperature	-55°C to +85°C (-67°F to +185°F)
Relative Humidity	0-95% non-condensing
PHYSICAL	
Dimensions	254mm x 203mm x 152 mm (10" x 8" x 6")
Tank Size	0.8L (27.05 fl oz)
Weight	5.88 kg (13 lbs)
Ingress Protection	IP66
Enclosure Material	NEMA 4X Fiberglass
On-Board Screen	4x20 character display
MECHANICAL	
Compressor Capacity	Up to 28.3 L/min
Orifice Line Fitting	Brass Swagelok tube fitting (for 3/8" outside diameter hose)
Connection to Desiccator	Barbed hose fitting for 5/16" ID hose
POWER	
Power Requirements	10.8 to 16.5VDC
Average Active Current[10]	27 mA
Peak Current (Purging)	16 A to fill tank to 90 psi (approx. 20 seconds)
COMMUNICATION	
SDI-12 Interface:	Version: 1.3 Protocol: 7 bit even parity, 1 stop bit Bit Rate: 1200 BPS Supply Voltage: 9.6 – 16 VDC
4-20mA	Optional
4-20mA OUTPUT	
Loop Voltage	9.6V – 33V
Resolution	0.37µA
Accuracy	0.12%*(420_stage_max_ft - 420_stage_min_ft) / 69.20[11] after loop compensation

[10] Based on 1 purge per day, 60 bubbles per minute, 15-minute measurement interval, and 8 second averaging

[11] In which 420_stage_max_ft and 420_stage_min_ft are the maximum & minimum stages (in ft) set for the 4-20 output

Appendix B TROUBLESHOOTING GUIDE

B.1 MECHANICAL INDICATORS

PROBLEM	POSSIBLE CAUSE	ACTIONS
Pressure dropping/excessive pump operation	System leak (either internal or at Bubbler line connections)	1) Ensure orifice line is correctly seated and tightly attached at all connection points. All fittings should be attached using Teflon tape to maintain tight seal. 2) Inspect orifice line for splices. Replace spliced line. 3) If Bubbler line connections are correct, an internal leak is indicated. Contact FTS Support to return Bubbler.
Compressor not running	Insufficient power	1) Ensure Bubbler has a direct power source. It cannot be fully powered through the Datalogger's SDI port (section 2.6.2). 2) Check power connections (including solar panel, if using). 3) Check battery (replace if necessary).
Incorrect Stage	A) Erroneous offset value	1) Set Stage directly by entering the staff gauge value (if known); or 2) Poll the sensor. Refer to Section 4.6.2.
	B) Blocked orifice line	1) Conduct a purge. 2) Ensure orifice is free from larger obstructions/blockages.
Slight pause in bubble release	Measurement being taken	No action required. This is normal operation.

B.2 MEASUREMENT VALUE FAULT INDICATOR

A fault is indicated if The M or M1 command returns a value of -99999.0.

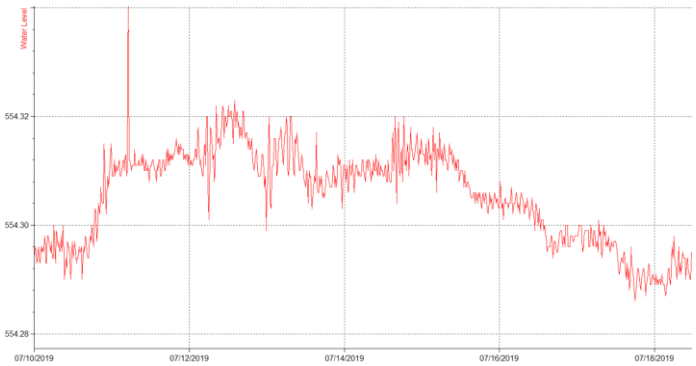
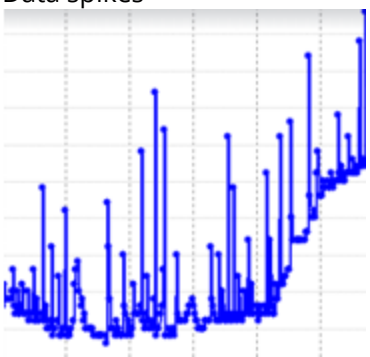
If after 45 seconds of purging, the line cannot be cleared, and the tank pressure is greater than 35 psi, a LINE_HIGH will be indicated in the status screen and the compressor will stop. The M and M1 commands will continue to be sent but will return values of -99999.0. The unit will continue to attempt to bubble (the solenoid will continue to open and close) in the event the blockage does get cleared and normal operations can resume.

Refer to the High Readings section in Section B3 for troubleshooting.

B.3 DATA INDICATORS

PROBLEM	POSSIBLE CAUSE	ACTIONS
High Readings	Orifice line obstruction	Prove the line: Use a 5-gallon bucket of water and a length of orifice line (approximately 5 feet) attached to the Bubbler. Take some readings. If the readings are correct, a line blockage is indicated. 1) Ensure the orifice line termination is free from silt/obstructions. 2) Use a wire to ream the orifice line termination. 3) Inspect line run for possible blockage points (break in the conduit/compressed areas).
Low Readings	A) Draw Down: caused by reduced depth of water on the downstream side of obstructions (bridge piers, boulders etc.). Often accentuated during periods of increased flow and debris accumulation.	Move the orifice line termination to a calm area.
	B) Fittings Leak Note: In cold weather fittings can shrink, causing a leak. Cold weather leaks are often indicated by low readings during cool periods followed by accurate readings during warm periods later in the day.	1) All fittings should be attached using Teflon tape to maintain tight seal. 2) Tighten all fittings and connection points.
	C) Spliced line leak	1) Spliced lines should be replaced. 2) If unable to replace spliced line, take measures to repair the integrity of the splice.

DATA INDICATORS (con't)

PROBLEM	POSSIBLE CAUSE	ACTIONS
Data painting (saw tooth graph)	 Figure B-1: Example of data painting	
	A) Buried orifice line termination	Ensure the orifice line termination is free from silt/obstructions.
	B) Orifice line termination not secure (moving in the flow)	Ensure the orifice line termination point is secured to prevent any movement.
	C) Moisture in orifice line	Remove any catenaries along the orifice line run (moisture can accumulate in lower points along the line's run).
	D) Samples are too frequent - dampening is required	Increase the sampling period (Averaging Duration) with the XSP command (see Section 5.2.3).
Data spikes 	Air intake path is restricted	1) Ensure there are no blockages in the air intake path, including possible blocked desiccant inlet vent 2) Remove any check valves or similar restricting attachments on the air inlet path (including check valves on the air inlet port of a desiccator) 3) Ensure each Bubbler has a dedicated desiccator and air intake path (i.e. do not run multiple Bubblers on the same desiccator)
For the curious: The atmospheric reference for the pressure transducer is based on the air pressure from the air inlet. A temporary difference in the atmospheric reference occurs when the air inlet path is plugged or restricted, this results in a temporary difference in the atmospheric reference until pressure equalizes. These periods will be displayed as data spikes which correspond to tank top ups (for a blocked valve) or when the check valves engage after the compressor stops.		

B.4 BUBBLER STATUS SCREEN FAULT INDICATORS

The Bubbler's status screen only displays a single fault. The possible faults are prioritized so in the case of multiple faults, the higher priority fault will be displayed. The following table lists the faults in order of priority from highest to lowest.

FAULT	POSSIBLE CAUSE	ACTIONS
BATTERY	Voltage has dropped below minimum 8.0 VDC	1) Replace the battery. Voltage this low results in deep discharge of battery and it is unlikely to recharge and hold a charge. 2) Check for possible causes for the power supply system failure. a) Ensure Bubbler has a direct power source. It cannot be fully powered through the Datalogger's SDI port (section 2.6.2) b) Check power connections c) Ensure solar panel is placed for maximum sun exposure d) Clean solar panel e) Replace the solar panel with one with a larger supply (the current draw exceeds the supply of the solar panel)
VOLTAGE_LOW	Voltage has dropped below minimum 10.8 VDC	Check for possible causes for the power supply system failure as in Step2 above
TEMPERATURE	Bubbler operating outside of its temperature range	1) Take physical measures to protect Bubbler from extreme environmental conditions such as placing in a shelter.
COMPRESSOR	Compressor failure	Contact FTS Support.
LINE_BLOCK	Blocked line	1) Conduct a purge 2) Ensure orifice is free from larger obstructions/blockages 3) Inspect along length of line for crimps, compressed areas. 4) May have to bleed tank, cut power and remove/replace line
LINE_HIGH	Tank pressure >35 psi	1) Take action as described in Section B3 – High Readings. 2) If fault continues after all apparent line blockages have been cleared, contact FTS Support.

FAULT	POSSIBLE CAUSE	ACTIONS
TANK_LEAK	Triggered if tank pressure has not increased by 0.5 psi after 10 seconds of compressor operation.	Contact FTS Support.
SYSTEM	Internal misconnection/damage	Contact FTS Support.
PUMP_RATE_LOW	Low pump cycle rate	Refer to Section B.5. If Fault continues, contact FTS Support.
PUMP_RATE_HIGH	High pump cycle rate	Refer to Section B.5. If Fault continues, contact FTS Support.

B.5 PUMP CYCLE RATE INDICATORS

Pump cycle rate faults are indicated If a Measurement command returns a health status code 65536 or 131072 ("Low pump cycle rate" or "High pump cycle rate"). Measurement commands which include the health Status Field are the M!, M1!, M2!, M3!, and M7! Commands. The stage reading in a measurement command which includes health status indicator of 65536 or 131072 ("Low pump cycle rate" or "High pump cycle rate") should be deemed suspect and ignored.

These status fields indicate the fault condition has occurred at sometime since the previous SDI-12 Measurement command was received. This means any transient faults which occurred between measurement commands will be reported, even if the fault was not active at the time of the last measurement command. If the user makes a follow-up measurement request, and the status field is active, then the stage accuracy is suspect.

If the bubbler is no longer experiencing a high or low pump cycle rate, it will remove the error code from the subsequent Measurement command and the stage value listed will now be considered correct.

B.5.1 Troubleshooting Low Pump Cycle Rate

A low pump cycle rate occurs when pressure in the tank is not decreasing at an expected rate, indicating the air in the system is restricted in some way. This can occur when there is a low voltage supply (< 10.8V) aggravated by environmental conditions such as extreme cold (< -40˚C/F) and humidity. Any stage reading returned with this fault should be discarded.

Conduct the following in order:

1) Confirm supply voltage. If not > 10.9V charge/replace battery.

2) Confirm the desiccant is dry. Inspect the desiccant in the clear polycarbonate plastic bowl of the dryer. If it is pink (wet), replace it. Blue indicates it is dry.

3) Disconnect the orifice line and bleed the tank. If the tank does not bleed, contact FTS Customer Support.

4) If the tank successfully bleeds, the blockage may be in the orifice line.

    a. Reconnect the orifice line and conduct a purge.

    NOTE: if there is a line blockage, the purge function may not perform as expected. The LINE_BLOCK fault will be indicated

    b. If purge does not work, inspect the orifice line and clear any blockages. Refer to section B.4 for detailed LINE_BLOCK actions. Confirm all blockages have been cleared by conducting a purge. If purge still unsuccessful, consider proving the line as detailed in section B.3 under "High Reading" actions.

5) If Low Pump Cycle Rate continues, contact FTS Customer Support

B.5.2 Troubleshooting High Pump Cycle Rate

A high pump cycle rate fault occurs when the compressor is running more often than expected and may indicate a leak in the system. Any stage reading returned with this fault should be discarded.

Conduct the following in order:

1) Confirm orifice line connection to the Bubbler is tight.

2) Inspect the orifice line for tears damage (tears, holes, poor connections).

3) If High Pump Cycle Rate continues contact FTS Customer Support

B.6 SDI-12 RESPONSE HEALTH STATUS CODES/ERROR INDICATORS

The Status field is the last field returned in any of the SDI-12 measurement commands. It shows all faults that occurred since the last measurement command was received. A value other than one which appears in the Status Code table means more than one status flag was detected. In that case, the returned value is the sum of the status codes detected.

For example: Status code 3 = Codes 1 and 2 triggered
Status code 7 = Codes 1,2, and 4 triggered

Section B.5.2 provides different methods which can be used to determine the individual status indicators if multiple status flags were triggered.

STATUS CODES		
VALUE	**MEANING**	**ACTION**
0	Bubbler operating normally	None required
1	Data logger & Bubbler out of sync	Synchronize the data logger and Bubbler by issuing the ***a*XDT!** command
2	Has rebooted	
4	Needs date & time set	Set the date and time. Issue the ***a*XDT*YYYYMMDD, HHMMSS*!** command (see section 5.2 for details)
256	Battery out of range	1) Ensure Bubbler has a direct power source. It cannot be fully powered through the Datalogger's SDI port (section 2.6.2). 2) Check power connections (including solar panel if using) 3) Check battery (replace if necessary)
512	Temperature out of range	Take measures to protect Bubbler from extreme ambient temperature conditions.
1024	Compressor fault	Contact FTS Support and return Bubbler to FTS for repairs
2048	Line blocked	1) Conduct a purge 2) Ensure orifice is free from larger obstructions/blockages 3) Inspect along length of line for crimps, compressed areas. 4) May have to bleed tank, cut power and remove/replace line
4096	Line pressure high	
8192	Tank leak	Contact FTS Support and return Bubbler to FTS for repairs
16384	System Error	Contact FTS Support and return Bubbler to FTS for repairs
32768	Voltage Low	Check battery connections, battery, and power system (solar panel) connections
65536	Low pump cycle rate	Refer to Section B.5. If Fault continues, contact FTS Support.
131072	High pump cycle rate	Refer to Section B.5. If Fault continues, contact FTS Support.

B.6.1 Managing Status Indicators

If using an Axiom Datalogger, status codes of 1, 2 and 4 (and by default 3 and 7) are managed by the Datalogger. When one of the aforementioned codes is detected, the Axiom Datalogger will automatically send the required X-command to rectify the situation. If your Axiom is continuously showing a health status indicator of 7, that indicates a failure of the Datalogger to fully communicate with the Bubbler and a site visit is required to determine the cause.

If using a non-AXIOM data logger the most common health status indicator will be 4. A "4" means the Bubbler is still operating normally, but the Bubbler's SD card's[12], time stamp will not be accurate. If your data logger can be programmed to set the Bubbler's date and time every 24 hours (as the Axiom does), the appearance of this indicator can be mitigated.

[12] The SD card is used by FTS factory personnel for troubleshooting.

Also, for non-AXIOM data loggers, if any configuration change was made or the Bubbler was rebooted (after a power cycle, for example), the ***α*XCON!** command should be issued to clear those status codes.

B.6.2 Determining Individual Status Codes when Several Indicated

A value returned other than one of the values listed in the table in section B.5 indicates multiple status/error flags. There are two methods which can be used to determine which health status/error messages are indicated: converting to binary or calculating.

Method 1) Convert to Binary

Convert the status value to binary – easily done by inputting the value into a programmer calculator and converting it or using an on-line binary converter. Each health status/error indicator is identified by a binary Bit. The Bits relate to the place numbers read from right to left, starting at Bit 0, followed by 1,2,3, etc.. A place number which has a "1" indicates that Bit is set. Set Bits identify the health status/error indicators which have been flagged.

> **Example**: The health status/error indicator value returned is 1031 after a measurement command followed by a send data command:
>
> 0D0! +5.23+0+23.5+7-1.3+20+30+12.5+1031

1031 converts to the binary sequence 0100 0000 0111 showing Bits 0,1,2, and 10 are set.

Decimal Digit Value	2048	1024	512	256	128	64	32	16	8	4	2	1
Sequence	0	1	0	0	0	0	0	0	0	0	1	1
BIT	11	10	9	8	7	6	5	4	3	2	1	0
Set		√								√	√	√

The health status/errors indicated by the set Bits are found in the following table:

BIT	INDICATES	BIT	INDICATES
0	DL & Bubbler out of sync	11	Line blocked
1	Has rebooted	12	Line pressure high
2	Needs date & time set	13	Tank leak
3-7	Not used (always 0)	14	System Error
8	Battery out of range	15	Voltage low
9	Temperature out of range	16	Pump rate low
10	Compressor fault	17	Pump rate High

Method 2) Calculating

1) Value (a) is returned from the get data (aD!) command in the health status field. Find the value (b) in the Health Status Table that is closest to but less than (a). Value (b) indicates the first health status indicator.

2) Subtract (b) from (a): a-b= c

3) Find the value (d) in the Health Status/Error Table that is closest to but less than (c). Value (d) indicates the second health status indicator.

4) Subtract (d) from (c): c-d = (e)

5) Find the value (f) in the Health Status/Error Table that is closest to but less than (e). Value (f) indicates the third health status indicator.

6) Continue in this fashion until the difference of the two values = 0

Example: 0D0! +5.23+0+23.5+7-1.3+20+30+12.5+263

1) Value (a) = 263. Value (b) = **256 Battery out of range**

2) 263-256 = 7. Health status value closest to 7 is **4= Needs date and time set**

3) 7 – 4 = 3 Health status value closest to 3 is **2= the Bubbler has rebooted**

4) 3-2 = 1 Health status Value closest to 1 is **1= data logger and Bubbler are out of Synchronization**

5) 1-1 = 0 No further indicators

STATUS CODES	
VALUE	**MEANING**
0	Bubbler operating normally
1	Data logger & Bubbler out of sync
2	Has rebooted
4	Needs date & time set
256	Battery out of range
512	Temperature out of range
1024	Compressor fault
2048	Line blocked
4096	Line pressure high
8192	Tank leak
16384	System Error
32768	Voltage Low
65536	Pump rate low
131072	Pump rate high

Appendix C USEFUL CONVERSIONS

C.1 Inches/Feet to PSI

INCHES	psi
0.25	0.009
0.5	0.018
0.75	0.027
1	0.0361
2	0.0723
3	0.1084
4	0.1445
5	0.1806
6	0.2168
7	0.2529
8	0.289
9	0.3251
10	0.3613
11	0.3974

INCHES	psi
20	0.7225
30	1.0838
40	1.4451
50	1.8063
60	2.1676
70	2.5288
80	2.8901
90	3.2514
100	3.6126
200	7.2253
300	10.8379
400	14.4505
500	18.0631

FEET	psi
1	0.4335
2	0.867
3	1.3005
4	1.7341
5	2.1676
6	2.6011
7	3.0346
8	3.4681
9	3.9016
10	4.3351

FEET	psi
20	8.6703
30	13.0054
40	17.3406
50	21.6757
60	26.0109
70	30.346
80	34.6812
90	39.0163
100	43.3515
200	86.703

C.2 Millimetres/Centimetres/Metres to psi

mm	cm	m	psi
1	.1	.001	0.0014
2	.2	.002	0.0028
3	.3	.003	0.0043
4	.4	.004	0.0057
5	.5	.005	0.0071
6	.6	.000	0.0085
7	.7	.007	0.01
8	.8	.008	0.0114
9	.9	.009	0.0128
10	1	.01	0.0142
20	2	.02	0.0284
30	3	.03	0.0427
40	4	.04	0.0569
50	5	.05	0.0711
60	6	.06	0.0853
70	7	.07	0.0996
80	8	.08	0.1138
90	9	.09	0.128
100	10	0.1	0.1422

mm	cm	m	psi
200	20	.2	0.2845
300	30	.3	0.4267
400	40	.4	0.5689
500	50	.5	0.7111
600	60	.6	0.8534
700	70	.7	0.9956
800	80	.8	1.1378
800	90	.9	1.2801
1000	100	1.0	1.4223
2000	200	2.0	2.8446
3000	300	3.0	4.2669
4000	400	4.0	5.6892
5000	500	5.0	7.1115
6000	600	6.0	8.5338
7000	700	7.0	9.9561
8000	800	8.0	11.378
9000	900	9.0	12.8007
10,000	1000	10.0	14.223
20,000	2000	20.0	28.4459
30,000	3000	30.0	42.6689
40,000	4000	40.0	56.8918
50,000	5000	50.0	71.1148

Appendix D PARTS AND ORDERING INFORMATION

FTS Bubbler ordering information

Part Number	Description
SDI-Bubbler	Bubbler, SDI

Spare Parts / Accessories Ordering Information

Part Number	Description
19861	Power terminal block, Bubbler
19862	Data terminal block, Bubbler
19865	Swagelok Nut Set, Bubbler
19864	Orifice line connector ferrule set for Swagelok fitting
18729	Barbed hose fitting for 5/16” ID hose For connecting desiccant tubing to the Bubbler
19443	1.5m SDI communication cable with flying leads both ends
19442	1.5m SDI communication cable, MC one end and flying leads other end
18945	8ft cable with 20A fuse, flying leads on both ends
19062	Orifice Tubing, .125" ID x .375" OD - 500ft Roll
19063	USGS Standard Orifice Fitting, Galvanized
19055	Desiccant Air Dryer – large (includes one charge of desiccant)
19057	Replacement desiccant - large
19060	Desiccant Air Dryer – small (includes one charge of desiccant)
19056	Replacement desiccant - small
19468	Desiccant tubing – 1ft sections
DESICCANT-BRKT-LRG	Desiccant bracket and screws - large
DESICCANT-BRKT-SM	Desiccant bracket and screws - small
19469	Barbed hose fitting for 5/16” ID hose For connecting desiccant tubing to the desiccant canister
20625	Inlet vent for desiccant air dryer
21069	Metal feet
21014	Keyway mounting plate

DOCUMENT REVISION HISTORY

Revision #	Date	Description
1	1 Aug 2017	SDI-12 commands based on ver 0.78 of the Bubbler SDI Command Set
2	14 Aug 2017	Updated for Axiom AS ver 3.8.0.57 (Bubbler extension).
3	10 Apr 2018	Added shield wire to SDI-12 connection, peak current info, power cable requirements. Updated Bubbler faults, part numbers, Bubbler clock information.
4	23 Jul 2018	Added 4-20mA information. X commands based on ver 0.90 of RD-5198 Bubbler SDI Commands.
5	13 Sept 2018	Added VOLTAGE_LOW to list of faults and Troubleshooting Guide.
6	25 Oct 2018	Updated sample period default, added information on setting Bubbler's timestamp, changed health status indicators/errors codes to Status codes, corrected Appendix C tables. JIRA-BB-577. Added FCC compliance statement.
7	04 Jun 2019	Added Australia/New Zealand regulatory compliance mark (BB-612). Added 4-20mA accuracy to specifications (BB-620, BB-640). Expanded installation instructions for desiccant (BB-670), added M7 command (BB-420)
8	11 Jul 2019	Updated M1 description. Updated Axiom Bubbler Extension screen shots.
9	13 Aug 2019	Added desiccant maintenance detail
10	21 Oct 2019	Updated part number, directions for new desiccant inlet vent (BB-762); expanded definition of Averaging Duration in Ch3, added information to XSH command, added use of XSH command and Data Spikes to Troubleshooting section (BB-773 and BB-784)
11	26 Nov 2019	Added silica gel handling precautions (OHS-423)
12	05 Feb 2020	Added Bubbler Response Times to Stage Changes (BB-653) Added instructions on mounting screws (BB-812), Corrected slope units for meters (aXSUP)
13	05 Nov 2020	Changed figure 1-1 to show new metal feet option (part# 21069). Removed feet from cover image ((BB-821). Added example picture of data spikes in Troubleshooting Section
14	15 Dec 2020	Referenced Swagelok ferrules are single use and added part# (BB-837)
15	12 Apr 2021	Added max orifice line length, drift spec, corrected large desiccant part number (BB-865, BB-841, BB-850)
16	02 Aug 2022	Added new field to XPUMP command (BB-972) More stuff

17	22 Oct 2022	Updated with new commands and error messages, troubleshooting for pump cycle rate indicators (new section B.5) (BB-972). Added mounting option part numbers(PM-417)
18	14 Dec 2022	Updated with information on periodic 4-20mA stage readings and aXSIP! Command.