MODEL 2950
TURBO™ LIQUID FLOW CONTROLLER
USER GUIDE

JULY 2021

Patents: www.tsi.com/patents

Prepared by: MSP - A Division of TSI
5910 Rice Creek Parkway, Suite 300
Shoreview, Minnesota, U.S.A. 55126
Phone: 651-287-8100
Fax: 651-287-8140
Internet: www.tsi.com

Revision Log

Title: User Guide Model 2950 Liquid Flow Controller

Document #: 6015650, Rev 0

Rev	Affected Pages	Description	CAPA / Project	Release Date
0	All	Preliminary Release	D/00380	July 2021

Address: 5910 Rice Creek Parkway, Suite 300, Shoreview, MN 55126, U.S.A.
Telephone: +01 (1) 651-287-8100
Fax: +01 (1) 651-287-8140
email: mspsales@tsi.com

Document Approval

Title: User Guide for the Model 2950 Liquid Flow Controller
Document No.: 6015650, rev 0

Approved:

____ Date: _____________
On behalf of the Product Manager

____ Date: _____________
On behalf of Safety

____ Date:_____________
On behalf of the Quality Assurance

TABLE OF CONTENTS

1 SAFETY

1.1 SAFETY NOTATIONS

The following safety notations that are used throughout the Liquid Flow Controller user documentation:

WARNING	*Significant potential for serious personal injury may exist if instructions are not followed correctly. Text appears in Red.*
CAUTION	*Potential damage to the equipment may occur if instructions are not followed correctly, but does not present significant potential for serious personal injury. Text appears in Blue.*
NOTE or TIP	*Additional information to aid the operator in carrying out the instructions. No equipment damage or personal injury is likely to occur if the instruction is not followed. Text appears in Black.*

1.2 CHEMICAL SAFETY

Always follow the spill handling procedures indicated in the SDS of the chemicals when leakage or spill occurs. Check the compatibility of the chemicals with the wetted materials of the Model 2950 Liquid Flow Controller.

The Model 2950 is capable of handling a variety of chemicals. The **user** is **responsible** for verifying that the wetted materials of the controller are compatible with the chemicals being sensed. These chemicals must also be checked for flammability and the potential of being toxic if inhaled and the appropriate precautions must be taken. They may also be an irritant to the eyes and skin. Refer to the Safety Data Sheet provided by your chemical supplier and take the following precautions for safe and proper use:

Shipment and Dropage Have the Potential to cause damage and leaks

Leakage Test is a Requirement Before Usage

- Always read the Safety Data Sheet
- Avoid contacting chemicals with eyes, skin, and clothing.
- Wear all necessary protective clothing
- Keep chemical containers tightly closed and away from heat and open flame.
- Use chemicals only in a well-ventilated area.
- If you smell chemicals and develop a headache, or feel faint or nauseous, leave the area immediately. Ventilate the area adequately before returning.

When connecting the controller, follow the guidelines in section 3.2 to avoid leaks.

1.3 HIGH PRESSURE SAFETY

The pressure rating of the Model 2950 depends upon the version of the controller being used. If the pressure rating is exceeded, the controller may rupture and release the chemical flowing through it.

WARNING: Do not exceed the pressure rating of the controller (see section 5.1)

1.4 Electrical Safety

The Model 2950 requires connection to a 10-30Vdc single fault power supply. (See "Specifications" for power requirements.) The primary supply voltage (ex. 120V) must not contact the secondary voltage (ex. 24V) under a power supply fault. An 'Information Technology' supply approved under the EN 60950 or the UL 1950 standard is recommended.

The controller generates a variable output nominally 25mA @ 130V to control the Piezo Valve. Exposure to uninsulated electrical voltage or current within the enclosure of the Model 2950 may result in electrical shock. Only certified technicians should service the 2950.

1.4.1 Grounding the Controller

The body of the controller should be grounded to minimize the risk of ESD damage or damage from an accidental power surge.

The 2950 should either be mounted to an electrically conductive grounded panel or a attached to a mounting screw with an attached ground wire to ensure that the 2950 is properly grounded.

1.5 Fire Safety

The Model 2950 is **not** designed for use in **hazardous locations**.

1.5.1 Emergency Shut-Down Procedure

In the event of an environmental catastrophe or any other hazardous equipment condition that warrants an emergency shut-down, operators are advised to immediately shut down power to the 2950.

1.5.2 Restarting the System After Emergency Shut-Down

Check for the presence of chemical fumes in the area surrounding the model 2950. If chemical fumes are detected, ventilate the compartment and the area surrounding the equipment adequately prior to restarting the system.

WARNING: Chemical fumes in heavy concentrations may potentially be ignited when the controller is powered up, resulting in fire and/or explosion. Do not power up the controller until the area surrounding the equipment have been adequately cleared of chemical fumes.

1.6 Temperature Safety

The Model 2950 can not withstand high or low temperature extremes and contains several components that may melt, freeze or rupture if exposed to extreme temperatures.

WARNING: Do not expose the flow controller to extreme temperatures, beyond the stated operational limits.

Extreme temperatures can cause the controller to rupture and release the chemicals flowing through it, which in turn might ignite or be toxic.

1.7 Location

The Model 2950 is **not** designed for use in **hazardous locations** (per directive ATEX: 94/9/EC).
The risk of explosion needs to be evaluated by the customer. Consider interlocking the flow valves for any hazardous materials and a warning label saying 'stay a safe distance while operating'. The controller should be located in a well-ventilated area away from possible ignition sources.

WARNING: A chemical leak may create an explosive environment. Follow the appropriate precautions for hazardous locations. Check the Lower Explosive Limit of the chemical being sensed and take all precautions necessary.

1.8 Orientation / Mounting

The 2950 is factory calibrated in the horizontal position (e.g. laying flat on a table with the inlet/outlet running horizontally). 2950 mounting orientation does not have a significant effect on flow measurement or control. After mounting; pressure transducers must be re-zeroed according to section 6.2

When installing piping connections, care should be taken to avoid supporting the body of the 2950 by the inlet tubing. Mounting holes are provided on the unit to allow proper installation.

1.9 Application Safety

Do not use this product in a medical application, as an emergency shut off or in a safety application where product failure could result in personal injury. Do not use this product in applications other than its intended use. Using this product in unintended applications could cause serious injury or death.

1.10 Installation

Before energizing the 2950, the following items should be checked:

- Electrical termination is tight
- No leaks are visible at 2950 piping connections

2 INTRODUCTION

2.1 PRODUCT DESCRIPTION

Liquid precursors are routinely used for gas-phase processing in microelectronic fabrication The intention of this product is to reliably control a liquid precursor at well-controlled and highly repeatable delivery rates for thin film deposition processes and other gas-phase processes used in semiconductor manufacturing.

Figure 1: Model 2950 Liquid Flow Controller

2.2 THE DESIGN PHILOSOPHY

The Model 2950 was specifically designed to work with the PE (Performance Enhanced) series of Turbo™ Vaporizers to provide a more robust solution for liquid source vapor delivery, primarily for Chemical Vapor Deposition applications. It is designed to quickly, precisely and repeatably control the flow of liquid or solvent soluble solid precursor at highly repeatable delivery rate to the Turbo™ Vaporizer, so the exact amount of vapor can be delivered to the process chamber.

In keeping with tight space constraints, the Model 2950 system has a modest footprint, with overall dimensions of 12.8 cm × 5.4 cm × 13.9 cm (5.0 in. × 2.1 in. × 5.5 in.). A dimensional drawing is provided in Appendix A**.**

2.3 PRINCIPLE OF OPERATION

The Model 2950 Liquid Flow Controller 2950 LFC works by reading a control signal from a process tool, which it uses as a set point for a sophisticated PID loop that provides the signal to the piezo valve on the MSP PE Turbo™ Vaporizer. Note the standard 2950 LFC does not have an embedded control valve. The controller uses the piezo control valve on the vaporizer to control the flow. Placing the control valve on the vaporizer versus inside the LFC enable a fast response time, extremely low dead volume, and liquid bubble suppression. The flow rate is measured by a high precision flow sensor and compared to the setpoint. The flow rate is determined by measuring the differential pressure across the high precision flow module.

The PID loop tightly controls the output signal to the piezo, by comparing the flow through the flow controller to the set-point signal and calculates the difference or error. It then uses the error measurements to calculate the output signal to device being controlled

Where P is a proportional gain factor, I is the integral gain, and D is the derivative gain. Additional factors are also used in the formula to adjust for offsets and non-linearities.
Default P, I and D parameters can be used, or the PID can be tuned using the 2950 Software Tool (see section 4.2). Proper tuning will provide a quick response with a small amount of

overshoot using different PID parameters for different flow rate zones and Bias/Offseting/offset if needed.

Once the flow controller has been tuned, the flowrate can be set, monitored and adjusted using one of several communication methods. Communication between the 2950 and the outside world can be done using one of several methods, including RS-485 Serial communication, EtherCAT, or an Analog Signal.

The output signal is continually adjusted to keep the feedback signal at the same level as the set point signal.

In order to precisely control the liquid flow rate entering a 28XXPE series Vaporizer, the PID Loop has a Bias/Offset/Offset function which can be used achieve a quick response with a minimum amount of overshoot and oscillation.

3 Installation and Setup

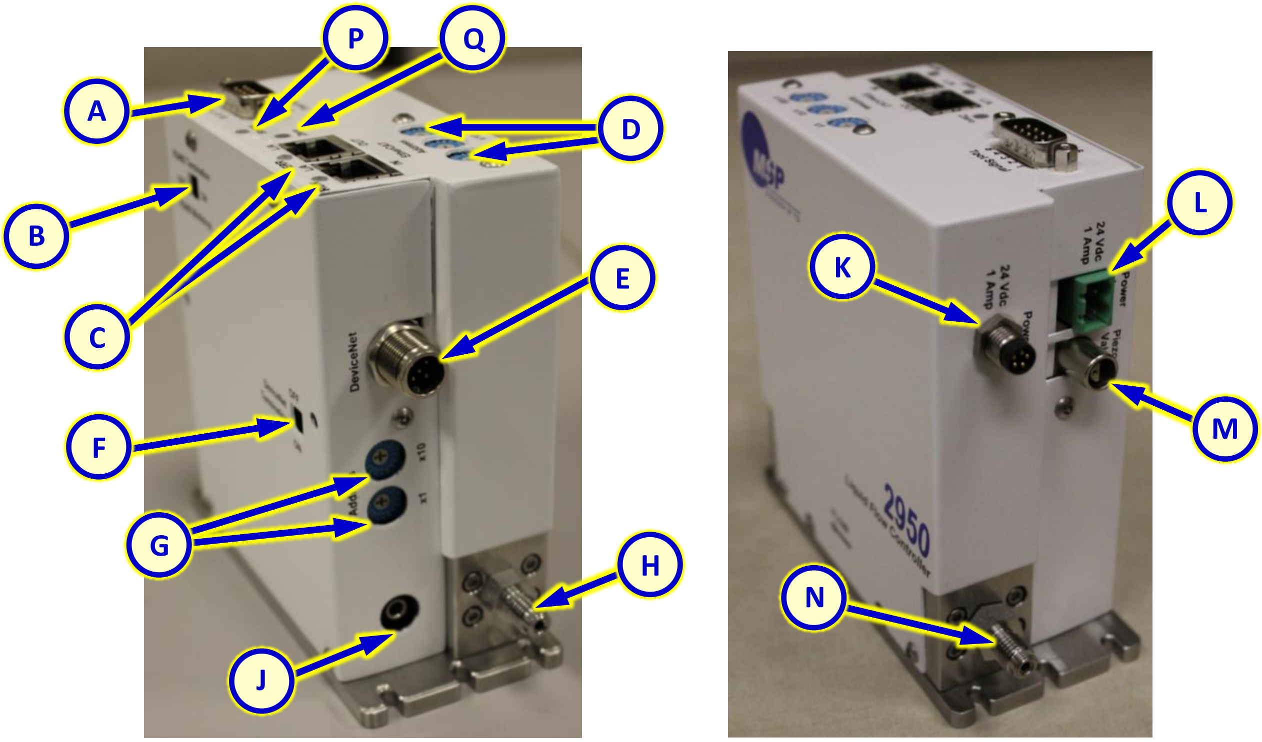


Figure 2: Connectors, Switches & Ports on the LFC

A	RS485/Analog IO Port	J	Firmware Port
B	RS 485 Termination Switch	K	M8 5 Pin Power Connector
C	EtherCAT Ports	L	Power Connector
D	EtherCAT Address Setting	M	Piezo Connector
E	DeviceNet Port (M5)	N	Liquid Outlet
F	DeviceNet Termination Switch	P	Status Light
G	DeviceNet Address Setting	Q	Zero Button
H	Liquid Inlet		

3.1 Location and Mounting

When installing the 2950 locate it in a dry well-ventilated area, free of chemical vapors and combustible gases. At least four ANSI standard #6 screw and washer or ISO standard 4 mm screw and washer should be used in four of the mounting slots See Appendix A for the mounting pattern needed. The LFC may be mounted in any position, however. it must be re-zeroed after installation or orientation change.

3.2 Plumbing

For ease of installation, stainless steel $^1/_8$" VCR male fittings are used on standard 2950 models. It is a good practice to check the chemical compatibility of the tubing and fittings used with the chemical that is intended to be run through the tubing and fitting being used. The 2950 was designed to work with a 28XXPE series Turbo™ Vaporizer, with the exit fitting of the 2950 connecting to the liquid inlet of a the vaporizer. The piezo valve on the vaporizer is not meant to be a shut off valve. Ensure the pneumatic shut–off valve on the MSP Turbo™ Vaporizer is properly plumbed to prevent undesired chemical flow.

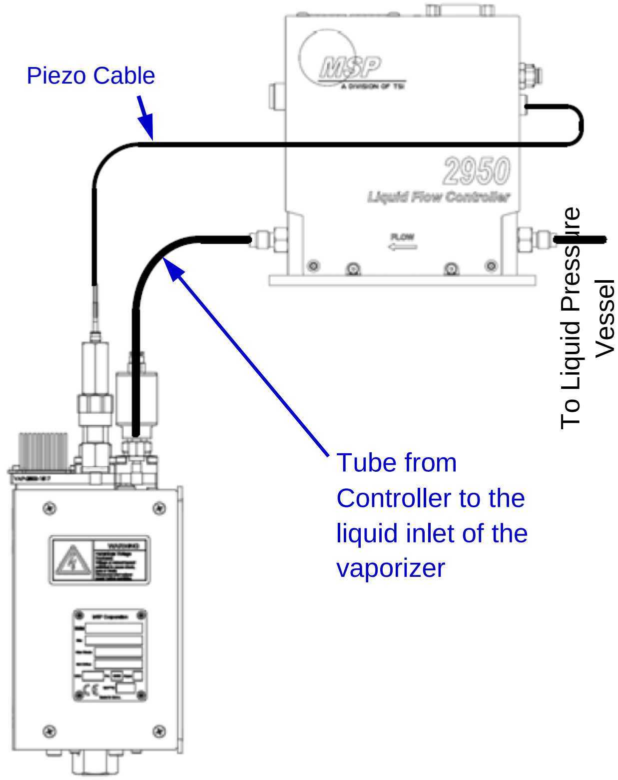


Figure 3: Connecting 2950 to a 28XXPE Vaporizer

When plumbing the 2950:

- Always use <u>two</u> wrenches when tightening/loosening any connections; finger tighten all the nuts; then use two wrenches, <u>but only one hand to tighten the nut</u>. With this technique, unnecessary torque on the fitting will be minimized.
- Avoid any over-torque on the liquid line connections so that nearby welded joints are not stressed. Pay particular attention to the stems at the inlet and the outlet.
- Tightening fittings requires an experienced, careful hand. When in doubt, try less torque rather than more. If a leak is observed, only then should you use additional torque.
- Use gasket of appropriate material
- Refer to the following manufacturer's installation instructions:
  VCR Fittings (Swagelok): Catalog No. MS-13-150, PAGE 27, *or equivalent catalog.*

3.3 Electrical Connections and Cabling

Serial communication is done through the DB9 connector on the top of the unit. The piezo cable included for connecting the Liquid Flow Controller to the Piezo Valve on the Vaporizer is a one (1) meter long cable (MSP part number 7004400). If a different length is needed, please contact the factory. The basic connections that are needed for the unit to function are the power and piezo connections.

CAUTION: To prevent damage to the Liquid Flow Controller and other components, make sure that there is no power to the Liquid Flow Controller when connecting cables.

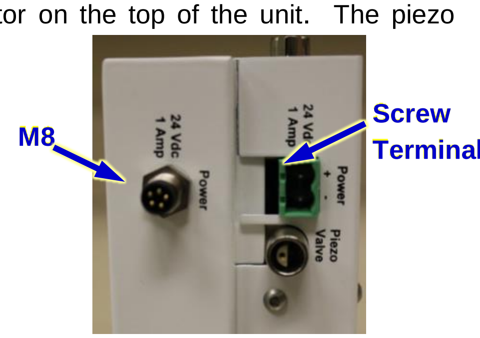


Figure 4: Power Connectors

3.3.1 *Power Connection*

There are two power connectors on the 2950. Power needs to be supplied to one **<u>OR</u>** the other. Do not connect power to both connectors. DC power should only be supplied to the 2950 from a <u>clean local power source</u>. The 2950 is a Class A EMC device (please see

Korean EMC statement in Appendix C.

• All DC power cables shall be less than 3m long

• DC power shall not be supplied from a DC distribution network.

One power connector option is a screw terminal connector 6015007 (Phoenix Contact PN: 1757019).

Pin	Description
1	+24V
2	not connected
3	Power Common
4	not connected
5	not connected

Table 5: M8 pin out

The second power connector option is an M8 with the following pin out. (ref: ETG.5003.2020 section 5.3.4). One possible M8 EtherCAT Power cable is the Omron XS3M-M524-10. The pin out of the M8 connector and the screw terminal connectors are as follows:

3.3.2 Piezo Valve Connector / PID Output

The 2950 Liquid Flow Controller uses a Proportional-Integral-Derivative (PID) loop to control voltage to the piezo valve on a PE series vaporizer. This connector drives the Piezo valve on the 28XX PE series of Vaporizer. The pin out is in the following table.

Pin	Description
1	0 - 0130Vdc Output
2	Return

Table 7: Piezo Pin Out

The standard 1 meter long cable is part number 7004400.

Figure 6: Location of Piezo Valve

3.3.3 Serial Port

The 2950 receives and sends analog signals and / or serial communicates through a DB9 connector located at the top of the 2950. Communication through the serial port is needed to add, delete or modify liquids being used in the Flow Controller (see section 4.2.2).

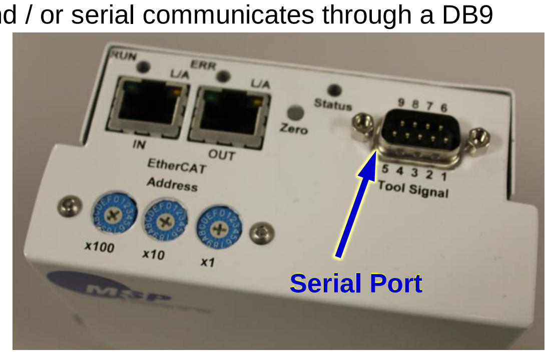


Figure 8: Location of Serial Port

The 2950 senses or receives a 0 to 5V or 0 to 10V (depending upon how it was configured) analog signal from the user's tool between pins 4 and 5 (see table 10).

Pin	Function
1	RS-485 (A+)
2	RS-485 (B+)
3	RS-485 ground
4	0-10V Valve Signal (Out)
5	Ground / Return
6	0-5V Setpoint Input
7	Ground / Return
8	0-5V Flow Monitor Out
9	Ground / Return

Table 9: Serial Port Pin Out

The signal from the user's tool is interpreted as a proportional signal ranging from 0% of full scale (corresponding to 0V) to 100% of full scale (corresponding to a 5 volt signal). The input impedance between a pair of Set-point Input pins (6 & 7) is 35 kΩ. The pinout of the connector is described in Table 9.

The Liquid Flow Controller also indicates that liquid is flowing through it, with a proportional signal between the Monitor Output pin (pin 8) and corresponding Return pin (pin 9). The signal ranges from 0 volts (indicating no flow) to 5 volts (indicating a maximum flow) for a given configuration of Flow Controller. The DB9 cable used should be shielded.

Be sure that the RS485 termination switch is in the 'ON' position to minimize errors in communications (see letter B, Figure 2)

Note: All of the return pins are internally connected.

Section 4.2 describes how to configure and PID tune the Liquid Flow Controller, including the parameters needed to establish communications. Since many computers have a USB port instead of an RS485 port, a option for a USB to RS485 converter is the Ulinx model number 485USBTB-2W-LS-A.

3.3.4 *EtherCAT Connections*

After the unit is set up, EtherCAT connections can be made. A shielded RJ45 cable (CAT 5 or CAT 6) should be used (for example: Harting 09474747014) to connect the 2950 LFC to the EtherCAT network.

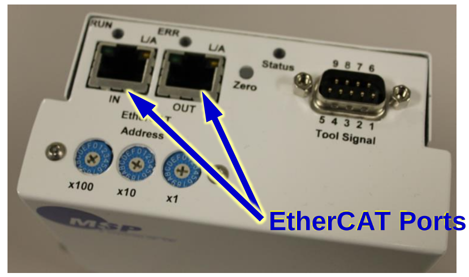


Figure 10: Location of EtherCAT Ports

Use a properly grounded ESD strap when connecting cables to the 2950 LFC.

3.3.5 *Firmware Upgrade Connection*

The UART port is used for firmware upgrades and is located on the side of the flow controller. It is letter J in Figure 2. It is for factory use only.

3.4 Turning the Power On and Communicating with the Unit

Before initially powering the controller, be sure that the tool output signals to the 2950 are in a safe state, either disconnected from the tool or properly grounded to prevent a run-away controller output (for example: if the 2950 is used with a PE version of an MSP Vaporizer, make sure that the shut off valve is closed.) After the Liquid Flow Controller is properly wired and ready to be powered up, then communication can be established.

3.5 Minimizing Gas Pockets & Priming the Sensor

Gas trapped inside the 2950 LFC can cause poor performance of the differential Pressure Liquid Flow Controller (2950 LFC), such as longer response times, reduced accuracy and erratic behavior.

To eliminate gas pockets in the 2950 LFC, a vacuum should be applied for several hours to the exit port to remove any unwanted gas in the unit and the lines going to the unit before running fluid through the Liquid Flow Controller (as shown in Figure 11).

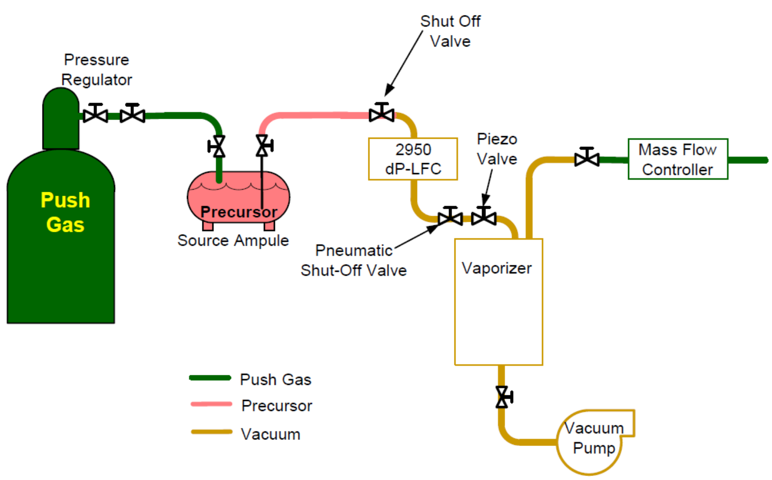


Figure 11: Evacuating the 2950LFC

When the 2950 LFC is connected in-line with a 2950 LFC Vaporizer, a valve upstream of the 2950 LFC can be shut, and the pneumatic shut off valve and piezo valve opened to allow the downstream vacuum to pull out all the gases trapped in the 2950 LFC.

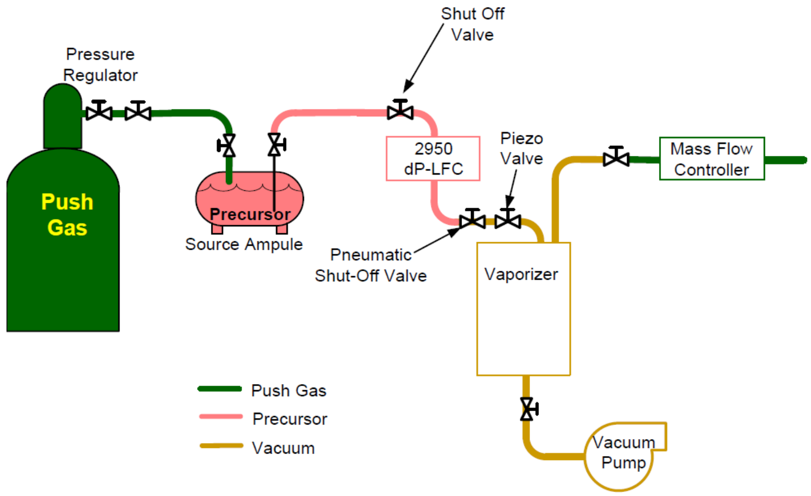


Figure 12: Priming the 2950 LFC

After the 2950 LFC has been evacuated, close the piezo valve and the pneumatic shut off valve on the vaporizer. Then open the valve upstream of the 2950 LFC and allow the liquid to fill the vacuum in the 2950 LFC to draw liquid into it and prime the unit.

Evacuation	Priming
• Close the Shut off Valve upstream of the 2950 LFC	• Close the Piezo Valve
• Open the Pneumatic Shut off Valve	• Close the Pneumatic Shut off Valve
• Open the Piezo Valve	• Open the upstream shut off valve
• Wait until the vacuum pulls the gas out of the 2950 LFC	• Allow the vacuum in the 2950 LFC to draw liquid in.

Table 13: Summary of Evacuation & Priming Procedures

4 OPERATING THE TURBO™ LIQUID FLOW CONTROLLER

4.1 INTRODUCTION

The model 2950 Turbo™ Liquid Flow Controller is designed to work with the 28XX PE series Turbo™ Vaporizers. It comes pre-programmed with one or more liquids calibrated at the factory or service center, with vaporization in mind.

4.2 CONFIGURING AND TUNING THE LIQUID FLOW CONTROLLER

The 2950 LFC can be configured and PID tuned after it has been connected (ref: section 3.3.3) to a computer using the *MSP 2950 Configuration Tool* software. The software is available in the **My Account** portion of the TSI web site (www.tsi.com). After creating an account on the TSI web site, register your 2950 LFC in the **My Instruments** section (using the serial number) to access the software.

It is designed to run on a computer that meets the following requirements.

Operating system: Windows 7 or greater
Speed: At least 2 GHz of processing speed
Communication: Serial communication (USB port or DB 9 Port)
Framework: Dot Net Framework 4.6.0

The communications parameters are in Table 13.

Parameter	Value
Baud Rate	115,200
Data Bits	8
Stop Bits	1
Parity	None

Table 15: Serial Parameters

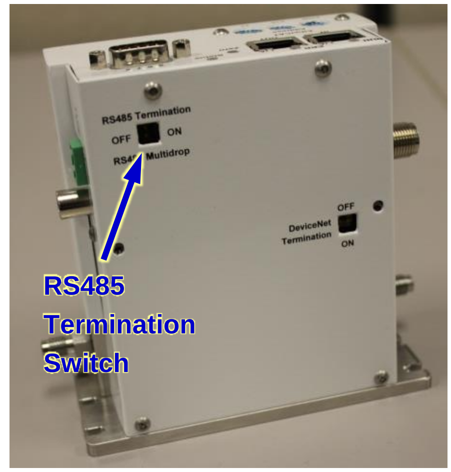


Figure 14: Location of RS485 Termination

Use a properly grounded ESD strap hen connecting cables to the 2950 LFC.

4.2.1 *PRODUCT OVERVIEW TAB*

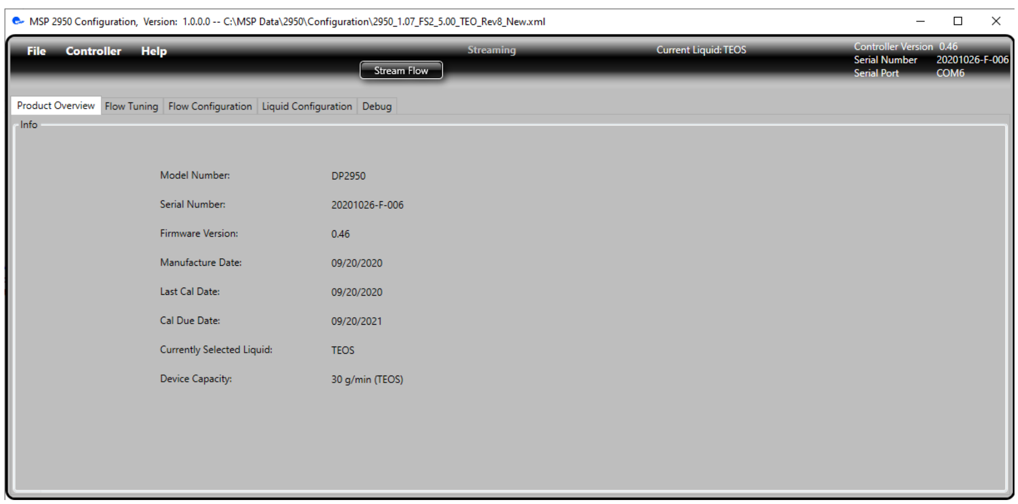


Figure 16: Product Overview Tab

When the 2950 Service Tool is started, it opens to the Product Overview tab. The product overview tab displays the basic information about the unit connected to the 2950 Configuration Tool, including the model number, serial number, firmware version etc, which is read from 2950 (ref: **Error! Reference source not found.**).

Communications can be established using the Controller Pull Down Menu. The essential items that need to be set are in the other tabs. They include selecting the liquid and entering the PID tuning parameters.

4.2.2 Establishing Communication

After a cable is connected to the serial port, select the Controller pull down window and select *Connect*. The *Connect* pop up window then appears (ref: Figure 17). Select the com port from the serial port pull down window and click the 'Ok' button.

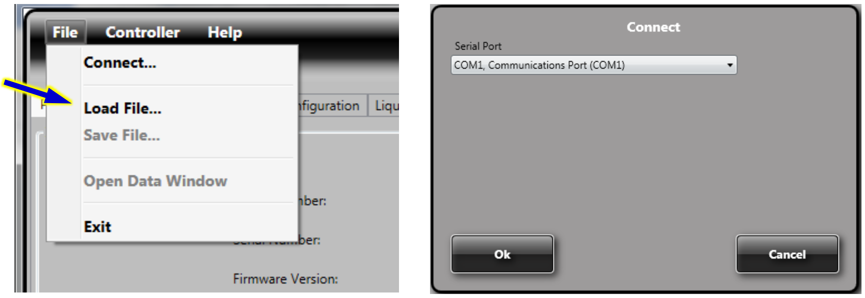


Figure 17: Establishing Communication

4.2.3 Flow Tuning Tab

The flow tuning tab is where the tuning parameters are entered and tuned.

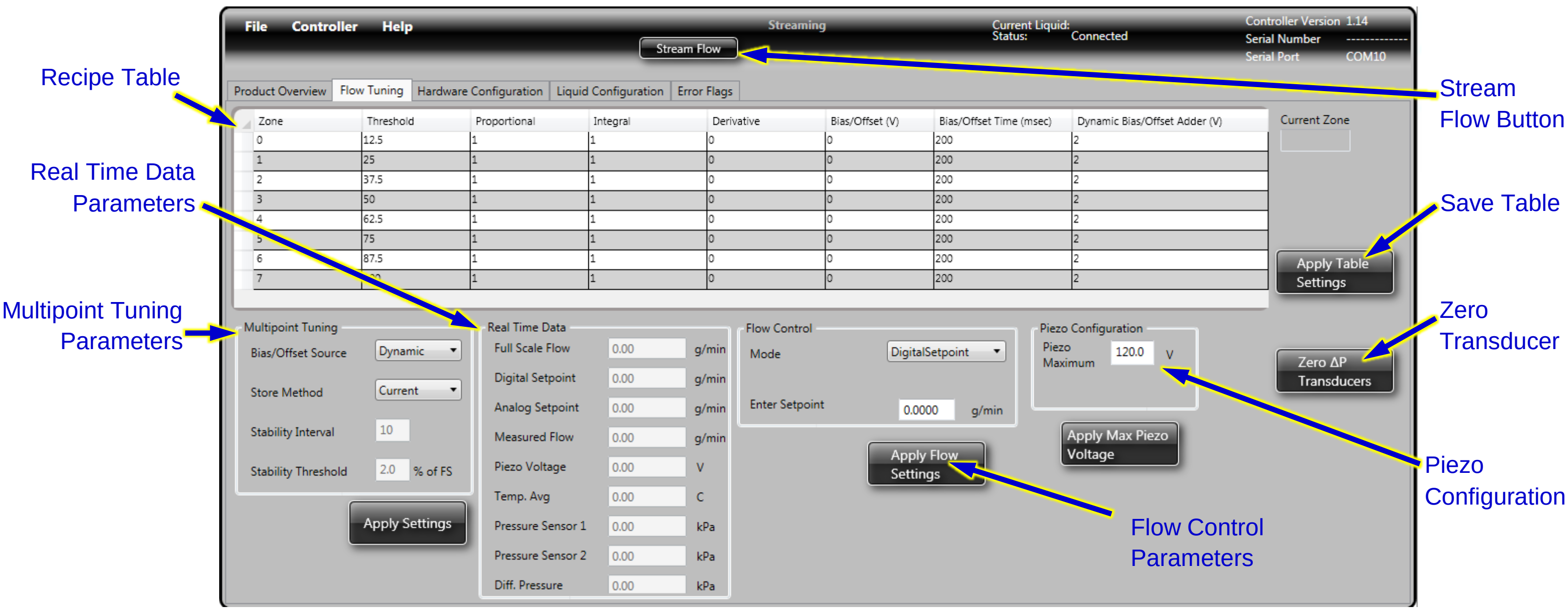


Figure 18: Flow Tuning Tab

In normal steady state operation, the output signal sent to the piezo valve is determined by the following simplified formula.

$$Signal_{current} = Proportional \times error + Integral \times \sum error + Derivative \times \Delta error + Signal_{previous}$$

The error is the difference between the setpoint and the sensor signal. The sum of errors is the sum of all errors ($\sum error$) that occurred plus the initial Bias/Offset value. The change of error ($\Delta error$) is how much the error has changed in the most recent iteration. As the system approaches steady state, the error goes to zero and the change of error goes to zero, so the output is dominated by the sum of errors and the integral factors.

The goal of tuning the Liquid Flow Controller (LFC) is to minimize overshoot, minimize response time and to dampen pressure spikes. However there is often a trade-off between these parameters.

Bias/Offseting and the Multi-point Tuning Window will allow the system to quickly reach steady state flow. Once the system is close to steady state flow, it uses the PID values in the

Bias/Offset table to adapt to minor disturbances in the system and adjust the output signal accordingly.

To test the effectiveness of the tuning, the 'Stream Flow Screen' can be used.

4.2.3.1 Loading or Saving the Recipe Table

When communication is first established, the tuning parameters that are on the 2950, are uploaded to the computer and displayed in the *Flow Recipe Table*. The Liquid Calibration parameters are also uploaded and available under the Liquid Configuration tab. A Recipe Table can also be loaded by selecting the Controller pull down menu and selecting 'Read Flow Recipe Table' (see Figure 19). In addition to the Current Liquid parameters that are loaded, parameters for additional liquids stored on the 2950 are also loaded into the Service Tool.

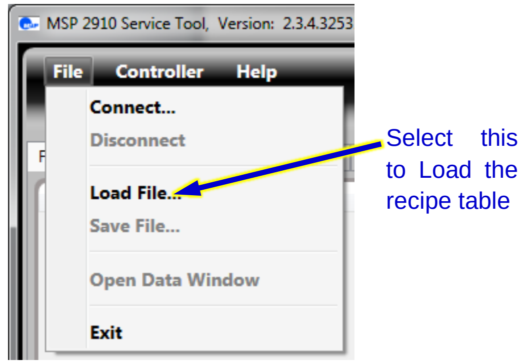


Figure 19: Location of Piezo Valve

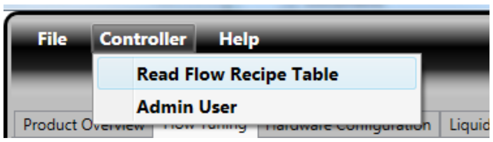
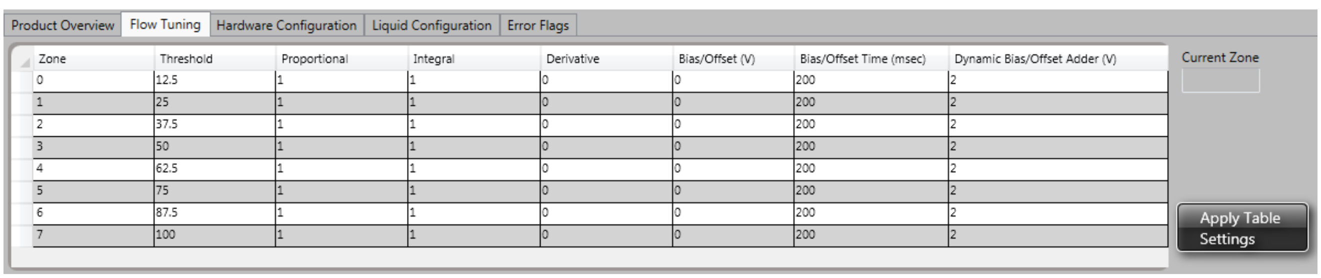


Figure 20: Reading the Flow Recipe Table

4.2.3.2 Recipe Table

Up to eight zones can be entered into the recipe table. The eight zones are numbered 0 through 7 on the left side of the table. The parameters being set in each zone are the Threshold, Proportional Gain, Integral Gain, Derivative Gain, Bias/Offset Voltage and Bias/Offset Time. Each zone corresponds to a range of set points based upon the threshold value.



Zone	Threshold	Proportional	Integral	Derivative	Bias/Offset (V)	Bias/Offset Time (msec)	Dynamic Bias/Offset Adder (V)
0	12.5	1	1	0	0	200	2
1	25	1	1	0	0	200	2
2	37.5	1	1	0	0	200	2
3	50	1	1	0	0	200	2
4	62.5	1	1	0	0	200	2
5	75	1	1	0	0	200	2
6	87.5	1	1	0	0	200	2
7	100	1	1	0	0	200	2

Figure 21: Flow Recipe Table

<u>Threshold</u>: corresponds to the upper most setpoint for the zone. It is a number ranging from 0.0% of full scale to 100.0% of full scale. In a given row, the threshold is the upper limit of the range of user setpoint that the PID parameters in that zone will be used for. The lower limit is the threshold of the zone below it on the table. For zone 0, the lower limit is 0% of full scale flow.

Note: the full scale for a given liquid is found in the Real Time Data parameter section.

For example, if the threshold for zone 0 is 15 and the threshold for zone 1 is 30, then if the setpoint is 25 the PID parameters of zone 1 would apply.

<u>Proportional Gain</u>: is the proportional value used in PID loop, while the controller is in PID Mode.

<u>Integral Gain</u>: is the integral value used in PID loop, while the controller is in PID Mode.

<u>Derivative Gain</u>: is the differential value used in PID loop, while the controller is in PID Mode.

Bias/Offset Voltage: is the piezo voltage that is used for the Bias/Offset Time when the set point is changed from zero to a value in the corresponding zone. These values are located in the Bias/Offset column of the Flow Recipe table (ref: Figure 21). If no Bias/Offset is desired, set the Bias/Offset Time to 0. For more details on how to use Bias/Offseting read section 4.2.3.3

Note: this value is only applied if the "Use Table Bias/Offset Value" click the value selected. Otherwise one of the Stored Bias/Offset Methods are used, either Current or Alternate.

Note: If 0V is sent to the piezo-valve on a 28XX series vaporizer that corresponds to the valve being fully open and a voltage between 100V and 120V (depending upon how it is tuned) corresponds to the valve being fully closed.

Bias/Offset Time: is the amount of time the Bias/Offset voltage is applied when the setpoint is changed from zero to a different value. The units of Bias/Offset time are milliseconds and it ranges from 0ms to 9999 ms.

Dynamic Bias/Offset Adder: although this parameter is in the Table, it is only used when the Bias/Offset Source is set to Dynamic rather than Recipe Table. This value is applied to the stored Dynamic Bias/Offset, to allow the piezo to be more closed (positive value) or more open (negative value) than the last stored operating voltage. The Dynamic Bias/Offset Adder voltage is generally set at 1 or 2 volts. The Dynamic Bias/Offset Adder can be applied to compensate for overshoot,

Save Table Button: After the values in the table have been changed. The Save Table Button needs to be clicked for the values in the table to be sent to the Liquid Flow Controller.

4.2.3.3 Multipoint Tuning Parameters - Bias/Offsetting

The multi-point tuning box is where the user selects the Bias/Offset Method used and the parameters used if a Dynamic Bias/Offset Method is used by the liquid flow controller.

The goal of Bias/Offsetting is to reach the desired flowrate as quickly as possible, while minimizing the downsides of a traditional control loop. The Bias/Offset Method used can reduce the response time, overshoot, oscillations and settling time. It does this by setting the output signal to predetermined value (Bias/Offset voltage) determined to match a given flowrate in a given zone, for a short period of time (the Bias/Offset Time). After this time expires control is turned over to standard PID loop.

The Bias/Offset Voltage is determined by one of three methods determined by the Bias/Offset Source and Store Method Settings.

The first method uses Bias/Offset values entered by the user and stored in the Recipe Table.

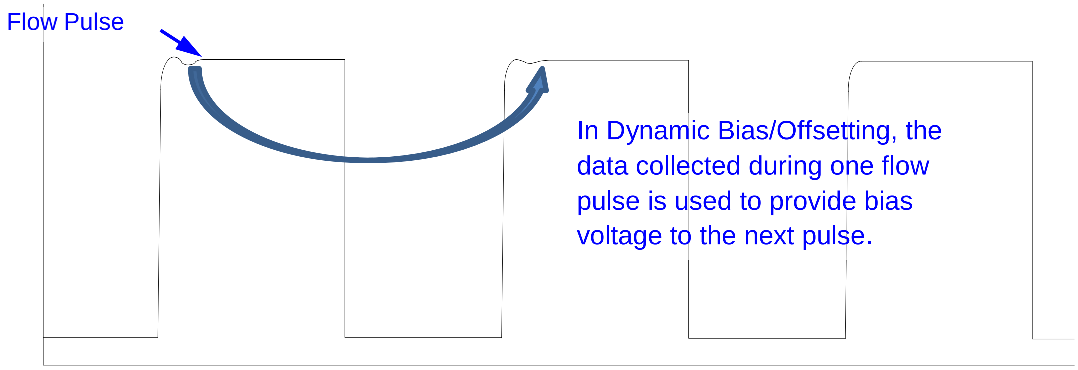


Figure 22: Dynamic Bias/Offsetting Concept

The other two methods are Dynamic, where the Bias/Offset voltage is determined by using data collected the last time the setpoint was operating in a given zone. Dynamic Bias/Offset also provides improved response time. When Dynamic Bias/Offset is chosen, the Bias/Offset Value is determined by either the Current Method or the Alternate Method.

The Current Method stores the last piezo voltage one half second before the trailing edge of the flow (before the set point was changed to zero).

The Alternate Store Method stores the piezo voltage at the time stability is first achieved. Stability is determined by using the Stability Threshold (% of full scale) and Stability Interval (number of cycles inside the threshold window) entered by the user, which are described below.

Stability Interval: for the Current Method is a fixed interval one half second before the flow is set to zero. For the Alternate Method, it is a variable interval after the setpoint before stability is declared. Stability is declared by summing the absolute value errors for each PID cycle and if the resulting error sum is less than a Stability Threshold then it is considered stable.

The graph in Figure 23 illustrates the previous concepts

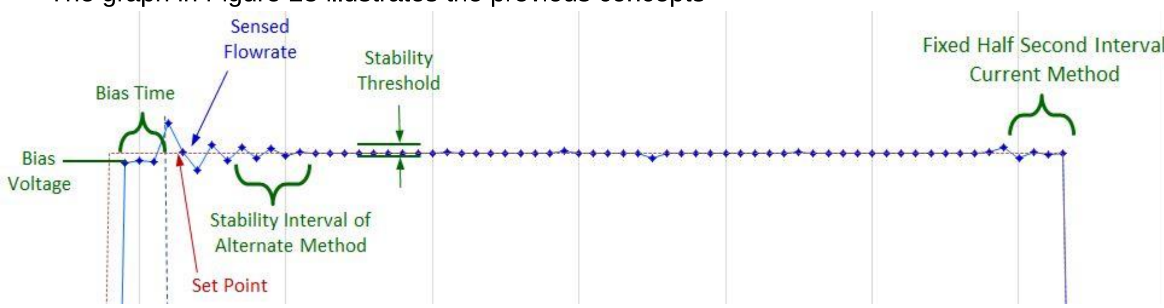


Figure 23: How Dynamic Bias Offset values can be determined

<u>Bias/Offset Source Pull Down:</u> is used to switch between using Bias/Offset voltages from the recipe table (by selecting Bias Source as Recipe Table) or using a Dynamic Store Method (by selecting the Bias Source as Dynamic). If no Bias/Offset is desired then select the Bias Source as Recipe Table and set the Bias/Offset Times in the Recipe Table to zero (0).

<u>Store Method:</u> is either Current or Alternate. Current uses the last voltage applied to the piezo, before the setpoint switched to zero, while the Alternate method uses the voltage applied just after the flowrate stabilizes as determined by the Stability Interval and Stability Threshold.

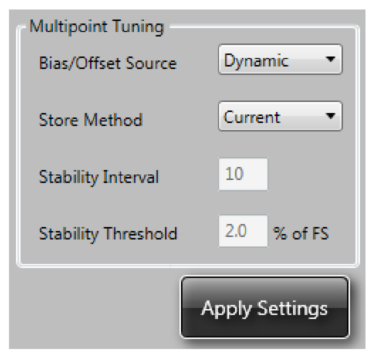


Figure 24: Multi-Point Tuning

<u>Stability Interval</u>: is the number of PID intervals over which the PID needs to be stable before the Bias/Offset is saved. The stability function adds up the absolute value errors of each PID cycle during the Stability Interval.

<u>Stability Threshold:</u> is the average error under which the PID is considered stable. The default is 2% and the acceptable range is between 0% & 100% of full scale. The Stability Threshold is generally 1% to 2% of setpoint.

<u>Dynamic Bias Offset Adder:</u>

Dynamic Bias/Offset tends to cause flow overshoot by causing the valve to open too quickly. To compensate for this overshoot, the Dynamic Bias/Offset Adder can be applied. The

Dynamic Bias/Offset Adder voltage is generally set at 1 or 2 volts and can be entered by the user in the Flow Recipe Table (Figure 21). This value is applied to the stored Dynamic Bias/Offset to allow the piezo to be more closed (positive value) or more open (negative value) than the last stored operating voltage.

For example if the flow controller determined and stored a Dynamic Bias/Offset of 64 volts for a zone 0 and the Bias/offset Adder is set to 2 volts then the piezo output for the next cycle in zone 0 will be 62 volts for the Zone 0 bias time. This will start the piezo valve to be more closed to limit overshoot in the next cycle.

Each time the setpoint is set to a value in that zone afterwards, that Dynamic Bias/Offset will be used as the Piezo Voltage for the Bias/Offset Time.

Apply Settings: To send the settings in the Multipoint Tuning box to the Liquid Flow Controller, the Apply Settings box needs to be clicked.

4.2.3.4 Real Time Data

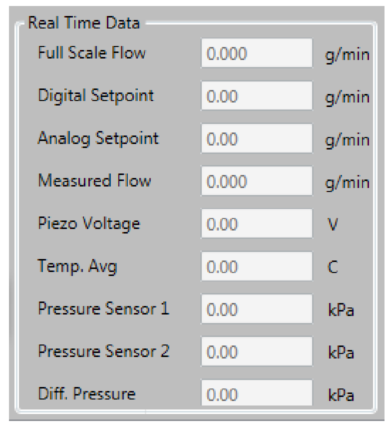


Figure 25: Real Time Data

The parameters in the Real Time Data Box are updated in real time after the Stream Flow Button is pressed. To see a graph of the parameters in Real time, the Data Window can be opened and used as described in section 4.3

Full Scale Flow: displays what the maximum settable flowrate for the 2950 LFC, with the liquid currently selected.

Digital Setpoint: displays the value of the digital setpoint in the 2950 LFC

Analog Setpoint: displays the value of the analog setpoint that the 2950 LFC received from the serial port, in the form of a 0 to 5 volt signal (where 5 volts is full scale) or from 0 to 10 volts (depending upon how the unit was set up). The analog voltage read by the 2950 is converted into grams per minute based upon the parameters of the liquid selected.

Measured Flow: displays the current flow measurement with units of grams per minute

Piezo Voltage: displays the voltage being supplied to the piezo connector

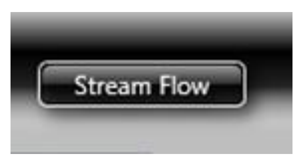


Figure 26: Stream Flow Button

Temperature Average: displays the current average temperature value from the two internal temperature sensor

Pressure Sensor 1: displays the pressure in kPa from the upstream pressure sensor

Pressure Sensor 2: displays the pressure in kPa from the downstream pressure sensor

Differential Pressure: displays the pressure difference between pressure sensor one and pressure sensor 2 in units of kPa.

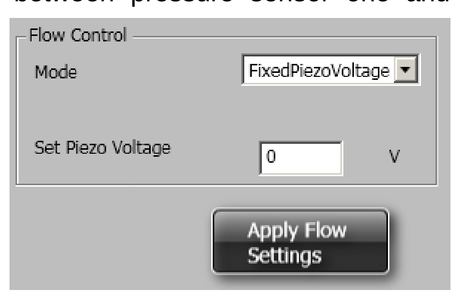


Figure 27: Flow Control Box

Stream Flow Button: Clicking this button starts and stops data being collected by the 2950 and sent to the Service Tool.

4.2.3.5 Flow Control Functions

Mode: is used to select how the piezo voltage is calculated.

AnalogSetpoint will use an analog signal from the serial port (pins 6 & 7) to determine the signal sent the piezo valve.

DigitalSetpoint will use digital flow setpoint received from either an EtherCAT setting or RS485 command to determine the signal sent the piezo valve.

FixedPiezoVoltage will set the signal sent the piezo valve to the set Piezo Voltage.

MaxPiezoVoltage will set the signal sent the piezo valve to the maximum piezo voltage value in the Piezo Configuration box.

Note: When the Flow Setpoint is less than 1% of Full Scale, the setpoint drops to 0.

Apply Flow Settings Button: will send the mode selected in the Flow Control Box to the attached 2950.

4.2.3.1 Piezo Configuration

Maximum Piezo Voltage: This is the upper limit of the voltage the 2950 will apply to the piezo valve connector.

Apply Max Piezo Voltage: saves the maximum piezo voltage to the 2950 when clicked.

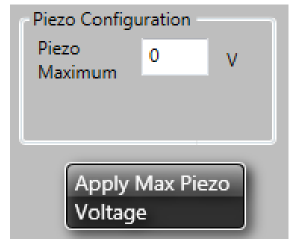


Figure 28: Piezo Configuration

4.2.3.2 Zero Pressure Transducer Button

To zero the Differential Pressure – Liquid Flow Controller's pressure transducers, first be sure that fluid is not flowing through the unit.

The sensors need to be zeroed when the unit is at operating pressure, with no flow while the piezo is at maximum voltage and with liquid is in the lines.

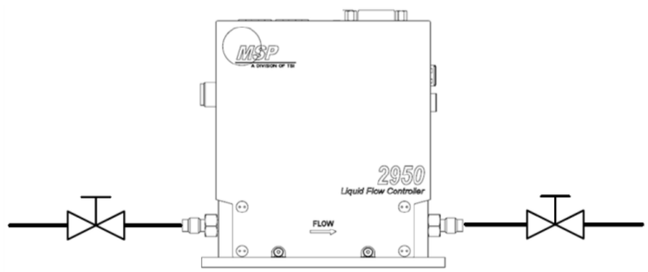


Figure 29: Shut Off Valves

Ensure that the controller is in its operating position and the system is fully charged. Close the downstream shutoff/piezo valve. The piezo voltage must be at or above piezo max setting.

- Apply full operating pressure
- Ensure that there is no flow or leaks
- Press and hold the zero button (Figure 2, letter Q) for 1 second or press the *Zero ΔP Transducer* button in the Service Tool software
- The status LED flashing green indicates a successful Zeroing
- The status LED flashing red indicates an error. The number of red flashes indicates the reason for the error.

Return Error Code	Description of Error
DOZBP_FAIL -1	Couldn't re-zero because no pressure reading from at least one pressure sensor
DOZBP_ FAIL -2	Couldn't re-zero because pressure sensor drifted too far from factory calibration
DOZBP_ FAIL -3	Couldn't re-zero because piezo valve is still on
DOZBP_ FAIL -4	Failed to save the new zero value

4.2.4 Hardware Configuration Tab

The hardware configuration tab is where analog signals being sent and received through the serial port at the top of the 2950 are configured. This is done using pull down selections in the Input / Output Configuration Box.

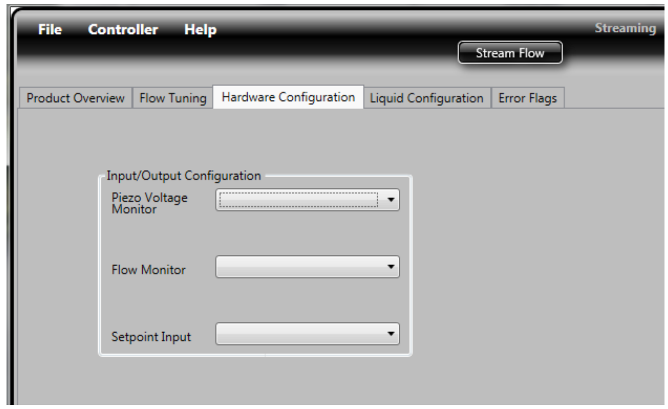


Figure 30: Hardware Configuration Tab

Figure 31: Tool Signal Pinout

4.2.4.1 Piezo Voltage Monitor

The user can configure the Piezo Voltage Monitor signal that the 2950 sends out using the drop down selections shown in Figure 32. The piezo voltage signal corresponds to pins 4 & 5 on the Tool Signal Port (DB9) which is located at the top of the 2950.

Pin	Function
4	Piezo Valve Signal (Out)
5	Ground / Return

Table 33: Piezo Voltage Monitor Pins

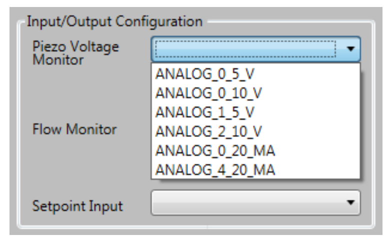


Figure 32: Piezo Voltage Monitor Configuration

4.2.4.2 Flow Monitor

The user can configure the Flow Monitor signal that the 2950 sends out using the pull down selections shown in Figure 34. The flow monitor signal corresponds to pins 8 & 9 on the DB serial port which is located at the top of the 2950.

Pin	Function
8	0-5V Flow Monitor Out
9	Ground / Return

Table 35: Flow Monitor Pins

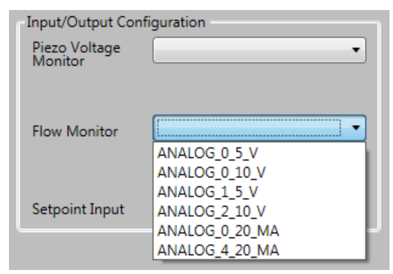


Figure 34: Flow Monitor Configuration

4.2.4.3 Setpoint Input

The user can configure the analog setpoint signal that the 2950 reads using the pull down selections shown in Figure 36. The analog setpoint signal is read from pins 6 & 7 on the DB serial port which is located at the top of the 2950.

Pin	Function
6	0-5V Setpoint Input
7	Ground / Return

Table 37: Serial Port Pin Out

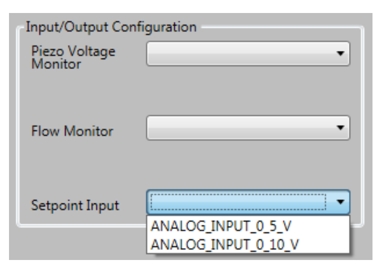


Figure 36: Setpoint Input Configuration

4.2.5 LIQUID CONFIGURATION

The liquid configuration tab is where the liquid being controlled by the Liquid Flow Controller is selected. This tab is also where new liquids can be created and its parameters defined or calibrated. The 2950 LFC can hold the properties of up to five different liquids in its memory and the Service Tool can save up to 10 sets of parameters on the computer. The more accurately these properties are defined, the more accurately the differential pressure flow controller will perform.

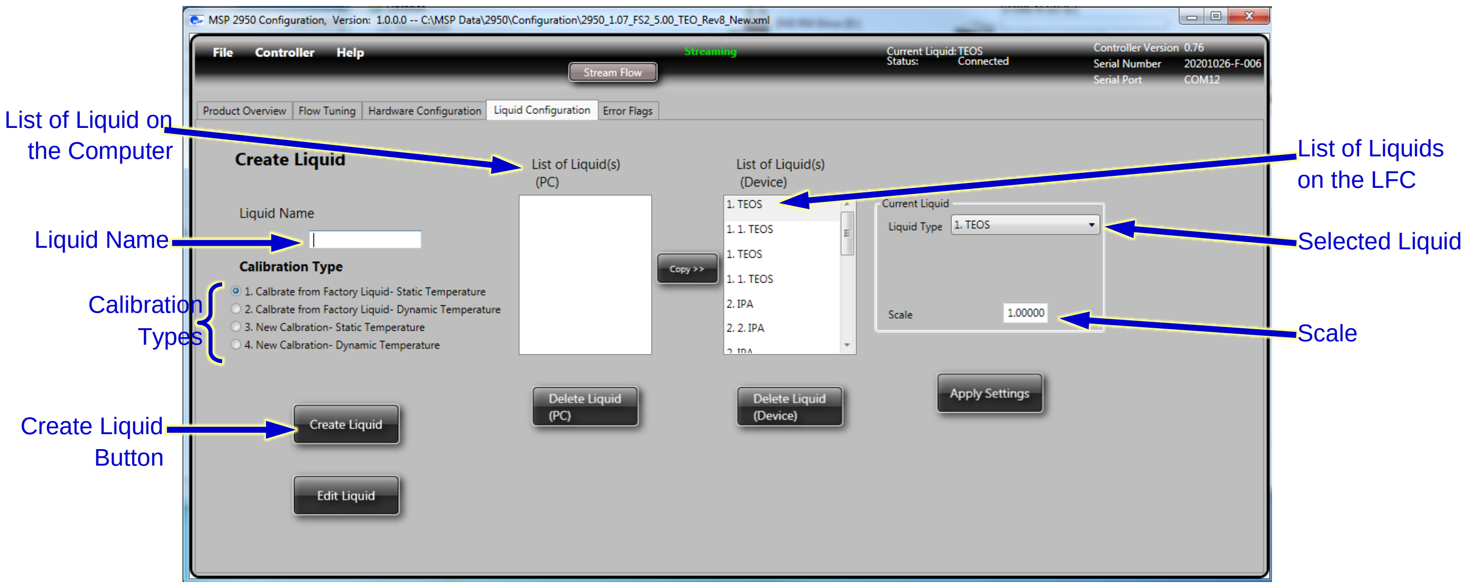


Figure 38: Liquid Configuration Tab

4.2.5.1 Selecting the Current Liquid

The accuracy of the Liquid Flow Controller depends upon the selecting a Liquid in the Liquid Flow tab whose parameters closely match the properties of the liquid flowing through it.

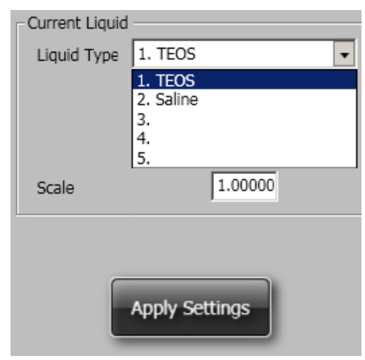


Figure 39: Selecting the Current Liquid

To select the liquid that is being controlled by the unit use the pull down menu in the Current Liquid Box. The liquids listed in the Liquid Type pull down menu come from the List of Liquids on the LFC (Device). To compensate for difference in liquids, the Scale is used to adjust the slope of the flow rate measured by the 2950 LFC. For example if the Scale factor is 1.05 then the value measured by the 2950 LFC is multiplied by 1.05 and sent out as the measured flow value. Click the Apply Settings button to save the changes to the physical dP-LFC.

4.2.5.2 Creating a New Liquid

The steps needed to create a new liquid are as follows:

- Enter the Liquid Name.
- Select the Calibration Type that will be used to calibrate the liquid by clicking the radio button to the left of the description.
  - Use a *New Calibration* if a reference Coriolis meter can be used otherwise use a *Calibration from Factory Liquid*.

- Use a Dynamic Temperature type of calibration if it is known how the liquid's density and viscosity changes with temperature otherwise a Static Temperature type should be selected.

• Then click the 'Create Liquid' button and a Calibration Screen will appear corresponding to the Calibration Type selected.

The accuracy of the flow measurement is dependent on the properties of the liquid, namely the density, viscosity and temperature. With many liquids, the density and viscosity change with temperature. If it is known how those properties change with temperature one of the Dynamic Temperature methods should be chosen for best accuracy. However, if exactly how much density and viscosity changes with temperature is unknown for a specific chemical, 'Static Temperature' can be selected.

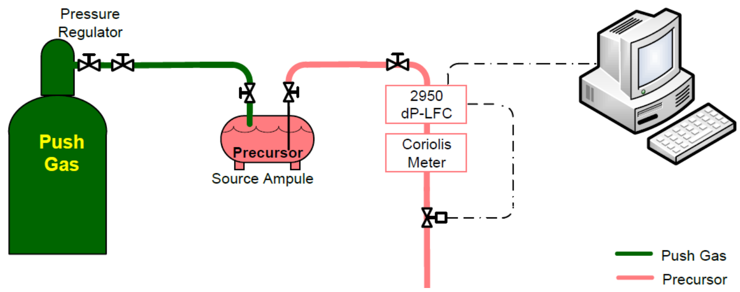


Figure 40: Calibrating 2950 LFC using a second flowmeter.

For the most accurate calibration of a new liquid through the differential Pressure – Liquid Flow Controller (2950 LFC), it should be calibrated against a reference flow meter that has better accuracy such as a Coriolis meter (see Figure 40). If the new fluid in the 2950 LFC can be calibrated against a reference flow meter, then a 'New Calibration' method should be chosen. If a reference flow meter is not available, a 'Factory Calibration' method should be selected.

Calibrating a Liquid using a 'Calibrate from Factory Liquid' type

A 'Calibrate from Factory Liquid' method should be chosen if a reference flow meter is not available. This method uses the factory calibrated liquid as the baseline, and creates a new calibration by adjusting the viscosity and density parameters used.

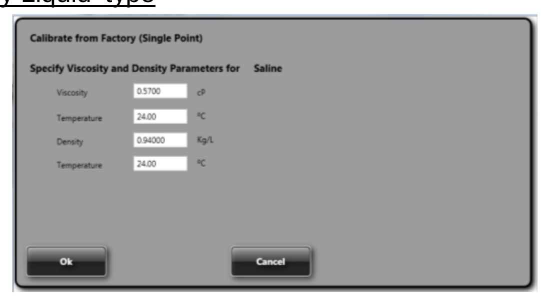


Figure 41: Calibrating a Liquid using a Factory Liquid using Static Temperature

A liquid that is calibrated using the "Calibrate from Factory Liquid-Static Temperature" should behave similar to the Factory calibrated liquid that comes preprogrammed on the 2950 2950 LFC and shouldn't change much with temperature or is only going to be operated at a single temperature. The more the temperature changes, the greater the error will be between the measured flow and the actual flow. When this type of calibration is selected, the user only needs to enter the viscosity, the temperature where that viscosity is known, the liquid's density, and the temperature at which that density is known (see Figure 41).

The other ‘Calibrate from Factory Liquid’ type is the “Calibrate from Factory Liquid-Dynamic Temperature” type. It should be used when liquid being measured and controlled behaves similar to the Factory calibrated liquid and its viscosity and/or density vary at known rates with respect to temperatures. When this type of calibration is selected, the user only needs to enter the viscosity at several temperatures and the liquid’s density at several temperatures where it is known (see **Error! Reference source not found.**).

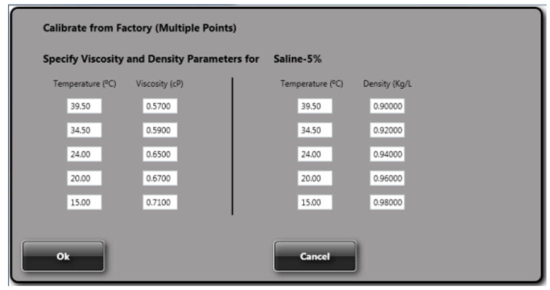


Figure 42: Calibrating a Liquid using a Factory Liquid using Dynamic Temperature

Note: If less than 5 points are known first enter the known points and the unknown points to the last points. Set any unused point to one of the known points. If this is not done then the curve will be way off. If you have only 3 temp/viscosity points, the remaining 2 points should be set to one of the 3 known points.

<u>Calibrating a Liquid using a ‘New Calibration’ type</u>

When choosing this method, a second flow meter is needed such as a Coriolis meter (see Figure 40). Ideally the reference meter used is more accurate than the 2950 LFC by an order magnitude. Although a ‘New Calibration’ method is more time consuming, it can result in the best accuracy.

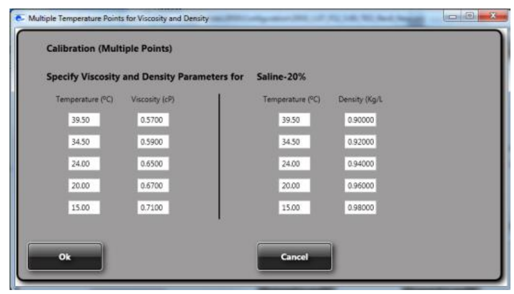


Figure 43: Entering Dynamic Temperature parameters for a New Calibration

Choosing the ‘Static Temperature’ version of a New Calibration (“New Calibration - Static Temperature”) method is that its density and viscosity change very little with respect to temperature. Another reason is if the 2950 LFC is only going to be operated at a single temperature so the density and viscosity remain steady. When this type of calibration is selected the window shown in **Error! Reference source not found.** will appear to enter the viscosity and density at a single temperature.

The “New Calibration - Dynamic Temperature” method should be chosen when the 2950 LFC’s properties at different temperatures are well known. When this method is selected, the pop-up window in Figure 43 appears. The viscosities and densities at different temperatures are then entered.

Note: If less than 5 points are known, set any unused point to one of the known points. If this is not done then the curve will be significantly off. If you have only 3 temp/viscosity points, the remaining 2 points should be set to one of the 3 known points.

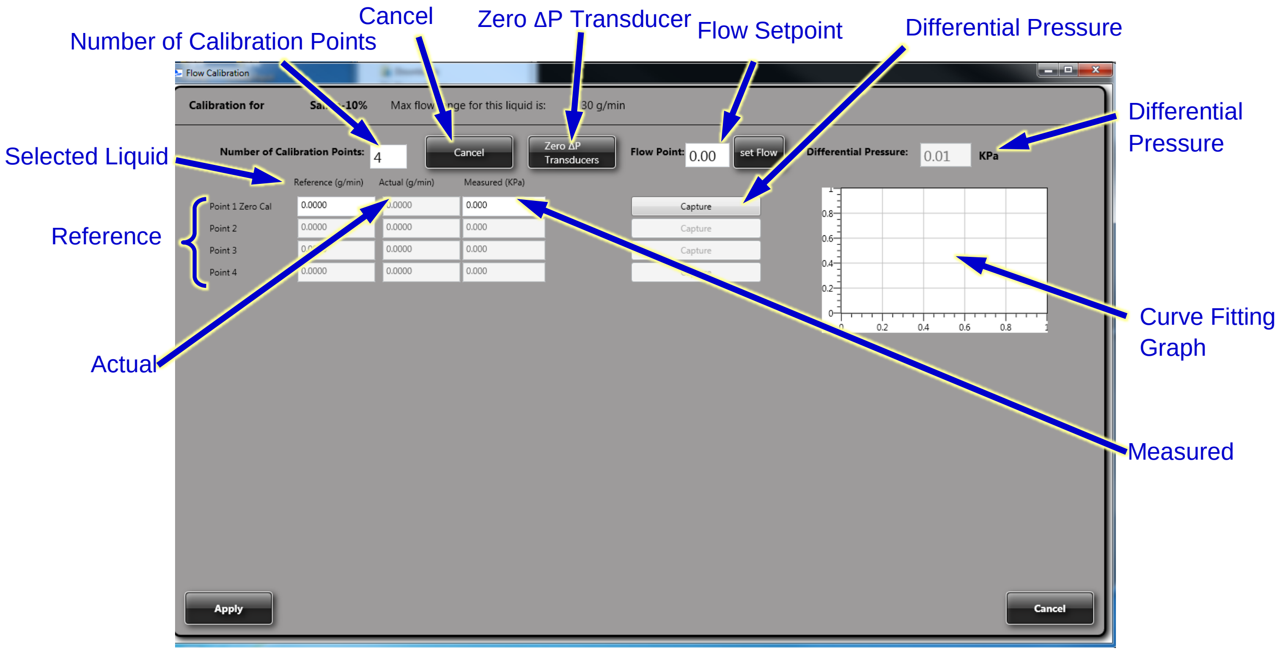


Figure 44: Calibrating a Liquid using a 'New Calibration' method

When entering a new liquid using a 'New Calibration' method, first press the 'Zero ΔP Transducer' button to reset the pressure transducer's offset (see Figure 44). If the transducers are not zeroed, an error message will appear.

Next, enter the Number of Calibration Points being used. The corresponding number of rows will appear below it. Generally the greater the number of points (up to a maximum of 10) that are used and the more evenly distributed they are, then the more accurate the calibration and the flow control will be. If the wrong number of rows was entered, pressing the 'Cancel' button will erase the rows, and the Number of Calibration points can be re-entered. Any data that has already been entered will be lost.

Each row of the calibration table will need to be entered in order, starting with the Point 1 – Zero Cal and going to the Number of Calibration Points entered. First enter the Flow Point (0.0 for the Zero Cal) and click the 'Set Flow' button. Then enter the flow rate measured from the reference flow meter. In order to achieve best accuracy, the reference flow rate should have at least four significant digits. For the Point 1 – Zero Cal, the reference value that is being entered is the offset value of the reference flow meter. This offset value, is subtracted from the rest of the Reference measurements entered and displayed in the 'Actual' column of the table.

Next enter the value from the Differential Pressure box into the Measured column of the table and click the 'Capture' Button on the right side of the row. At which point a new Flow point can be entered, and the next row of calibration data can be collected and entered into the table.

After the final point is entered into the table and the Capture button is clicked a curve will be displayed. If the curve fit is acceptable, it will turn green indicating a good fit. If the curve fit doesn't fit the data point close enough, a red message stating "warning, this is not a proper fit" will appear. If that occurs, review the calibration points to make sure that they were entered correctly and correct them if needed. If the points were entered correctly, the user can proceed past the warning, however the accuracy of the flow measurements may not be as good as expected.

After a new liquid is entered, select the Apply button in the lower left corner of the window.

4.2.5.3 Editing an existing Liquid

After the liquids are entered, they can be edited by highlighting the liquid in the List of Liquids and click the *Edit Liquid* button

If the calibration type was a 'Calibrate from Factory Liquid' type of calibration, then a pop up window will appear and the density and viscosity of the liquid can be edited. For a liquid created using the 'Calibrate from Factory Liquid – Dynamic Temperature' the window that will appear (see Figure 45 **Error! Reference source not found.**) includes two graphs showing the fit curve. After the viscosity and density parameters are adjusted the curve fit can be checked using the Check Fit button.

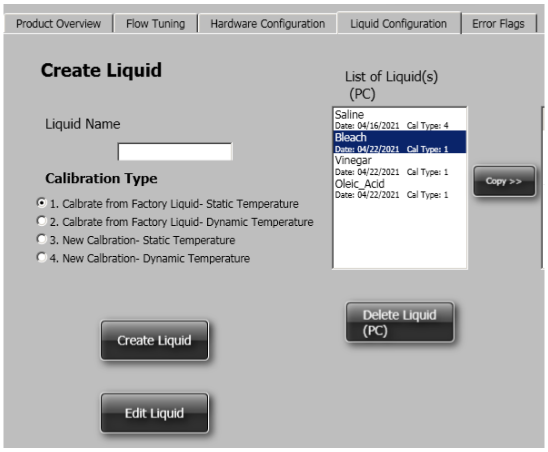


Figure 45: Edit Factory Calibrated Liquid

If the liquid was created with a 'New Calibration' type of calibration, then an Edit Liquid Calibration window will appear (see Figure 46). Again, after the viscosity, density, reference flow rates and pressure parameters are adjusted the curve fit can be checked using the Check Fit button and the $R_{squared}$ value displayed. The $R_{squared}$ value should be above 0.9999 for the best results.

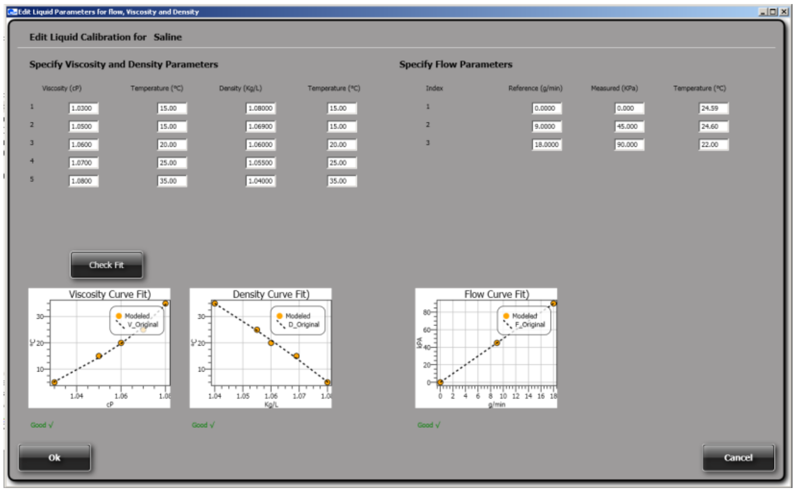


Figure 46: Location of Piezo Valve

4.2.5.1 Adding a new or edited liquid on to the 2950 LFC

After a new liquid has created or edited it appears in the List of Liquids (PC) table (see figure 35). It then needs to be copied to the 2950 LFC by highlighting the liquid selecting the 'Copy' button. After it has been added, highlight the liquid in the List of Liquids (Device) table and click the Apply Liquid button. If there are already five liquid on the 2950 LFC, one of them will need to be deleted with the delete button before another can be added.

4.2.6 ERROR FLAGS TAB

The Error flags tab allows the user to enable or disable the Error Flags used by the 2950.

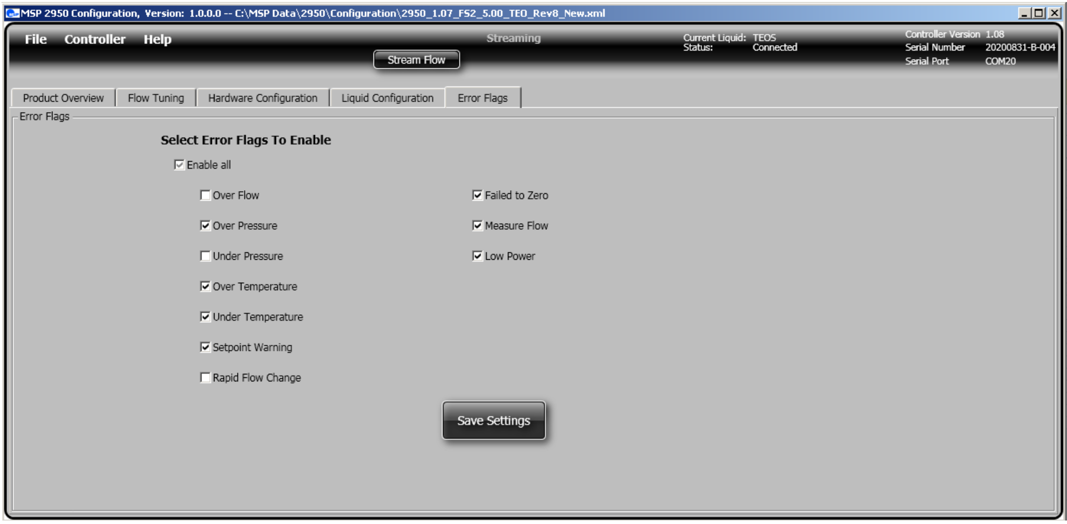


Figure 47: Setting Error Flags on the Error Flags tab

These include:

<u>Over Flow:</u> occurs if the flow rate goes 2% above the set point
<u>Over Pressure:</u> occurs if the pressure of either pressure sensor goes above 360kPa
<u>Over Temperature:</u> occurs if the liquid temperature goes above 45½°C
<u>Under Pressure:</u> occurs if the inlet pressure sensor reads less than 90kPa
<u>Under Temperature</u>: occurs if the temperature goes below 14½°C
<u>Set Point Warning</u>: occurs if the flow controller cannot control within 5% of setpoint within 30 seconds.
<u>Rapid Flow Change</u>: occurs if there is a sudden, unintended change of flow is detected
<u>Failed to Zero</u>: occurs if it couldn't re-zero because flow setpoint wasn't zero, or pressure difference from factory zero was too high
<u>Measure Flow</u>: occurs if a flow measurement failed due to an internal error
<u>Low Power</u>: occurs if the supply voltage drops below 10 volts

4.3 SETTING AND MONITORING THE FLOW RATE IN THE SERVICE TOOL

After configuring the differential pressure flow controller (2950 LFC), the flow rate and several other parameters can be monitored in the Data Window. To open the Data Window (see Figure 48), use the file pull down menu and select the *Open Data Window*.

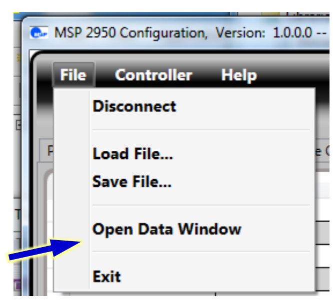


Figure 48: Open Data Window

Once the Data Window is opened, the chart and log checkboxes can be used to select the parameters to be either graphed on the screen on the screen if the 'chart' check box is selected or logged to a csv file if the log file is checked.

The flow rate can be set and read from several sources, as described in the following sections:

• an analog signal through the Tool Signal (DB9) port (see section 4.4)
• RS-485 serial commands through the Tool Signal (DB9) serial port (see section 4.5)
• via EtherCAT communications. (see section 4.6)

Note: EtherCAT commands will be given priority, unless the dP-LFC is in Pre-Operational Mode

When the Flow Setpoint is less than 1% of Full Scale, the setpoint drops to 0.

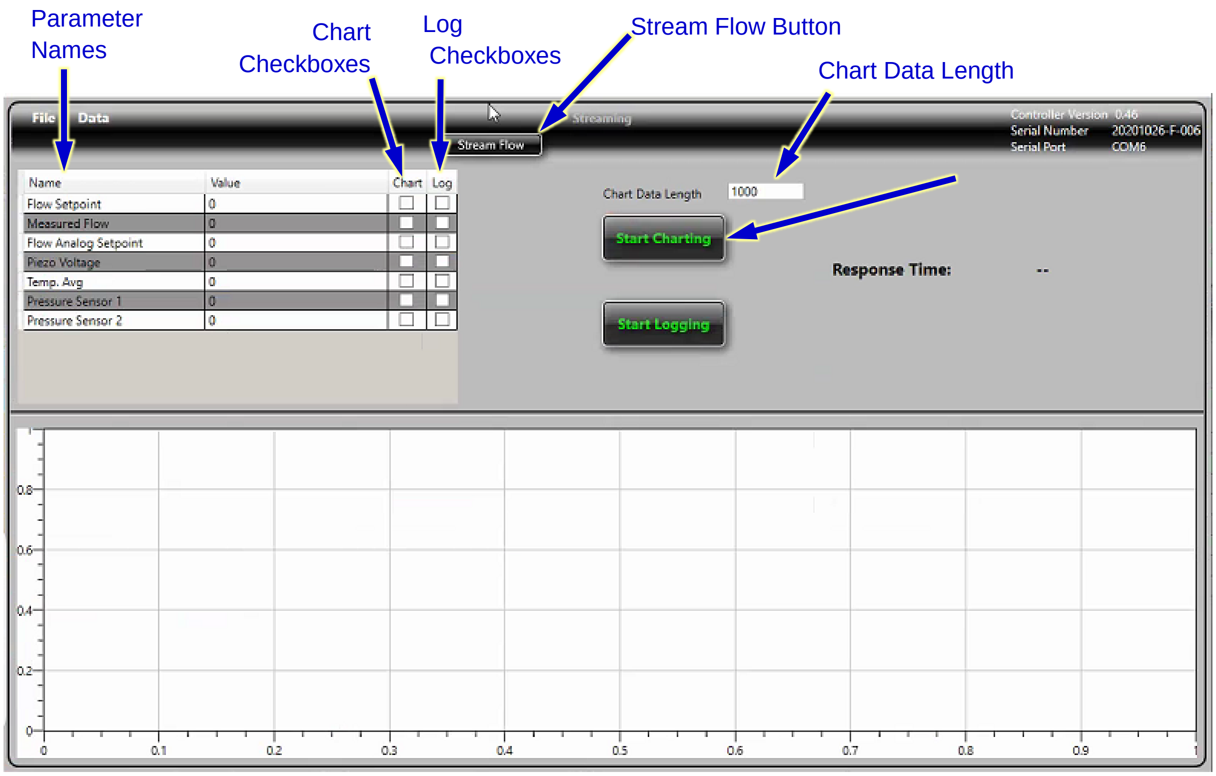


Figure 49: The Data window

Once the flow rate has been set, clicking the Stream Flow button will command the 2950 LFC to send data to the Service Tool. To display the data being received from the 2950 LFC, the *Start Charting* button can be pressed and data will be displayed as a graph. New data is added to the right side of the graph. When the number of data points displayed on the graph exceeds the value in the Chart Data Length, the oldest data points are removed from the left side of the graph.

To start the data being logged to a data file, the Start Logging button need to be pressed.

4.3.1 Saved Files

The logged data selected is stored in csv file called DPLFC_YYYY_MM_DD_TT-TTTT.csv
Where YYYY is the year
MM is the month
DD is the day
TT-TTTT is the time

in file location C:\Users*username*\AppData\Roaming\MSP\Logs
where the *username* is username that was used to log into the computer.

Configuration files are located in the following path:
C:\MSP Data\2950\Configuration\

4.4 Analog Set Point Signal over Tool Signal (DB9) Port

To use an analog set point, apply a 0-5V or 0-10V set point signal (depending upon input setpoint configuration (see section 4.2.4) to pin 6 & 7 on the Tool Signal (DB) Port, where maximum voltage signal corresponds to the maximum flow rate for a given flow controller configuration and 0V to no flow.

To monitor the flow rate, read the signal (depending upon how it was configured) between pins 8 & 9 on the Tool Connector. Additional information on configuring the flow monitor signal see section 4.2.4 and the electrical pin out can be found in section 3.3.3.

To monitor the piezo voltage, read the signal (depending upon how it was configured) between pins 4 & 5 on the Tool Connector. Additional information on configuring the flow monitor signal can be found in section 4.2.4

4.5 Serial Communication over Tool Signal (DB) Port

The serial command set is found in section 8.

The serial command set can be used to monitor and adjust the set point during normal operations. In addition it can be used to send PID values. Note: the 2950 LFC Service Tool is needed to add new liquids and set up their parameters (see section 4.2.5)

4.6 Communication over EtherCAT

The set point can be set and the flow monitored over EtherCAT as well. Additional information on the command set can be found in section 9.

The 2950 can be connected to an EtherCAT network, through the RJ45 connectors at the top of the unit. The EtherCAT address is set with the dial switches on the top of the unit before powering on the on. Make sure that the input cable is in the connector labeled 'IN' and the output cable is in the connector labelled 'OUT'. When the cable is connected the Link Activity light turns solid yellow and flashes when communication occurs . When properly connected and communicating, the EtherCAT Run Light will be green and steady.

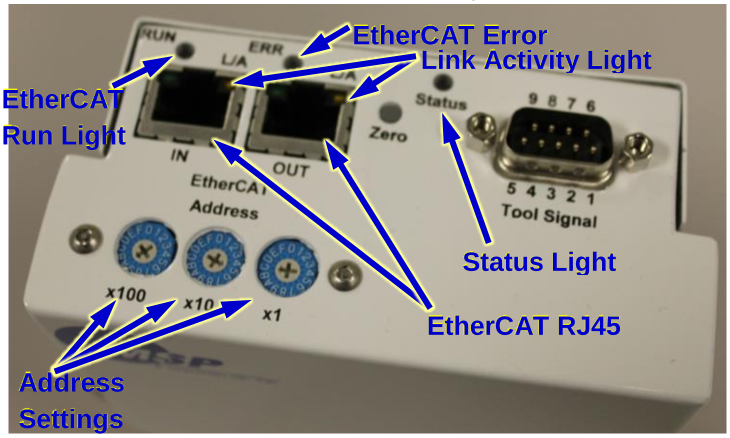


Figure 50: Location of Piezo Valve

When EtherCAT is connected to the 2950, the EtherCAT master will assume control and the values received from the EtherCAT will be given precedence over commands sent to the 2950 from other protocols.

When EtherCAT is used to set the Mode or the Flow Setpoint, the device saves the mode or setpoint, and the mode or setpoint will then be maintained as long as it remains in contact with the EtherCAT network. If the 2950 loses communication with the EtherCAT network, it applies the EtherCAT Actuator Safe State.

If Actuator Safe State was set to Unactuated, the next time the device is powered up and EtherCAT communication cannot be established and the piezo voltage will go to max and stay there.

The only way to recover the 2950 from the EtherCAT 'Actuator Safe State' without using EtherCAT is to send the instruction WSMOD or WSSMF (SetPoint - Mass FlowRate) to the RS485 port or using the Service Tool Software.

The EtherCAT ERR light has the following meanings:

Light	Meaning
Off	• No Error
Single Flash	• No Sync Error • Synchronization Error • Distributed Clock PLL Error • EtherCAT Stack Local Error
Double Flash	• Sync Manager Watchdog
Blinking	• Other EtherCAT error

4.7 STATUS LIGHTS

The status light turns red when the controller is initially powered up, then turns green after a second, when it starts running. If the status light turns red after the controller has been running or doesn't turn green after is it has been powered for more than 30 seconds, then a fault has occurred. If a fault occurs, see Section 6.2 Troubleshooting.

5 Configurations and Compatibility

The Liquid Flow Controller was specifically designed for use with the 28XX PE series of vaporizers and is available in two different configurations, each having a variety of models are available to work over a variety of flow ranges. The 2950 series uses the piezo valve on the PE Turbo™ Vaporizers while the 2950-V series LFCs have a piezo valve on the controller.

Figure 2 • Adjusting the Piezo Valve Gap

5.1 Piezo Valve Located on the Vaporizer:

When a 2950 Liquid Flow Controller does not have an integrated piezo valve and is used to control the Piezo Valve on the 28XX Performance Enhanced (PE) series of Vaporizers, then the tuning procedure in the Vaporizer's user guide should be followed.

5.2 2950-V Series Piezo Valve on the Liquid Flow Controller

After the Liquid Flow Controller is installed, it might be necessary to adjust the Piezo Valve (also referred to as tuning the piezo valve). The goal of this adjustment is to make sure that:

a) the valve will close (with the leakage within the application tolerance);
b) the wide-open maximum flow rate is at or slightly beyond the specified high flow limit for the application
c) it regulates flow rate within the desired flow range accurately and repeatably.

The following is a step-by-step guide to tune the control valve on the 2950.

The Gap Adjustment Nut is located next to the exit fitting on the liquid flow controller.

CAUTION: Never Over-Tighten the Gap Adjustment Nut. Adjustments should be EXTREMELY small (less than a 5° turn). Do not exceed ~5 degrees of rotation during tuning. When turning the Gap Adjustment Nut clockwise, carefully monitor the flow signal and when the signal reads zero, Stop turning the nut immediately. Over-tightening will deform the Piezo Valve's Control Surface.

Do not exceed ~5 degrees of rotation during tuning.

Before adjusting the valve make sure:

1. The temperature of the vaporizer system is set to the maximum expected process temperature and left at this temperature for about an hour;
2. The carrier gas flow rate is set to the maximum expected process flow rate;
3. A crescent wrench is available for tuning if unable to adjust by hand.

The following is a procedure for the gross adjustment of an MSP control valve, which is done before the fine adjustment:

A 15/16" open ended wrench is need to adjust the nut.

1. Make sure that the liquid temperature is stable.

2. Set a suitable push gas pressure for the liquid supply, ideally below 200kPa. Less pressure is often more suitable than over pressurizing the liquid supply. Verify that there is flow when input is set at full scale (5V) and the rate is higher or equal to the desired high flow limit.
3. Close Position Tuning
   i) Set valve at zero flow position (by setting voltage to the piezo valve to high; typically 90-100V);
   ii) Turn the gap adjusting nut downward (cw) to reach a leak level that is < 1% of full scale or is tolerable with the application;
4. Open Position Tuning
   i) Set valve at open position (by setting voltage to the piezo valve to zero);
   ii) Adjust the push gas pressure to arrive at the maximum desired liquid flow rate.

It is possible to repeat steps 3 and 4 a few times before a desirable flow range can be established.

The following is a step by step guide to tune an MSP control valve:

1. Loosen the jam nut
2. Make sure the vaporizer is at maximum expected process conditions for temperature and flow rates as mentioned above. Then set the liquid flow set point to 50% of the liquid flow controllers full scale flow.
3. Observe the piezo voltage, the desired voltage is 30V ± 2V. If the piezo voltage is greater than 32V, the valve is too far open and needs to be slightly closed, which requires a clockwise turn of the Gap Adjustment Nut, and vice versa for readings under 28V.
4. Carefully adjust the Gap Adjustment Nut to either open or close the valve.
5. Set the liquid flow set point to zero, then set it back to 50% of the LFC full scale flow and observe the piezo voltage reading.
6. Repeat steps 3 and 4 until the piezo reading is 30V ± 2V.
7. Set the liquid flow set point to zero, then set it to 90% of the LFC maximum and observe the piezo voltage reading. The voltage should be above 15V. If not, slightly turn the Gap Adjustment Nut counter-clockwise to open the valve. Repeat this step to ensure the piezo voltage is above 15V for most carrier gas flow rates and liquid pressure. However, if the carrier flow is high or the liquid pressure is low, then below 15V may be required.
8. Tighten jam nut to finger tight.

6 MAINTENANCE AND SERVICE

6.1 PREVENTATIVE MAINTENANCE

The 2950 Liquid Flow controller is essentially maintenance free. However the Controller' calibration can be periodically checked and recertified by the factory or a service center as needed. Please consult the factory. There are no user serviceable parts inside of the unit.

To clean outside surfaces, a cloth moistened with distilled water or isopropyl alcohol may be used. Do not submerge unit in liquid when cleaning. Do not pour liquids on, submerge the unit or let liquid come in contact with the electrical connectors of the Liquid Flow Controller.

6.2 Zeroing the Unit

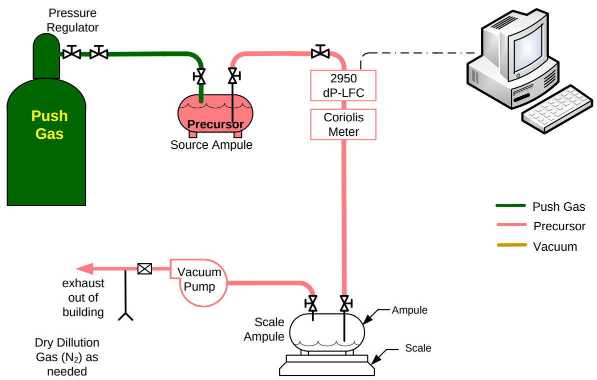


Figure 51: Location of Piezo Valve

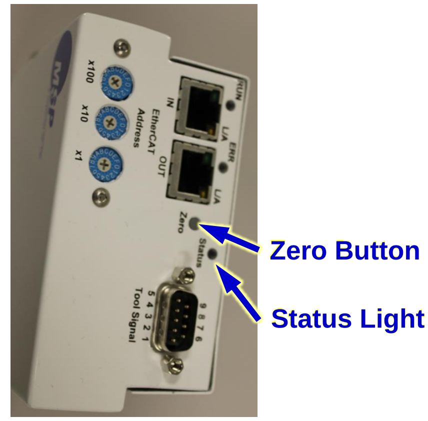


Figure 52: Location of Piezo Valve

To Re-zero the unit. Shut off flow through the unit. After the flow has been shut off, the zeroing function can be started in one of four ways:

- Press the Zero Button on the top of the unit, and hold it down for 1 second.
- In EtherCAT write 1 to index #x2nnC subindex 0x01
- Send the serial command >DOZBP{cr}{lf}
- Using the 2950 Service Tool under the Flow Tuning Tab, click the Zero ΔP Transducer button. See section 4.2.3.6

After the Zero Button has been pressed or a zeroing command sent, wait several seconds. Then the status light will flash green four times and the unit will be re-zeroed.

The sensors need to be zeroed when the unit is at operating pressure, with no flow while the piezo is at maximum voltage and with liquid is in the lines.

Ensure that the controller is in its operating position and the system is fully charged. Close the downstream shutoff/piezo valve. The piezo voltage must be at or above piezo max setting.

- Apply full operating pressure
- Ensure that there is no flow or leaks
- Press and hold the zero button (Figure 2, letter Q) for 1 second or press the *Zero ΔP Transducer* button in the Service Tool software
- The status LED flashing green indicates a successful Zeroing
- The status LED flashing red indicates an error. The number of red flashes indicates the reason for the error.

Return Error Code		Description of Error
DOZBP_FAIL_NO_PRESSURE _RDG	-1	Couldn't re-zero because no pressure reading from at least one pressure sensor
DOZBP_FAIL_ _PRESSURE _DIFF	-2	Couldn't re-zero because pressure sensor drifted too far from factory calibration
DOZBP_FAIL_VALVE_NOT_OFF	-3	Couldn't re-zero because piezo valve is still on
DOZBP_FAILED_WRITING_NVRAM	-4	Failed to save the new zero value

6.3 Power / Status Light

The status light is solid green when the 2950 has sufficient power, and running properly. If the Power / Status Light is dark or not lit, then the 2950 doesn't have enough power to run.

Blinking Red means that it can't measure flow.

Blinking yellow, that means one of the following warning conditions occurred: Overflow, Over Pressure, Under Pressure, Over Temperature, Under Temperature, Temperature Change, Clog, or Failure to Re-Zero.

To clear the errors stored in the unit, hold down the zero button for five seconds.

6.4 TROUBLESHOOTING

If the unit isn't functioning properly please check the troubleshooting table and if necessary consult the factory.

Table 6-1 Troubleshooting

Symptom	Possible Problem	Possible Solution
LED is dark	• No power or low power	• Make sure that power is on • Check that power is connected correctly and that it is between 10V & 30Vdc
	• Circuit Board Damage	• Consult Factory
LED flashes red continuously	• An internal error prevents the flow from being measured.	• Consult the Factory
LED flashes red for 3 seconds	• A re-zeroing error occurred	• Make sure that the Set Point is at Zero • Make sure that the Piezo output is at maximum voltage • Make sure that ΔP between pressure sensors is less than 35kPa • There is a pressure sensor failure – consult factory
LED flashes yellow	• One or more warnings occurred.	• Check the Error Flags, with the Service Tool, sending the ERF Serial command or the error index in EtherCAT.
LED is green		• No Errors, the unit has sufficient power
No Flow through the valve.	• No upstream pressure	• Check the compressed air to the shut off valve on the PE series Turbo™ Vaporizer
	• No downstream vacuum	• Check that the downstream pressure is less than the upstream pressure
	• Clogged or bubble in the line	• Check inlet filter • Contact Factory
Flow rate doesn't respond to Control signal (Too low or No Flow at all)	• Liquid Path is obstructed	• Check upstream and downstream valving • Possible clog inside flow controller • Check Piezo Valve Connection
	• Controllers thinks it is being programmed	•Make sure that pins 4 & 5 are not connected
	• Incorrect Operation Mode was selected	• Verify Operation mode is set to Analog control Mode 0 – Analog Control

Symptom	Possible Problem	Possible Solution
		Mode 1 – Digitial Control Mode 2 – Piezo Override to Fixed Voltage Mode 3 – Piezo Overide Closed
	• EtherCAT communications active	• Disconnect the EtherCAT cable or set the LFC to Pre-Operational mode. Then change the Mode or Flow Setpoint
	• Analog Signal missing or reverse polarity (mode 0 only)	• Hardware configuration using the configuration software •Verify the Fuill scale flow in the flow tuning section of the Configuration software
	• Analog Signal Scaled	• Check the analog signal scale
	• Upstream Pressure Sensor Disconnected or Failed	• Check if yellow LED if flashing and the error flag for under pressure is triggered • Check if piezo voltage goes to zero • Consult factory
	• Downstream Pressure Sensor Disconnected or Failed	• Check if yellow LED if flashing and the error flag for over pressure is triggered • Check if piezo voltage goes to max. • Consult factory
	• Controller not receiving signal	• Check that the positive signal is applied to pin 2 and ground is connected to pin 7
No Signal (analog)	• No Power	• Check that the 24Vdc is applied to pin 1 and pin 6 is connected to ground
No Signal (Serial Communications)	• Cable disconnected	• Check Cable
	• Communications protocol not set up correctly	• Check that the baud rate and other communications values are match those given in the manual
No Signal (EtherCAT)	• Cable disconnected	• Check Cable
Controller Leaks	• Connection not tight	• Make sure they are tight and that no dust or dirt build-up is present in the fittings
	• Internal Leak	• Consult factory or Service Center
Pressure Spikes occurring when opening valve with a low flow	• Low flow going through the dead volume in the atomizer, effects the response time.	• Increase the I value of the PID parameters, however this may result in greater time before the fluid reaches the heat exchanger

6.5 SERVICE

MSP should be consulted if any persistent operating difficulties arise. The controller contains voltages as high as 150Vdc. Disconnect all power going into the unit, before opening the enclosure.

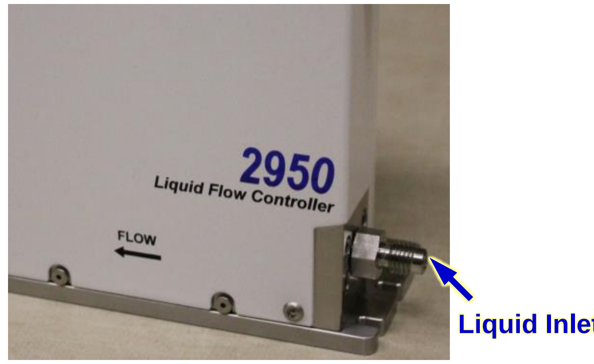


Figure 53: Liquid Inlet

6.5.1 REPLACING WIRE MESH

There is a sintered wire mesh disk (part number: 6014773) and kalrez o-ring (part number 6012401) that could be replaced if needed. To replace it, unscrew the liquid inlet.

Figure 54: Filter under the liquid inlet

Figure 55: Wire Mesh Filter

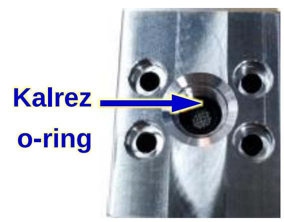


Figure 56: o-ring in place

7 SPECIFICATIONS

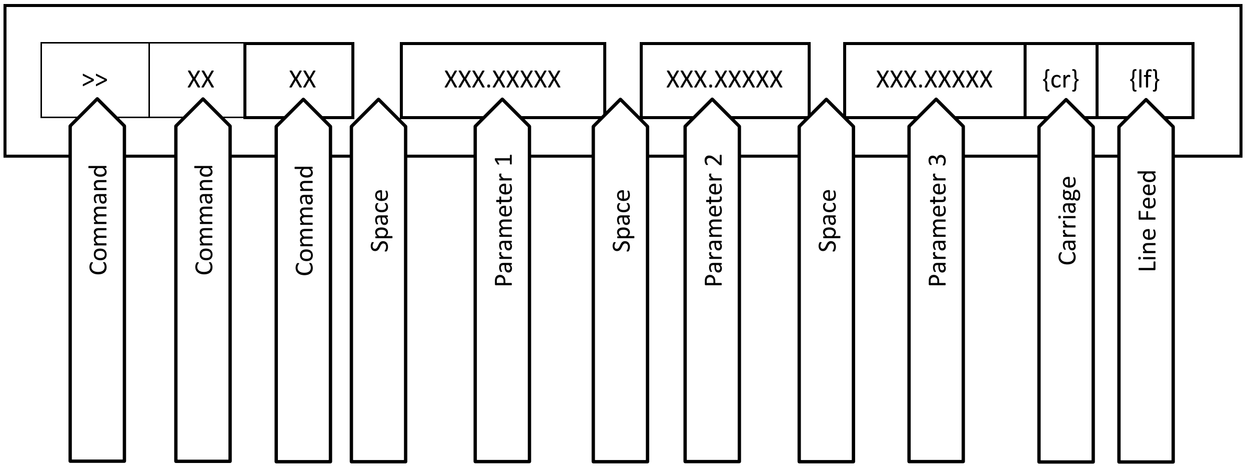
Table 7-1 Specifications for the Model 2950 (subject to change without notification). For additional product specifications refer to the 2950 Data Sheet P/N5002628; available on www.tsi.com

Flow Controller	Spec
Wetted Materials	SS316 / Kalrez / Nickel / BNi-5 or Ni 650 On units with a built in valve, PEEK is also a wetted material.
Overpressure Resistance	300kPa
Maximum Pressure Drop	5 mbar
Capillary Inner Diameter	Depends upon model selected
Port Connectors	$^{1}/_{8}$” Male VCR fitting
Dimensions	4.75” x 5.87” x 1.19”
Weight	1.0 lb (0.5 kg)
Mounting Slots	four slots 0.15”wide on a 4.75” x .75” pattern
Operating Temperature	10°C to 50°C
Ambient Storage Temperature	-10°C to 60°C
Operating Humidity	20% to 80% non-condensing
Electrical Supply	10Vdc - 30VDC, 1 A Single fault tolerant supply approved to EN60950 or UL1950 standard
Maximum Piezo Output	130V, 150mA+ for short periods
Tool Signal Input Impedance	296 kΩ
Tool Signal Output	0-5V, min required impedance 31 kΩ

8 SERIAL COMMAND SET

Table 7-1 Specifications for the Model 2950 (subject to change without notification)

Serial Command String Format



Command Sentinal : describes whether the data was sent to the controller or sent from the controller

> means that the string was sent to the controller

< means that the string was the controllers response.

Command Category: is a two character parameter that describes the action to be performed.

DO is 'Do'
RD is Read Data
RM is Read Measurement
RS is Read Setting
WD is Write Data
WM is Write Measurement
WS is Write Setting

The serial command set is used to monitor and adjust the set point during normal operations. In addition it can be used to send PID values. Note: the 2950 LFC Service Tool is needed to add new liquids and set up there parameters.

To send commands without the 2950 Configuration Software, HyperTerminal or PuTTY could be used to communicate with the 2950.

Type	Command	Description
RP	METRICS	Reads Metrics Parameters, currently the only metrics are: version and number of valve cycles
RP	METRICSHEADER	Reads the header which describes the metrics parameters
RM	PRZ	Measured inlet and exit pressure after the zero offset is applied.
RM	PDF	The pressure drop between the two pressure sensors
RM	TMP	Temperature measurements (inlet & exit)

Type	Command	Description
RM	TAV	Average Temperature measurement
RM	QMC	Mass Flowrate
RS/WS	SMF	Setpoint of Mass Flow Rate
RS	VPZ	Voltage to the Piezo Valve
RD	ERF	Error/Warning Flags
RD/WD	ERM	Error/Warning Mask
DO	BSS	Start the LED's blinking
DO	ZBP	Calibrate the Zero Flow (Zero Button Pressed)
RS/WS	MOD	PID Mode
RS/WS	PID	Send PID values to the Recipe Table
RS/WS	LNB	Set the liquid number of the liquid being run
RS/WS	LNM	Name of the Liquid being controlled
RS/WS	LTB	Thermal Breakdown Temperature
RS/WS	LTW	Thermal Breakdown Warning Temperature
RD/WD	SN	Serial Number of the Unit
RD/WD	MF	Manufacturer's name
RD/WD	MN	Model Number
RD/WD	MD	Date of Manufacturing
RD/WD	VER	Firmware Version

Types of Commands Include:
Read Data (RD); Read Setting (RS); Read Measurement (RM)

In the examples
{cr} means carriage return
{lf} means linefeed
{sp} means space

METRICS
This command returns the Metrics of the 2950 flow controller

Example:
Command Sent: **>RPMETRICS**{cr}{lf}
Expected Response: **< RPMETRICS**{sp}**XX**{sp}**YYYYYYYYYY**{cr}{lf}
where **XX** is the version of the 2950 being queried
and **YYYYYYYYYY** is number of piezo valve cycles that the 2950 performed

METRICSHEADER
This command returns a header for the metrics of the 2950 flow controller

Example:
Command Sent: **>RPMETRICSHEADER**{cr}{lf}
Expected Response: **<RPMETRICSHEADER**{sp}**MetricsVersion**{sp}**PVCycles**{cr}{lf}
where **MetricsVersion** is a text string '*MetricsVersion*'
and **PVCycles** is a text string '*PVCycles*'

PRZ • (Press Zero Button)

This command is the equivalent to pressing the zero button and is used to zero the flow sensor. Shut off valves should be closed upstream and or downstream of the 2950 flow controller to insure that there is no flow going through it when the command is set. Issuing this command will change the offsets of the in inlet and exit pressure sensors so they measure the same pressure when no flow is going through the capillary tube sensor, effectively zeroing the sensor.

Example:
Command Sent: **>RMPRZ**{cr}{lf}
Expected Response: **<RMPRZ**{sp}**XXX.XXXXX**{sp}**YYY.YYYYY**{cr}{lf}
where **XXX.XXXXXX** is the pressure reading from the inlet pressure sensor in kPa
and **YYY.YYYYY** is the pressure reading from the exit pressure sensor in kPa

PDF • (Pressure Difference)

This command returns the pressure drop (difference) between the inlet and the exit before it is converted into a flow rate

Example:
Command Sent: **>RMPDF**{cr}{lf}
Expected Response: **<RMPDF**{sp}**XXX.XXXXX**{cr}{lf}
where **XXX.XXXXXX** is the pressure drop reading between the inlet and the exit in kPa

TMP • (Temperature)

This command returns the temperature measurements at the inlet and the outlet

Example:
Command Sent: **>RMTMP**{cr}{lf}
Expected Response: **<RMTMP**{sp}**XXX.XXXXX**{sp}**YYY.YYYYY**{cr}{lf}
where **XXX.XXXXXX** is the temperature reading from the inlet temperature sensor in °C
and **YYY.YYYYY** is the pressure reading from the exit pressure sensor in °C

TAV • (Temperature Average)

This command returns the average temperature measurements between the inlet and the outlet temperature

Example:
Command Sent: **>RMTAV**{cr}{lf}
Expected Response: **<RMTAV**{sp}**XXX.XXXXX**{cr}{lf}
where **XXX.XXXXXX** is the average temperature reading from the inlet and exit of the sensor in °C

QMR • (Mass Flow Rate)

This command returns the mass flow rate measurement form the controller

Example:
Command Sent: **>RMQMR**{cr}{lf}
Expected Response: **<RMQMR**{sp}**XXX.XXXXX**{cr}{lf}
where **XXX.XXXXXX** is the measured mass flow rate in grams per minute

SMF • (Setpoint of Mass Flow Rate)

Depending upon how this command is written, this command can be used to either write or read the setpoint

Examples:
Writing the Setpoint

Command Sent: **>WSFSP**{sp}**XXX.XXXXX**{cr}{lf}
Expected Response: **<WSFSP**{sp}**XXX.XXXXX**{cr}{lf}
where **XXX.XXXXXX** is the mass flow rate Setpoint in grams per minute

Reading the Setpoint
Command Sent: **>RSFSP**{cr}{lf}
Expected Response: **<RSFSP**{sp}**XXX.XXXXX**{cr}{lf}
where **XXX.XXXXXX** is the mass flow rate Setpoint in grams per minute

VPZ • (Voltage to Piezo Valve)
This command returns the voltage sent to the piezo valve connector

Example:
Command Sent: **>RSVPZ**{cr}{lf}
Expected Response: **<RSVPZ**{sp}**XXX.XXXXX**{cr}{lf}
where **XXX.XXXXXX** is the voltage sent to the Piezo Valve in volts

ERF • (Error Flags)
This command returns the error flags set by the flow controller

Example:
Command Sent: **>RDERF**{cr}{lf}
Expected Response: **<RDERF**{sp}**ABCDEFGHJKLMNPQ**{cr}{lf}
where **A** is the *over flow bit* that indicates that the flow is higher than the value set with the WSFSF command
where **B** is the *over pressure* bit that indicates a pressure at either pressure sensor exceeds 360kPa
where **C** is the *under pressure* bit that indicates that pressure at P1 fell below 90kPa
where **D** is the *over temperature* bit that indicates that the liquid temperature is greater than 45°C
where **E** is the *under temperature* bit that indicates that the liquid temperature is below than 14.5°C
where **F** is reserved for future use
where **G** is the *unable to reach set point* bit that indicates that the Liquid Flow Controller was unable to reach set point within 5% in 30 seconds
where **H** is the *rapid flow fluctuation* bit that a clog might have occurred
where **J** is the *failed to re-zero* bit that the pressure offset required to zero flow controller is too great.
where **K** is the *can't measure flow* bit that indicates a failure to measure flow
where **L** is the *low power* bit that indicates that the power voltage is below 10V
where **M** is reserved for future use
where **N** is reserved for future use
where **P** is reserved for future use
where **Q** is reserved for future use

BSS • (Set LED blinking)
This command is used as a production test. When this command is sent, the 2950 blinks for 1 minute at a rate of 300ms on and 300ms off.

Example:
Command Sent: **>DOBSS**{cr}{lf}
Expected Response: **< DOBSS**{cr}{lf}
Then the LED blinks for 1 minute at a rate of 300ms on and 300ms off.

ZBP • (Zero Button Pressed)

This command is the equivalent to pressing the zero button and is used to zero the flow sensor. Shut off valves should be closed upstream and or downstream of the 2950 flow controller to insure that there is no flow going through it when the command is set. Issuing this command will change the offsets of the in inlet and exit pressure sensors so they measure the same pressure when no flow is going through the capillary tube sensor, effectively zeroing the sensor.

Example:
Command Sent: **>DOZBP**{cr}{lf}
Expected Response: **< DOZBP**{cr}{lf}

MOD • (PID Mode)

This command sets the PID mode of operation

Examples:
Reading
Command Sent: **>RSMOD**{cr}{lf}
Expected Response: **<RSMOD**{sp}**XX**{cr}{lf}

where **XX** is the PID mode

- Mode 00 runs PID control on the valve using the setpoint from the analog input signal
- Mode 01 runs PID control on the valve using the setpoint from the digital signal
- Mode 02 overides PID control, using the value from the WSVOO command to set the voltage
- Mode 03 overides PID control, to fully close the valve using the value from the WSVPM command to set the voltage
- Modes greater than 03 are reserved for future use

PID • (Send PID values to Recipe Table)

This is the command used to set the PID parameters and Bias/Offset time parameters for the 2950 flow controller.
Up to eight zones (00 through 07) can be set up to minimize overshoot and response time.

Example:
Command Sent:

>WSPID{sp}**AA**{sp}**BBB.BBBBB**{sp}**CCC.CCCCC**{sp}**DDD.DDDDD**{sp}**EEE.EEEEE**{sp}**FFF.FFFFF**{sp}**GGGG**{cr}{lf}

Expected Response:

<WSPID{sp}**AA**{sp}**BBB.BBBBB**{sp}**CCC.CCCCC**{sp}**DDD.DDDDD**{sp}**EEE.EEEEE**{sp}**FFF.FFFFF**{sp}**GGGG**{cr}{lf}

- where **AA** is the *PID Zone Index* which is a value between 00 and 07, for a total of eight zones
- where **BBB.BBBBB** is the *upper limit of the zone* defined as a % of full scale flowrate value. The lower limit is 1 unit of full scale above the upper limit zone below it or zero in the case of zone 00
- where **CCC.CCCCC** is the *Proportional Gain* used in that zone
- where **DDD.DDDDD** is the *Integral Gain* used in that zone
- where **EEE.EEEEE** is the *Derivative Gain* used in that zone
- where **FFF.FFFFF** is the *Bias/Offset Value* used in that zone, which is the amount of voltage applied to the piezo valve when the setpoint changes from zero to a setpoint value within the zone. The Bias/Offset value is applied for the length of time set by the Bias/Offset time. To turn the Bias/Offset voltage off, set the Bias/Offset time to zero.
- where **GGGG** is the *Bias/Offset Time* sets the length of time that the Bias/Offset voltage is applied. The Bias/Offset time is in milliseconds, with the smallest increment being 11.1ms

LNB • (Liquid Number)

This command writes or reads the index number of the liquid that the flow controller is using to determine a flow rate from a pressure drop measurement.

Example:
Command Sent: **>WSLNB**{sp}**XX**{cr}{lf}
Expected Response: **<WSLNB**{sp}**XX**{cr}{lf}
where **XX** is a two digit number between 01 and 03, where 01 is TEOS and numbers 02 and 03 are user defined.

LNM • (Liquid Name)

This command writes or reads the name of the liquid that the flow controller is using to determine a flow rate from a pressure drop measurement.

Example:
Command Sent: **>WSLNM**{sp}**XXXXXXXXXXXXXXXXXXXX**{cr}{lf}
Expected Response: **<WSLNM**{sp}**XXXXXXXXXXXXXXXXXXXX**{cr}{lf}
where **XXXXXXXXXXXXXXXXXXXX** is a twenty digit string intended for the name of the liquid being controlled

SN • (Serial Number of the Unit)

This command reads the serial number of the 2950 Flow Controller that is being queried

Example:
Command Sent: **>RSSN**{cr}{lf}
Expected Response: **<RSSN**{sp}**XXXXXXXXXXXXXXXXXXXX**{cr}{lf}
where **XXXXXXXXXXXXXXXXXXXX** is a twenty digit string of the serial number of the unit being queried

MF • (Manufacturer's Name)

This command reads the manufacturer's name of the 2950 Flow Controller that is being queried

Example:
Command Sent: **>RSMF**{cr}{lf}
Expected Response: **<RSMF**{sp}**XXXXXXXXXXXXXXXXXXXX**{cr}{lf}
where **XXXXXXXXXXXXXXXXXXXX** is a twenty digit string of the manufacturer's name of the unit being queried

MN • (Model Number)

This command reads the manufacturer's model number of the 2950 Flow Controller that is being queried

Example:
Command Sent: **>RSMN**{cr}{lf}
Expected Response: **<RSMN**{sp}**XXXXXXXXXXXXXXXXXXXX**{cr}{lf}
where **XXXXXXXXXXXXXXXXXXXX** is a twenty digit string of the manufacturer's model number of the unit being queried

MD • (Date of Manufacturing)

This command reads the date that the 2950 Flow Controller was manufactured

Example:
Command Sent: **>RSMD**{cr}{lf}
Expected Response: **<RSMD**{sp}**DD/MM/YYYYY**{cr}{lf}
where **DD** is the day of the month that the unit was manufactured
where **MM** is the month that the unit was manufactured

where **YYYYY** is the year that the unit was manufactured

VER • (Firmware Version)
This command reads the version of firmware that is installed on the 2950 Flow Controller

Example:
Command Sent: **>RSVER**{cr}{lf}
Expected Response: **<RSVER**{sp}**X.XX**{cr}{lf}
where **X.XX** is the version of firmware that is installed on the 2950 Flow Controller

9 ETHERCAT COMMAND SET

Table 7-1 Specifications for the Model 2950 (subject to change without notification)

The following is the Command set based on ETG5003-1 standard

Index	SubInd	Name	Type	Bits	Default	Access
#x1000		Device Type				RO
#x1001		Error Register				
#x1008		Manufacturer Device Name				RO
#x1009		Manufacturer Hardware Version				RO
#x100A		Manufacturer Software Version				RO
#x100B		Manufacturer Bootloader Version				RO
#x1018		Identity Object				
	0x01	Vendor ID	BOOL			RO
	0x02	Product Code	BOOL			RO
	0x03	Revision Number	BOOL			RO
	0x04	Serial Number	BOOL			RO
#x10F1		Error Settings				
	0x01	Local Error Reaction				RW
	0x02	Sync Error Counter Limit				RW
#x10F3		Diagnosis History				
	0x01	Maximum Messages				RO
	0x02	Newest Message				RO
	0x03	Newest Acknowledged Message				RW
	0x04	New Messages Available				RO P
	0x05	Flags				RW
#x10F8		Timestamp Object				RW P
#x1600		Output Mapping 0				
	0x01	Subindex 001				RO
	0x02	Subindex 002				RO
	0x03	Subindex 003				RO
#x1601		Output Mapping 1				
	0x01	Subindex 001				RO
	0x02	Subindex 002				RO
	0x03	Subindex 003				RO
#x1A00		Input Mapping 0				RW
	0x01	Subindex 001				RW
	0x02	Subindex 002				RW
	0x03	Subindex 003				RW
	0x04	Subindex 004				RW
	0x05	Subindex 005				RW
	0x06	Subindex 006				RW
	0x07	Subindex 007				RW

Index	SubInd	Name	Type	Bits	Default	Access
	0x08	Subindex 008				RW
	0x09	Subindex 009				RW
	0x0A	Subindex 00A				RW
	0x0B	Subindex 00B				RW
	0x0C	Subindex 00C				RW
	0x0D	Subindex 00D				RW
	0x0E	Subindex 00E				RW
	0x0F	Subindex 00F				RW
	0x10	Subindex 010				RW
#x1C00		Sync Manager Type				
	0x01	Subindex 001				RO
	0x02	Subindex 002				RO
	0x03	Subindex 003				RO
	0x04	Subindex 004				RO
#x1C12		Sync Manager 2 assignment				
	0x01	Subindex 001				RW
	0x02	Subindex 002				RW
#x1C13		Sync Manager 3 assignment				
	0x01	Subindex 001				RW
	0x02	Subindex 002				RW
#x1C32		SM Output Parameter				
	0x01	Synchronization Type				RW
	0x02	Cycle Time				RO
	0x04	Synchronization Types Supported				RO
	0x05	Minimum Cycle Time				RO
	0x06	Calc and Copy Time				RO
	0x08	Get Cycle Time				RW
	0x09	Delay Time				RO
	0x0A	Sync0 Cycle Time				RW
	0x0B	SM-Event Missed				RO
	0x0C	Cycle Time Too Small				RO
	0x20	Sync Error				RO
#x1C33		SM Input Parameter				
	0x01	Synchronization Type				RW
	0x02	Cycle Time				RO
	0x04	Synchronization Types Supported				RO
	0x05	Minimum Cycle Time				RO
	0x06	Calc and Copy Time				RO
	0x08	Get Cycle Time				RW
	0x09	Delay Time				RO
	0x0A	Sync0 Cycle Time				RW
	0x0B	SM-Event Missed				RO
	0x0C	Cycle Time Too Small				RO
	0x20	Sync Error				RO
#x2000		Zone 0 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
#x2001		Zone 1 Config		208		

Index	SubInd	Name	Type	Bits	Default	Access
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time (ms)	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2002		Zone 2 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2003		Zone 3 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2004		Zone 4 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2005		Zone 5 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2006		Zone 6 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2007		Zone 7 Config		208		
	0x01	End Point	Real			RW
	0x02	Proportional Gain	Real			RW
	0x03	Integral Gain	Real			RW
	0x04	Derivative Gain	Real			RW

Index	SubInd	Name	Type	Bits	Default	Access
	0x05	Bias/Offset Time	Real			RW
	0x06	Bias/Offset Voltage	Real			RW
	0x07	Dynamic Bias/Offset Offset	Real			RW
#x2008		Liquid Config				
	0x01	Liquid Name	String(20)			RO
	0x02	Viscosity	Real			RO
	0x03	Density	Real			RO
	0x04	Selected Liquid	?			RO
#x2009		Setpoints				
	0x01	Piezo Voltage Override Setpoint	Real			RW
	0x02	Piezo Voltage Override	UInt16			RW
	0x03	Ramped Setpoint	Real			RO P
	0x04	Multipoint Tuning Store Mode	UInt	16		RW
	0x05	Multipoint Tuning Bias/Offset Source	UInt	16		RW
	0x06	Multipoint Tuning Stability Threshold	Real	32		RW
	0x07	Multipoint Tuning Stability Interval	UInt	16		RW
#x200A		Measurements	DT200A			
	0x01	Upstream Pressure	Real			RO P
	0x02	Downstream Pressure	Real			RO P
	0x03	Pressure Drop	Real			RO P
	0x04	Temperature	Real			RO P
	0x05	Mass Flow Rate	Real			RO P
	0x06	Piezo Voltage	Real			RO P
#x200B		Zero Adj - Downstream Press Sens				
		Command	Array[0..3]			RW
		Status	USINT			RO
		Response	Array[0..1]			RO
#x200C		Zero Adj - Upstream Press Sens				
	0x01	Command	Array[0..1]			RW
	0x02	Status	USINT			RO
	0x03	Response	Array[0..1]			RO
#x200D		Zero Button				
	0x01	Command	Array[0..1]			RW
	0x02	Status	USINT			RO
	0x03	Response	Array[0..1]			RO
#x200E		Rapid Flow Change				
	0x01	Reset Rapid Flow Change Warning	Array[0..1]			RW
		Input Data of the Module				
#x6000		Sensor: Flow (floating)				
	0x01	Flow Reading [Real]	Real			
#x6001		Sensor: Pressure (floating)				RO P
	0x01	Pressure Reading [Real]	Real			
#x6002		Sensor: Temperature (floating)				RO P
	0x01	Temperature Reading [Real]	Real			
#x6009		Actuator				RO P
	0x01	Actuator Setpoint [Real]	Real			
#x600F		Status				RO P
	0x01	Service in Progress	BOOL			RO P
	0x02	Invalid Data Input	BOOL			RO P
	0x03	Ramp Active	BOOL			RO P
	0x04	Valve Control Mode (fully open)	BOOL			RO P

Index	SubInd	Name	Type	Bits	Default	Access
	0x05	Valve Control Mode (fully closed)	BOOL			RO P
	0x06	Valve Control Mode (position control)	BOOL			RO P
	0x0D	New Message in Diagnosis History	BOOL			RO P
	0x0E	TxPdoState	BOOL			RO P
	0x0F	Input Cycle Counter	Bit2			RO P
		Output Data of the Module				
#x7003		Controller: Flow SP (floating)				
	0x01	Flow SP	BOOL			RW P
#x7008		Controller: Ramp Time	DT7008	48		
	0x01	Ramp Time				RW P
#x7009		Actuator	DT7009	24		
	0x01	Actuator Control				RW P
#x700F		Status	DT700F	32		
	0x0F	Output Cycle Counter				RW P
#x8000		Sensor: Flow (floating)	DT8000	48		RW
	0x01	Flow Data Unit				
#x8001		Sensor: Pressure (floating)	DT8001	48		RW
	0x01	Pressure Data Unit				
#x8002		Sensor: Temperature (floating)	DT8002	48		RW
	0x01	Temperature Data Unit				
#x8008		Controller: Ramp Time	DT8008	48		RW
	0x01	Max Ramp Time				
#x8009		Actuator	DT8009	24		RW
	0x01	Safe State				
#x800A		Active Liquid Calibration Index	DT800A	24		RW
	0x01	Index				
#x9000		Sensor: Flow (floating)	DT9000	48		
	0x01	Flow Reading Zero Offset				RO
#x9001		Sensor: Pressure (floating)	DT9001	144		
	0x01	Pressure Sensor Full Scale				RO
	0x02	Pressure Reading Zero Offset				RO
	0x03	MFC Pressure High Threshold Alarm				RO
	0x04	MFC Pressure Low Threshold Alarm				RO
#x9002		Sensor: Temperature (floating)	DT9002	112		
	0x01	Temperature Sensor Full Scale				RO
	0x02	MFC Temp High Threshold Alarm				RO
	0x03	MFC Temp Low Threshold Alarm				RO
#x9008		Controller Ramp Time	DT9008	48		
	0x01	Min Ramp Time				RO
#x900A		Liquid Parameter Instance 1	DT900A	3744		
	0x01	Liquid Calibration Index				RO
	0x02	Liquid Number				RO
	0x03	Liquid Symbol				RO
	0x04	Liquid Name				RO
	0x05	Minimum Full Scale				RO
	0x06	Nominal Full Scale				RO
	0x07	Configured Full Scale Range				RO
	0x08	Minimum Flow SP				RO
	0x09	Maximum Flow SP				RO
	0x0A	Device Bin Number				RO
	0x0B	Liquid Calibration File Revision				RO

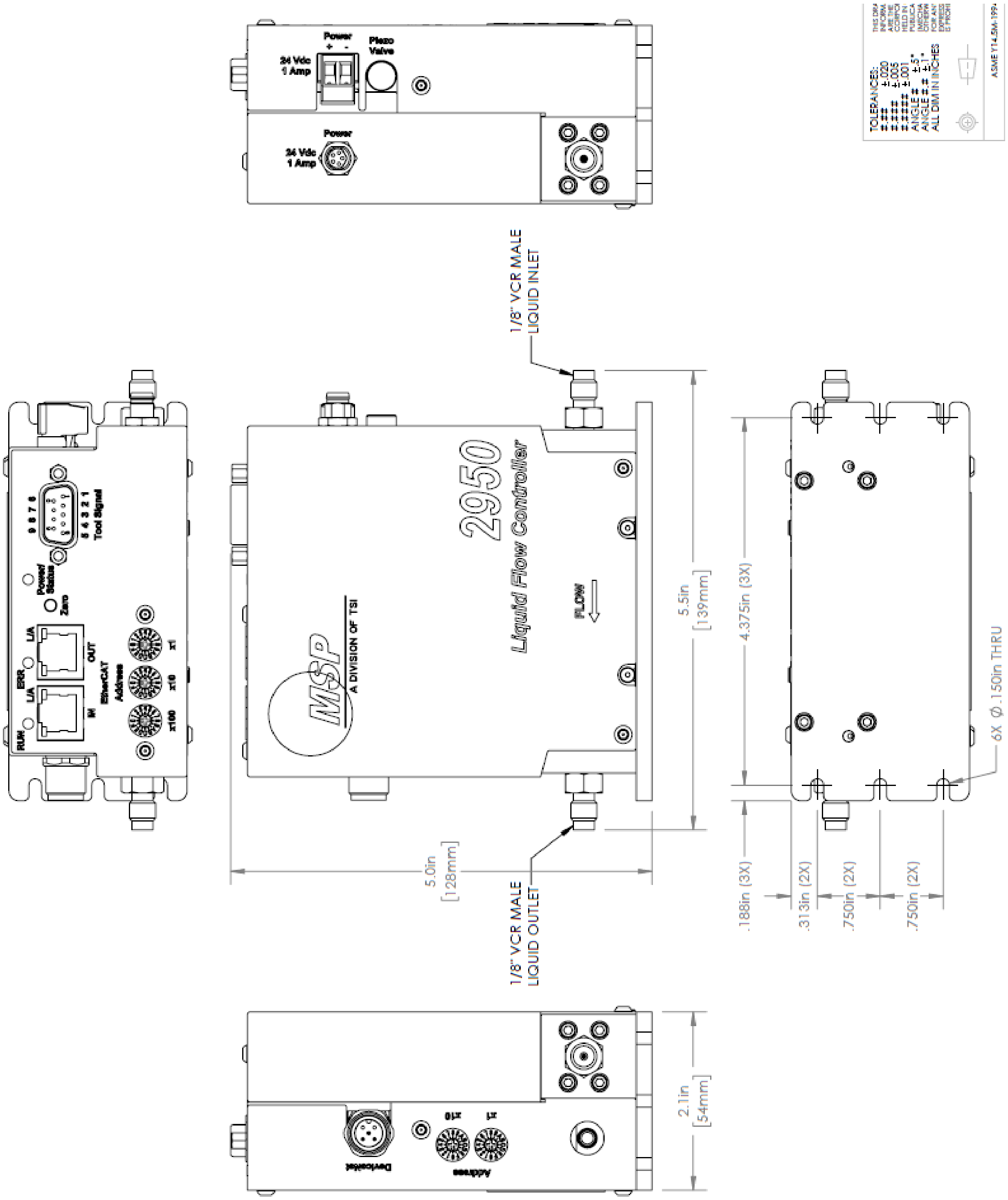
Index	SubInd	Name	Type	Bits	Default	Access
		Number				
	0x0C	Revision of Supported Liquid Table				RO
	0x0D	Date of Factory Calibration				RO
	0x0E	Date of Last Calibration				RO
	0x0F	Cardinal Points Array Size				RO
	0x10	Cardinal Points				RO
#x900B		Liquid Parameter Instance 2	DT900B	3744		
	0x01	Liquid Calibration Index				RO
	0x02	Liquid Number				RO
	0x03	Liquid Symbol				RO
	0x04	Liquid Name				RO
	0x05	Minimum Full Scale				RO
	0x06	Nominal Full Scale				RO
	0x07	Configured Full Scale Range				RO
	0x08	Minimum Flow SP				RO
	0x09	Maximum Flow SP				RO
	0x0A	Device Bin Number				RO
	0x0B	Liquid Calibration File Revision Number				RO
	0x0C	Revision of Supported Liquid Table				RO
	0x0D	Date of Factory Calibration				RO
	0x0E	Date of Last Calibration				RO
	0x0F	Cardinal Points Array Size				RO
	0x10	Cardinal Points				RO
#x900C		Liquid Parameter Instance 3	DT900C	3744		
	0x01	Liquid Calibration Index				RO
	0x02	Liquid Number				RO
	0x03	Liquid Symbol				RO
	0x04	Liquid Name				RO
	0x05	Minimum Full Scale				RO
	0x06	Nominal Full Scale				RO
	0x07	Configured Full Scale Range				RO
	0x08	Minimum Flow SP				RO
	0x09	Maximum Flow SP				RO
	0x0A	Device Bin Number				RO
	0x0B	Liquid Calibration File Revision Number				RO
	0x0C	Revision of Supported Liquid Table				RO
	0x0D	Date of Factory Calibration				RO
	0x0E	Date of Last Calibration				RO
	0x0F	Cardinal Points Array Size				RO
	0x10	Cardinal Points				RO
#x900D		Liquid Parameter Instance 4	DT900D	3744		
	0x01	Liquid Calibration Index				RO
	0x02	Liquid Number				RO
	0x03	Liquid Symbol				RO
	0x04	Liquid Name				RO
	0x05	Minimum Full Scale				RO
	0x06	Nominal Full Scale				RO
	0x07	Configured Full Scale Range				RO
	0x08	Minimum Flow SP				RO
	0x09	Maximum Flow SP				RO
	0x0A	Device Bin Number				RO

Index	SubInd	Name	Type	Bits	Default	Access
	0x0B	Liquid Calibration File Revision Number				RO
	0x0C	Revision of Supported Liquid Table				RO
	0x0D	Date of Factory Calibration				RO
	0x0E	Date of Last Calibration				RO
	0x0F	Cardinal Points Array Size				RO
	0x10	Cardinal Points				RO
#x900E		Liquid Parameter Instance 5	DT900E	3744		
	0x01	Liquid Calibration Index				RO
	0x02	Liquid Number				RO
	0x03	Liquid Symbol				RO
	0x04	Liquid Name				RO
	0x05	Minimum Full Scale				RO
	0x06	Nominal Full Scale				RO
	0x07	Configured Full Scale Range				RO
	0x08	Minimum Flow SP				RO
	0x09	Maximum Flow SP				RO
	0x0A	Device Bin Number				RO
	0x0B	Liquid Calibration File Revision Number				RO
	0x0C	Revision of Supported Liquid Table				RO
	0x0D	Date of Factory Calibration				RO
	0x0E	Date of Last Calibration				RO
	0x0F	Cardinal Points Array Size				RO
	0x10	Cardinal Points				RO
#xF000		Semiconductor Device Profile	DTF000	48		
	0x01	Index Distance				RO
	0x02	Maximum Number of Modules				RO
#xF010		Module Profile List	DTF010	48		
	0x01	SubIndex 001				
#xF380		Active Exception Status	USINT	8		RO P
#xF381		Active Device Warning Details	DTF381	48		
	0x01	SubIndex 001				RO P
#xF382		Active Manufacturer Warning Details	DTF382	48		
	0x01	SubIndex 001				RO P
#xF383		Active Device Error Details	DTF383	48		
	0x01	SubIndex 001				RO P
#xF384		Active Manufacturer Error Details	DTF383	48		
	0x01	SubIndex 001				RO P
#xF390		Latched Exception Status	USINT	8		RO P
#xF391		Latched Device Warning Details	DTF391	48		
	0x01	SubIndex 001				RO P
#xF393		Latched Device Error Details	DTF393	48		
	0x01	SubIndex 001				RO P
#xF3A1		Device Warning Mask	DTF3A1	48		
	0x01	SubIndex 001				RW
#xF3A2		Manufacturer Warning Mask	DTF3A1	48		
	0x01	SubIndex 001				
#xF3A3		Device Error Mask	DTF3A3	48		
	0x01	SubIndex 001				
#xF3A4		Manufacturer Error Mask	DTF3A3	48		RW

Index	SubInd	Name	Type	Bits	Default	Access
#xF501		Device Information	DTF501	496		
	0x01	Manufacturer				RO
	0x02	Model				RO
	0x03	Serial				RO
#xF6F0		Input Latch Local Timestamp	DTF6F0	48		
	0x01	Input Latch Local Timestamp				
#xF6F2		Input Latch ESC Timestamp (64-bit)	DTF6F2	80		
	0x01	SubIndex 001				RO P
#xF9F0		Manufacturer Serial Number	STRING(20)	160		RO
#xF9F1		CDP Functional Generation Number	DTF9F1	48		
	0x01	SubIndex 001				RO
#xF9F2		SDP Functional Generation Number	DTF9F2	48		
	0x01	SubIndex 001				RO
#xF9F3		Vender Name	STRING(40)	320		RO
#xF9F4		Semiconductor SDP Device Name	DTF9F4	96		
	0x01	SubIndex 001				RO
#xF9F5		Output Identifier	DTF9F5	24		
	0x01	SubIndex 001				RW P
#xF9F6		Time Since Power On	UDINT	32		RO
#xF9F7		Total Time Powered	UDINT	32		RO
#xF9F8		Firmware Update Functional Generation Number	UDINT	32		RO
#xFB10		Zero Adjust for Flow Sensor	DTFB10	72		RO
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFB11		Zero Adjust for Pressure Sensor	DTFB11	72		RO
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFB12		Set Temperature Sensor	DTFB12	72		
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFBF0		Device Reset Command	DTFBF0	88		
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFBF1		Exception Reset Command	DTFBF1	80		
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFBF2		Store Parameters Command	DTFBF2	72		
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFBF3		Calculate Checksum Command	DTFBF3	104		
	0x01	Command				RW
	0x02	Status				RO
	0x03	Response				RO
#xFBF4		Load Parameters Command	DTFBF4	72		
	0x01	Command				RW

Index	SubInd	Name	Type	Bits	Default	Access
	0x02	Status				RO
	0x03	Response				RO

APPENDIX A MECHANICAL DIAGRAM



APPENDIX B INSTALLATION, HANDLING AND WARRANTY

1. *RECEIVER'S RESPONSIBILITY*

- Check packaging integrity for dents or cuts in box, evidence of dropping such as crushed corners etc. Document any damage that may have occurred during shipping **prior to opening** the shipping carton.
- Examine the content taken out from the carton, but leave clean-room-bagged items in their original clean room bags.
- Un-bag only in a clean-room environment. When unbagging, check all vacuum fitting connections, note any loose parts, bent or twisted tubes, etc.
- Handle un-bagged units only in a clean room environment, and only with clean room gloves.
- Check all packaging material after removal of the vaporizer and ensure no parts or accessories are left inside.

2. *INSTALLER'S RESPONSIBILITY*

- The unit is fragile, be careful not to drop the unit.
- Always use <u>two</u> wrenches when tightening/loosening any connections; finger tighten all the nuts; then use two wrenches, <u>but only one hand to tighten the nut</u>. With this technique, unnecessary torque on the fitting will be minimized.
- Avoid any over-torque on the connections so that nearby welded joints are not stressed. Pay particular attention to the stems at the gas inlet, liquid inlet, and the mixture outlet.
- Tightening fittings requires an experienced, careful hand. When in doubt, try less torque rather than more. If a leak is observed, only then should you use additional torque.
- Refer to the following manufacturer's installation instructions:

VCR Fittings (Swagelok): Catalog No. MS-01-24 R10, PAGE 18, *or equivalent catalog.*

3. *MINOR LEAK RECOVERY*

If a minor leak is observed around the fitting connections, attempt to tighten the problematic fitting without using any undue torque until the leak stops. When further tightening of the connection fitting shows no improvement, replace the gasket with a new one. Each Flow Controller has been leak checked at the factory several times prior to shipping it to the customer. If the leak persists, a crack may have been introduced during shipping. For those cases, please notify MSP.

4. *REMOVER'S RESPONSIBILITY*

When removing the Flow Controller from the tool, the person removing the unit must follow all of the same practices for disconnecting fittings, and handling the unit, as described Sections 2 and 4 above.

5. *SHIPPER'S RESPONSIBILITY*

When handling the unit, the shipper must follow all the same handling instructions as described in Section 1 and 2 above.

The shipper is responsible for proper packaging so that the unit arrives at its destination without any additional damage being created during transport. Pay particular attention to the atomizer head assembly so that it is not bent or so that it does not receive impacts during transport.

MSP provided an original carton with the unit. It is recommended that the user return the unit in this same carton because this carton has been designed and tested to protect the unit.

6. *Warranty Information*

Warranty

MSP products are warranted to be free from defect in material or workmanship for a period of 12 months following shipment. Products must be returned to factory for warranty repair. MSP will repair or replace the product at no cost to the customer. However, the customer will bear the shipping costs.

Fitting-Joints

MSP uses UPG or VCR type fittings to connect the LFC to the user's equipment. MSP cannot warrant any connections that are not made by MSP staff. It is the user's responsibility to ensure that the installer is qualified to make the fitting-connections. Making proper fitting connections requires expertise obtained by both formal and on-the-job training.

7. *Returning Material to MSP*

Before returning any goods to MSP, contact MSP's sales department for a Returned Material Authorization (RMA) number. The sender should include a cover-letters detailing the requested repair. The sender should also arrange for any necessary accounting documents, such as a purchase order, prior to sending the goods.

In addition, MSP ***requires*** the following things for any goods shipped, which have been, or may have been exposed to hazardous materials:

- Status of Contamination Declaration. This must be on MSP's form and must be contained on the outside of the shipping carton. Contact MSP for a copy of this form. At MSP's discretion, customer-supplied decontamination forms may be accepted, so long as an original signature is present.
- MSDS for each hazardous material to which the goods were, or may have been, exposed. The MSDS and must be contained on the outside of the shipping carton.

8. *Installation, Training, and Consultation by MSP*

MSP has particular expertise in the design, construction and fitting of vaporizers to various industrial tools. If assistance is desired in any of these areas, please contact MSP.

Appendix C Korean EMC Statement

사용자안내문

사 용 자 안 내 문
이 기기는 업무용 환경에서 사용할 목적으로 적합성평가를 받은 기기로서 가정용 환경에서 사용하는 경우 전파간섭의 우려가 있습니다.

※ 사용자 안내문은 "업무용 방송통신기자재"에만 적용한다.