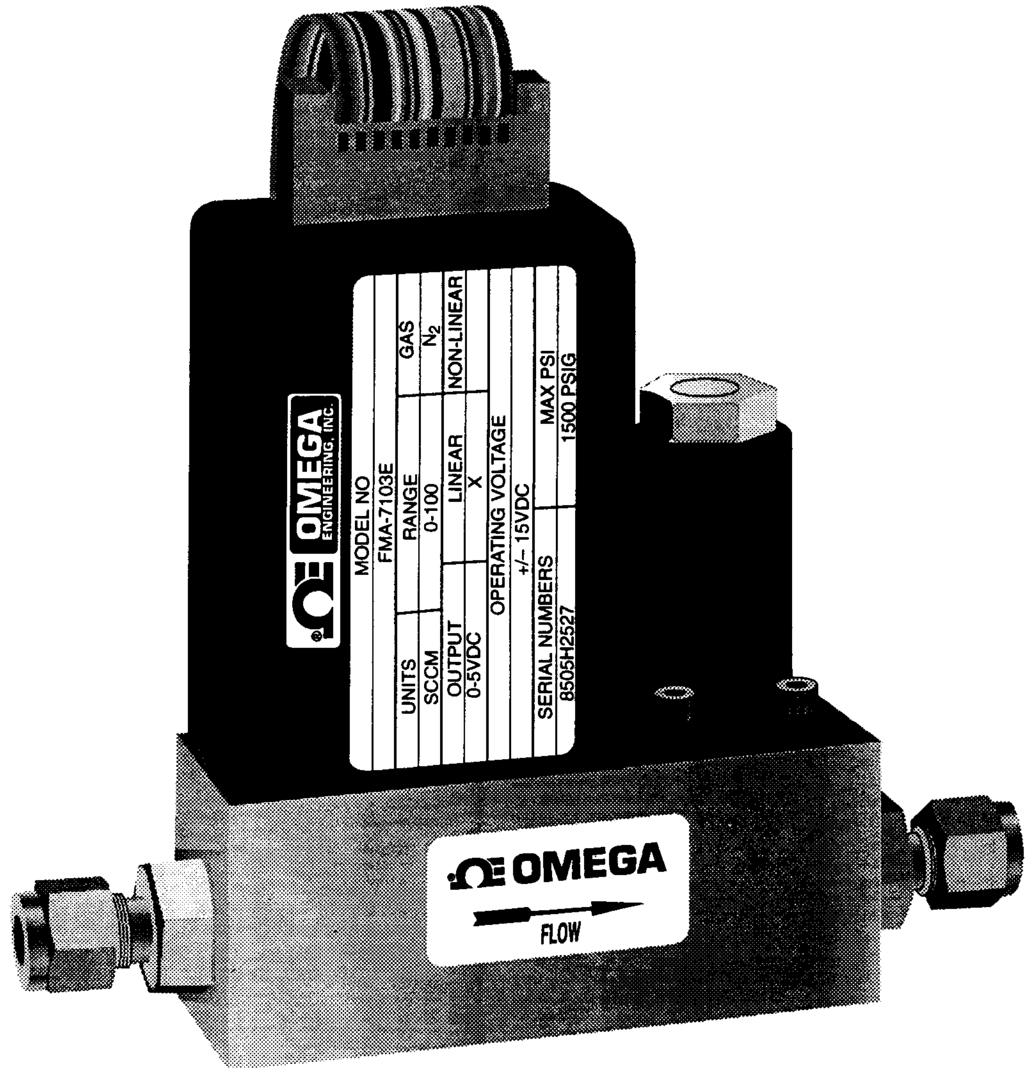
FMA-7000E

Flow Controller



OMEGA®

An OMEGA Technologies Company

Operator's Manual

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Safety

WARNING

Read this publication in its entirety before performing any operation. Failure to understand and follow these instructions could result in serious personal injury and/or damage to the equipment.

Should this equipment require repair or adjustment, contact OMEGA. It is important that servicing be performed only by trained and qualified service personnel. If this equipment is not properly serviced, serious personal injury and/or damage to the equipment could result.

CAUTION

This instrument contains electronic components that are susceptible to damage by static electricity. Observe proper handling procedures during the removal, installation, or other handling of internal circuit boards or devices.

Handling Procedure:

1. Remove power to the unit.

2. Ground personnel, via a wrist strap or other safe, suitable means, before installing, removing or adjusting any printed circuit card or other internal device.

3. Transport printed circuit cards in a conductive bag or other conductive container. Do not remove boards from protective enclosure until the immediate time of installation. Immediately place removed boards in protective container for transport, storage, or return to factory.

NOTE

This instrument is not unique in its content of ESD (electrostatic discharge) sensitive components. Most modern electronic designs contain components that utilize metal oxide technology (NMOS, CMOS, etc.). Experience has proven that even small amounts of static electricity can damage or destroy these devices. Damaged components, even though they appear to function properly, exhibit early failure.

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1 Introduction

1.1 Purpose

The OMEGA® FMA-7000E Mass Flow Controller is a mass flow measurement device designed for accurately measuring and rapidly controlling flows of gases. This instruction manual is intended to provide you with all the information necessary to install, operate and maintain the mass flow controller. This manual is organized into five sections:

Section 1 - Introduction

Section 2 - Installation

Section 3 - Operation

Section 4 - Maintenance

Section 5 - Replacement Parts

Read this manual in its entirety before attempting to operate or repair the unit.

1.2 Description

The FMA-7000E Mass Flow Controller is used widely in the Semiconductor industry as well as many others, where manual, electronic or computer controlled gas handling occurs. The instrument consists of three basic units: a flow sensor, a control valve and an integral electronic control system. This combination produces a stable gas flow, which eliminates the need to continuously monitor and readjust gas pressures. Standard features include:

- FAST RESPONSE CONTROL permits rapid gas setting times with little or no over/undershoot. Refer to Figure 1-1.
- SOFT START provides a flow ramping function which slows down the introduction of the process gas for those processes which cannot tolerate rapid flow transition. Refer to Section 2.6 and Figure 1-2.
- VALVE OVERRIDE permits you to fully open and close the control valve independent of the command setting. Refer to Section 2.8.
- SETPOINT (Command) permits you to program the mass flow controller with an external 0–5 V dc command voltage in lieu of a command potentiometer. Refer to Section 2.7.
- LOW COMMAND VALVE INHIBIT (Auto Shutoff) prevents the valve from opening whenever the setpoint is less than 2% of full scale.
- REMOVABLE CLEANABLE SENSOR permits you to clean or replace the sensor. Refer to Section 4.4.
- OUTPUT LIMITING prevents possible damage to delicate data acquisition devices by limiting the output to +6.8 V dc and –0.7 V dc.

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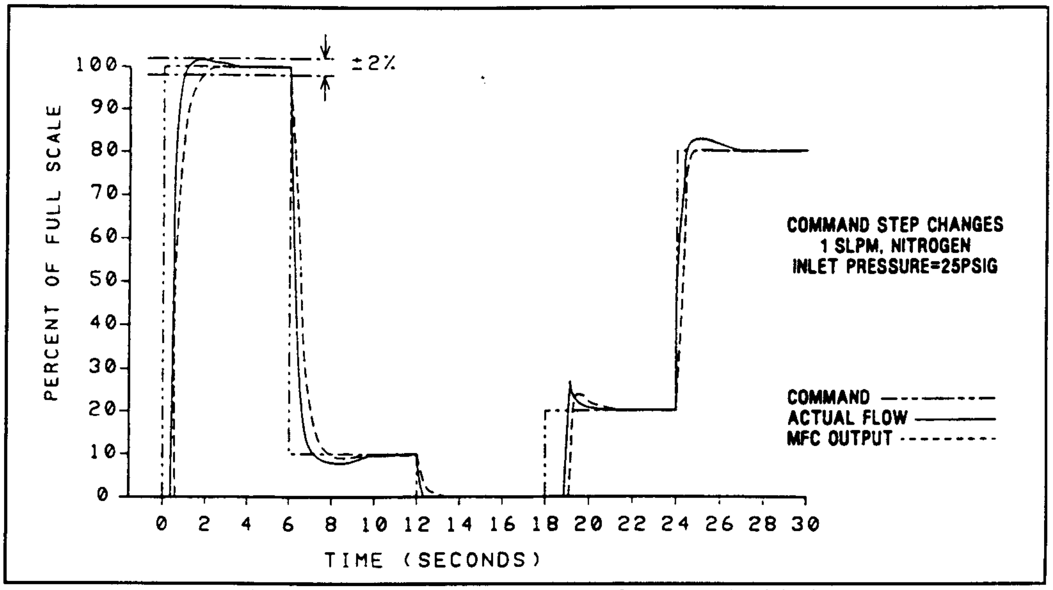

Figure 1-1. Command Steps, Soft Start Disabled

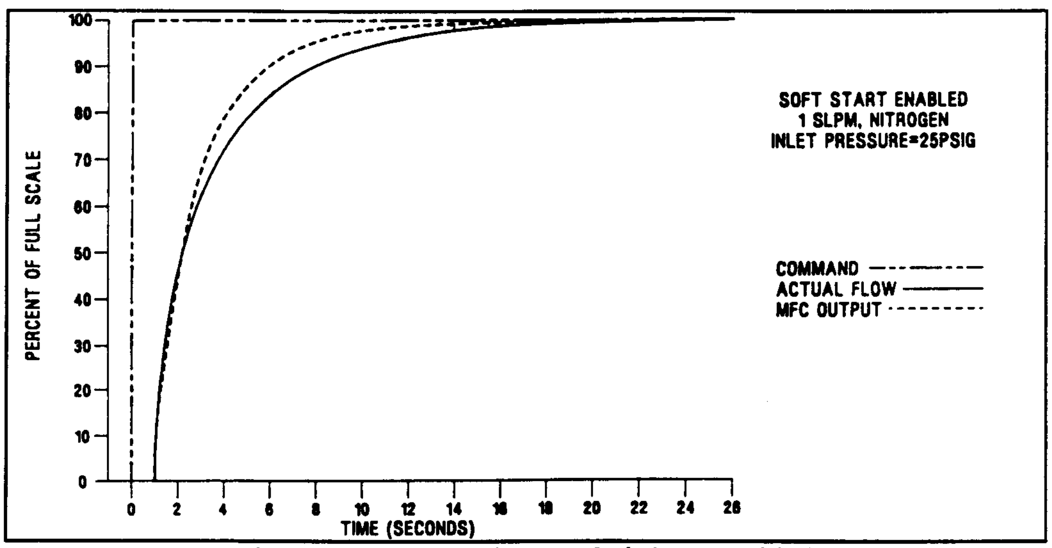

Figure 1-2. Command Steps, Soft Start Enabled

- VALVE OFF is accessed via terminal J on the card edge or pin 4 on the D-connector version. This feature allows you to close the control valve independently of the command signal by supplying a TTL level low signal to the proper terminal. This function is useful when performing repetitive flow operations or as a safety shutdown. Refer to Section 2.11.

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- VALVE TEST POINT/PURGE is accessed via terminal D on the card edge or pin 7 on the D-connector version. This feature allows you to monitor the control valve voltage during operation. Also, grounding this terminal will cause the control valve to fully open independent of the command signal. Refer to Section 2.10.

1.3 Specifications

CAUTION

Do not operate this instrument in excess of the specifications.

Standard Ranges

3 sccm to 30 slpm* (nitrogen equivalent)

Accuracy

±1% full scale including linearity at calibration conditions.

±1.5% full scale including linearity for flow ranges greater than 20 slpm.

Repeatability

0.25% of rate

Response Time

Less than 3 seconds response to within 2% of full scale final value with a 0 to 100% command step.

Power Requirements

+15 V dc ±5%, 35 mA

−15 V dc ±5%, 180 mA

3.5 watts power consumption

Ambient Temperature Limits

Operating: 5 to 65°C (40 to 150°F)

Non-Operating: −25 to 100°C (−13 to +212°F)

Working Pressure

1500 psi (10.342 MPa) maximum

Differential Pressure

5 to 50 psi (minimum pressure drop depends on gas and range). Refer t Orifice Sizing. Section 4.6.

Output Signal

0–5 V dc into 2000 ohms or greater. Maximum ripple 3 mV.

5 Volt Reference Output

5 Volts ±0.2%. Maximum load 1k ohms.

Temperature Sensitivity

Zero: less than ±0.075% F.S. per degree C.
Span: less than ±1.0% F.S. Shift over 10–50°C range

Power Supply Sensitivity

±0.09% full scale per % power supply voltage variation

Mounting Attitude Sensitivity

±0.5% maximum full scale deviation after re-zeroing

Command Input

0–5 V dc. Input resistance 200 k ohm

Leak Integrity

1 x 10^{-9} Atm. scc/sec Helium

Control Range

50 to 1

Mechanical Connection

Compatible with most popular mass flow controllers.
Refer to Figure 2-1.

Electrical Connection

Card edge, 20 terminals, gold over low stress nickel plated copper.

*Standard temperature and pressure in accordance with SEMI (Semiconductor Equipment and Materials International) standard: 0°C and 101.3 kPa (760 Torr).

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2 Installation

2.1 Unpacking Instructions

Remove the Packing List and verify that you have received all equipment. If you have any questions about the shipment, please call the OMEGA Customer Service Department at 1-800-622-2378 or (203) 359-1660.

When you receive the shipment, inspect the container and equipment for any signs of damage. Note any evidence of rough handling in transit. Immediately report any damage to the shipping agent.

NOTE

The carrier will not honor any claims unless all shipping material is saved for their examination. After examining and removing contents, save packing material and carton in the event reshipment is necessary.

2.2 Recommended Storage Practice

Provide intermediate or long-term storage for the equipment as follows:

1. Store in the original shipping container.
2. Store in a sheltered area, with the following conditions.
   - Ambient temperature 21°C (70°F) nominal, 32°C (90°F) maximum/7°C minimum (45°F).
   - Relative humidity 45% nominal, 60% maximum/25% minimum. Upon removal from storage, a visual inspection should be conducted to verify the condition of the equipment as "as received". If the equipment has been in storage for an excess of ten (10) months or in conditions in excess of those recommended, all pressure boundary seals should be replaced and the device subjected to a pneumatic pressure test in accordance with applicable vessel codes.

2.3 Gas Connections

Standard inlet and outlet connections supplied on the unit are 1⁄4" compression fittings for flow rates up to 10 slpm, and 3⁄8" compression fittings for higher flow rates.

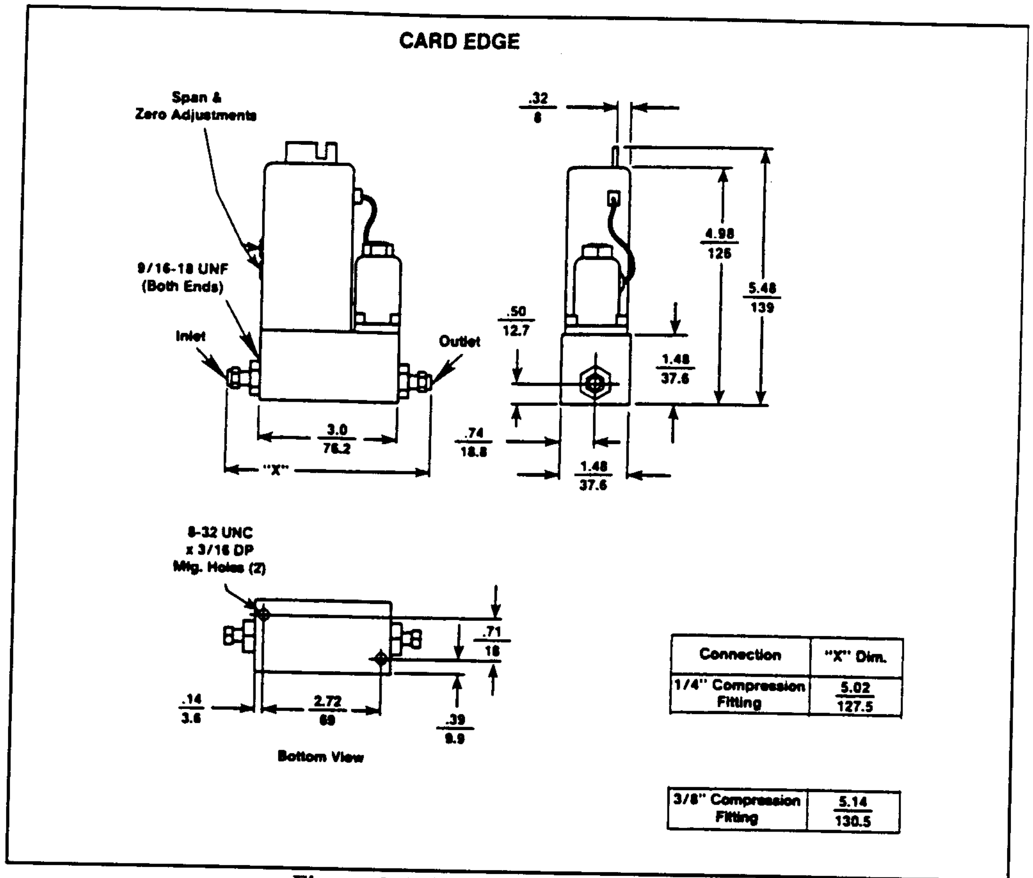

Figure 2-1. FMA-7000E Dimensions

2.4 Installation (Refer to Figures 2-1 through 2-3)

Follow these guidelines when installing the unit:

- Locate the FMA-7000E in a clean dry atmosphere relatively free from shock and vibration.
- Leave sufficient room for access to the electrical components.
- Install in such a manner that permits easy removal if the instrument requires cleaning.

CAUTION

When installing the controller, take care that no foreign materials enter the inlet or outlet of the instrument. Do not remove the protective end caps until time of installation.

CAUTION

When used with a reactive (sometimes toxic) gas, contamination or corrosion may occur as a result of plumbing leaks or improper purging. Check plumbing carefully for leaks and purge the controller with dry Nitrogen before use.

- The mass flow controller can be installed in any position. However, mounting orientations other than the original factor calibration (see data sheet) will result in a ±0.5% maximum full scale shift after re-zeroing.
- When installing controllers with full scale flow rates of 10 slpm or greater, be aware that sharp abrupt angles in the system piping directly upstream of the controller may cause a small shift in accuracy. If possible have at least 10 pipe diameters of straight tubing upstream of the mass flow controller.

NOTE

The control valve in the FMA-7000E provides precision control and is not designed for positive shut off. If positive shut off is required, install a separate shut-off valve in-line.

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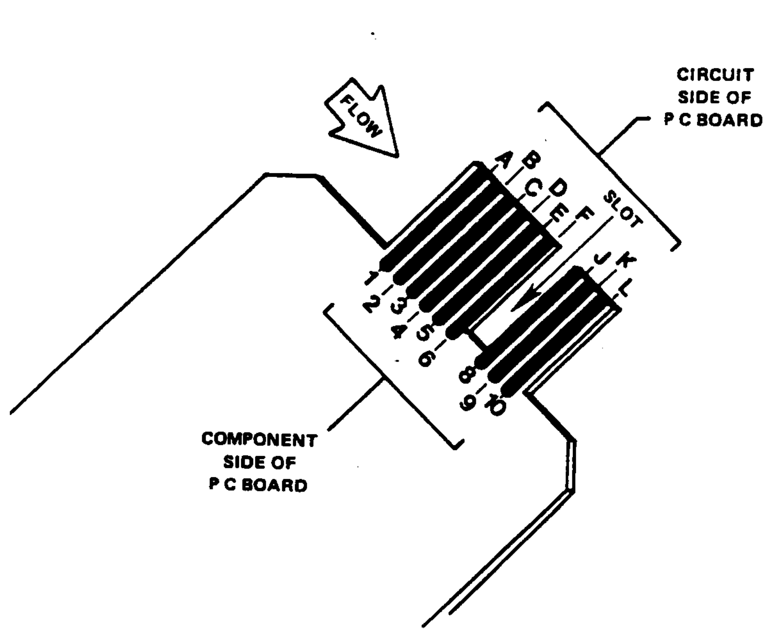

Terminal Designation

FMA-7000E	Card Edge		FMA-7000E
Chassis Ground	1	A	Command Input
0-5 Volt Signal Common	2	B	Command Common
0-5 Volt Signal Output	3	C	Supply Voltage Common
+ 15 Vdc Supply	4	D	Valve Test Point/Purge
Not used	5	E	Not used
Not used	6	F	- 15 Vdc Supply
Slot	7	H*	Slot
Not used	8	J*	Not used
Valve Override	9	K*	Not Used
+ 5V Ref. ** or Valve Return or Not used	10	L*	Valve Off

* Unit designates Pins H, J, K, & L as G, H, I, & J.
** Jumper Selectable

Figure 2-2. FMA-7000E Card Edge Connector Comparison Guide

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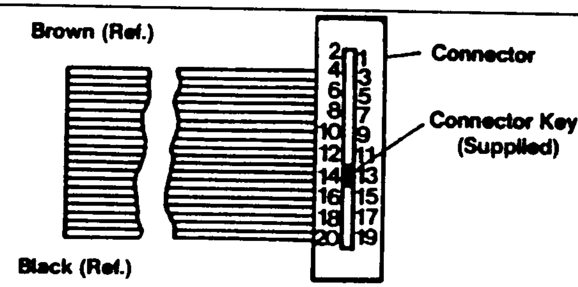

PCB No.	Connector Pin No.	Function	Color Code
1	1	Chassis Ground	Brown
A	2	Command Input (Command Pot "S")	Red
2	3	0-5 V Signal Common	Orange
B	4	Command Common (Command Pot "CCW")	Yellow
3	5	0-5 V Signal Output	Green
C	6	Supply Voltage Common	Blue
4	7	+15 Vdc Supply	Violet
D	8	Valve Test Point/Purge	Gray
5	9	Not Used	White
E	10	Not Used	Black
6	11	Not Used	Brown
F	12	-15 Vdc Input	Red
7	13	Slot	Orange
H	14	Slot	Yellow
8	15	Not Used	Green
J	16	Not Used	Blue
9	17	Valve Override	Violet
K	18	Not Used	Gray
10	19	+5 V Reference Output (Command Pot "CW")** or Valve Return**	White
L	20	Valve Off	Black

**Jumper Selectable

Figure 2-3. FMA-7000E Card Edge Connector Hook-Up Diagram

CAUTION

Since the FMA-7000E control valve is not a positive shut-off, a separate solenoid valve may have been installed for that purpose. It should be noted that a small amount of gas may be trapped between the downstream side of the mass flow controller and the solenoid resulting in a surge upon actuation of the controller. This surge can be reduced in magnitude by locating the controller and solenoid valve close together or by moving the solenoid valve upstream of the controller.

2.5 In-Line Filter

We recommend that an in-line filter be installed upstream from the controller to prevent the possibility of any foreign material entering the flow sensor or control valve. Periodically replace or ultrasonically clean the filtering element.

MAXIMUM FLOW RATE	RECOMMENDED FILTER SIZE
100 sccm	1 micron
500 sccm	2 micron
1 to 5 slpm	7 micron
10 to 30 slpm	15 micron

Table 2-1 Recommended Filter Size

NOTE

The table above lists the maximum recommended porosity for each flow range. We recommend that you use the minimum micron porosity that does not limit the full scale flowrate due to excessive pressure drop through the filter.

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Electrical Interfacing

To insure proper operation, connect the unit per Figure 2-3 and configure according to Sections 2.6 to 2.13.

As a minimum, make the following connections for new installations:

Chassis Ground
0–5 Volt Signal Common
0–5 Volt Signal Output
+15 V dc Supply
–15 V dc Supply
Command Input
Command Common
Supply Voltage Common
Valve Return (Refer to Section 2.12 for jumper configuration)

For installations which will be connected to OMEGA secondary electronics, the card edge version must have the 5 volt reference enabled on pin 10. Refer to Section 2.11.

NOTE

To obtain access to the jumpers for the following options, the electronics cover can must be removed. Remove the can by removing the three screws and the valve connector. Replace the can before returning the unit to service.

2.6 Soft Start

Refer to Figures 3-3, 3-4. To enable soft start, place the red jumper on the controller printed circuit board at J2 in the right hand (ss) position.

To disable soft start, place the red jumper on the controller printed circuit board at J2 in the left hand (n) position.

2.7 Remote Setpoint (Command) Input

If the mass flow controller is to be commanded by an external 0–5 V dc signal, the command potentiometer is not used.

Hook up the command input as follows:

Card Edge Connector: Connect the external command voltage to terminal A, and external command return to terminal B. Refer to Figures 2-2 and 2-3.

2.8 Valve Override

The valve override function allows full opening and closing of the valve independent of the command setting. The unique command reset feature prevents flow overshoot when the controller goes from valve override closed to normal control.

The valve override for the mass flow controller is as follows:

1. To open the valve apply +15 V dc to the valve override terminal.
2. To close the valve apply –15 V dc to the valve override terminal.
3. To return the controller to normal operation, isolate the valve override terminal.

Card Edge: Access the valve override function from terminal 9. Refer to Figure 2-3.

NOTE

For normal operation, leave terminal 9 open (floating).

2.9 Valve Test Point/Purge

Refer to Figures 2-2 and 2-3. The valve voltage can be monitored on pin D of the card edge version. This voltage relative to circuit common is proportional to the valve voltage per the following equation:

Valve Voltage = –14.2-Voltage at the valve voltage test point (TP3)

Grounding the valve test point pin will cause the valve to open fully regardless of command input voltage.

2.10 Valve Off

Refer to Figures 2-2 and 2-3. The control valve can be forced closed regardless of command input signal by applying a TTL level low (<.4 V dc) to terminal L of the card edge version. A TTL level high or floating at this pin has no effect.

CAUTION

Do not ground terminal 10 when 5 volt reference output is enabled. Irreparable damage to the PC Board may result.

2.11 5 Volt Reference Output/Valve Drive Configuration

Card Edge: Refer to Figures 2-3 and 3-3. Terminal 10 can be jumper selected as 5 volt reference output, external valve return or "not used". The 5 volt reference output is required by OMEGA secondary electronics, or if a potentiometer is to be used to generate the command signal. To enable the 5 volt reference output on terminal 10, place the yellow jumper at J1 in the D-E position. To disable the 5 volt reference output, place the yellow jumper at J1 in the E-F position.

CAUTION

Do not ground terminal 10 when 5 volt reference output is enabled. Irreparable damage to the PC Board may result. To minimize the effect of resistance in the connection wiring, a separate "external valve return" can be accessed on pin 10. To enable this feature, place the black jumper at J1 in the B-D position and connect terminal 10 to power supply common. If the "external valve return" is not enabled, place the black jumper at J1 in the B-C position.

NOTE

If the "external valve return" feature is not enabled, the valve voltage is returned internally on the printed circuit board and the connection wiring resistance must be less than 0.2 ohms.

Notes

3 Operation

3.1 Theory of Operation

The thermal mass flow sensing technique works as follows:

A precision power supply provides a constant power heat input (P) at the heater, which is located at the midpoint of the sensor tube. Refer to Figure 3-1. At zero, or no flow conditions the heat reaching each temperature sensor is equal. Therefore the temperatures T1 and T2 are equal. When gas flows through the tube the upstream sensor is cooled and the downstream sensor is heated, producing a temperature difference. The temperature difference T2-T1, is directly proportional to the gas mass flow.

The equation is:

$$\Delta T = A \bullet P \bullet Cp \bullet m$$

Where:

ΔT	=	Temperature difference T2-T1 (°K)
Cp	=	Specific heat of the gas at constant pressure (kJ/kg-°K)
P	=	Heater power (kJ/s)
m	=	Mass flow (kg/s)
A	=	Constant of proportionality (S2-K2/kJ2)

A bridge circuit interprets the temperature difference and a differential amplifier generates a linear 0–5 V dc signal directly proportional to the gas mass flow rate.

The flow restrictor shown in Figure 3-1 performs a ranging function similar to a shunt resistor in an electrical ammeter. The restrictor provides a pressure drop that is linear with flow rate. The sensor tube has the same linear pressure drop/flow relationship. The ratio of the restrictor flow to the sensor tube flow remains constant over the range of the meter. Different restrictors have different pressure drops and produce controllers with different full scale flow rates. The span adjustment in the electronics affects the fine adjustment of the controllers full scale flow.

In addition to the mass flow sensor, the FMA-7000E Mass Flow Controller has an integral control valve and control circuit, as shown in Figure 3-2. The control circuit senses any difference between the flow sensor signal and adjusts the current in the modulating solenoid valve to increase or decrease the flow.

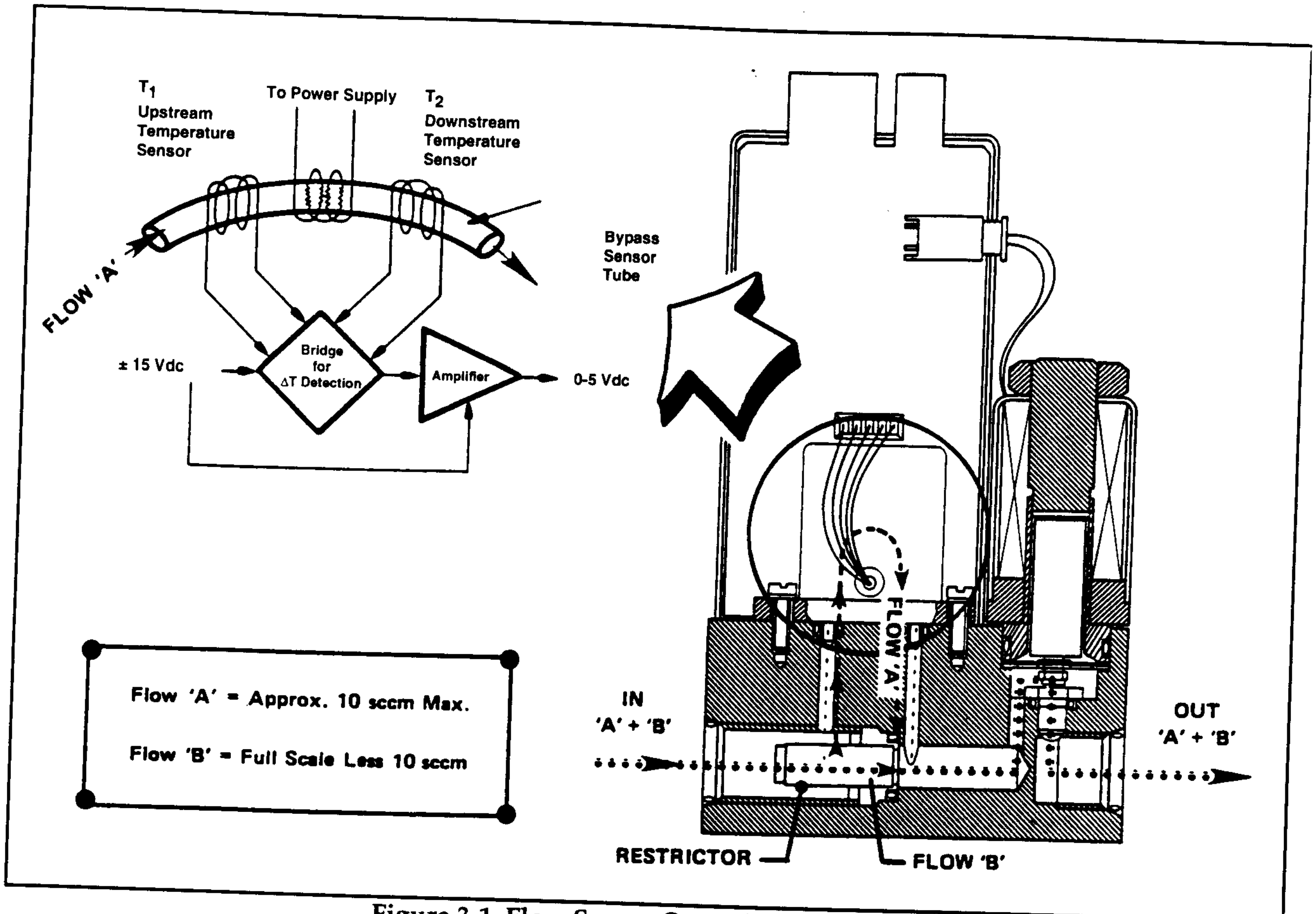


Figure 3-1. Flow Sensor Operational Diagram

The FMA-7000E has the following features incorporated in the integral control circuit:

- Fast Response, adjusted by the anticipate potentiometer. This circuit, when properly adjusted, allows the high frequency information contained in the sensor signal to be amplified to provide a faster responding flow signal for remote indication and use by the control valve.
- Soft Start, enabled by moving a jumper on the PC Board. This circuit provides a slow injection of the gas as a protection to the process, particularly those using a volatile reactive gas. Full gas flow is achieved in approximately 15 seconds. Refer to Section 2.6.
- Precision 5 Volt Reference allows the direct connection of a command potentiometer to a 0–5 volt command signal to the controller. A precision 10-turn 2K ohm potentiometer with an integral turn counter is recommended; this will permit repeatable adjustments of command to 1 part in 1000. Refer to Section 2.13 for activation.

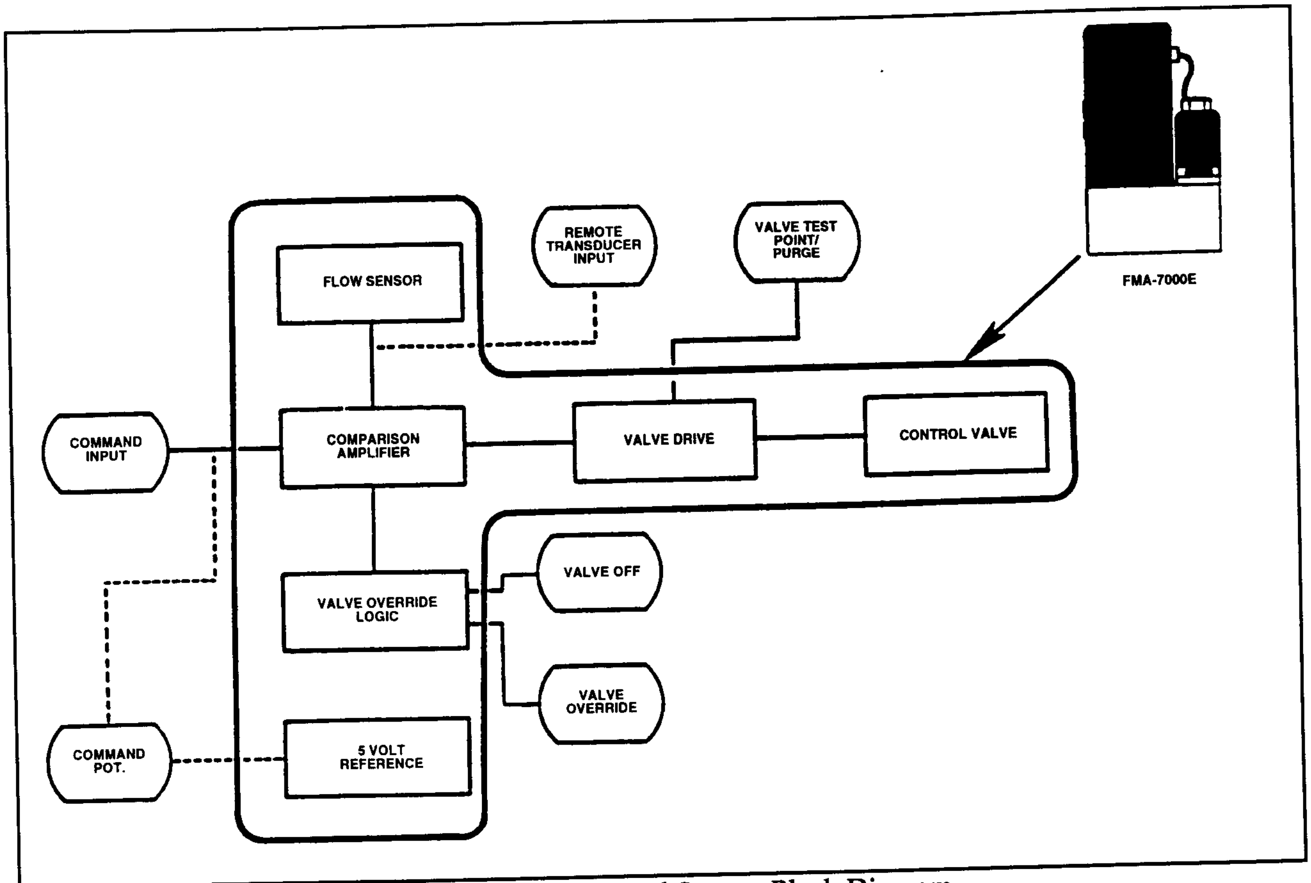


Figure 3-2. Flow Control System Block Diagram

- Valve Override allows full opening and closing of the control valve independent of the command setting. Refer to Section 2.8.
- Valve Off is accessed via terminal J on the card edge version. This feature allows you to close the control valve independently of the command signal by supplying a TTL level low signal to the proper terminal. This function is useful when performing repetitive flow operations or as a safety shutdown. Refer to Section 2.12.*
- Valve Test Point/Purge is accessed via terminal D on the card edge version of the FMA-7000E only. This feature allows you to monitor the control valve voltage during operation. Also, grounding this terminal will cause the control valve to fully open independent of the command signal. Refer to Section 2.11.*

3.2 Operating Procedure

1. Apply power to the controller and allow approximately 45 minutes for the instrument to warm up and stabilize its temperature.
2. Turn on the gas supply.
3. Command 0% flow and observe the controller's output signal. If the output is not 0 mV dc (±10 mV dc), check for leaks. If none are found, refer to the re-zeroing procedure in Section 3.3.
4. Set the command for the desired flow rate to assume normal operation.

3.3 Zero Adjustment

Each unit is factory adjusted to provide a 0 ± 10 mV dc signal at zero flow. The adjustment is made in our calibration laboratory which is temperature controlled to 21.1°C (70°F ± 2°F). After initial installation and warm-up in the gas system, the zero flow indication may be other than the factory setting. This is primarily caused by changes in temperature between our calibration laboratory and the final installation. The zero flow reading can also be affected to a small degree by changes in the line pressure and mounting attitude.

To check zero, always mount the controller in its final configuration and allow a minimum of 20 minutes for the temperature of the controller and its environment to stabilize. Using a suitable voltmeter check the controller output signal. If it differs from the factory setting, adjust it by removing the lower pot hold plug (which is located closest to the controller body). Adjust the zero potentiometer (refer to Figure 3-6) until the desired output signal is obtained.

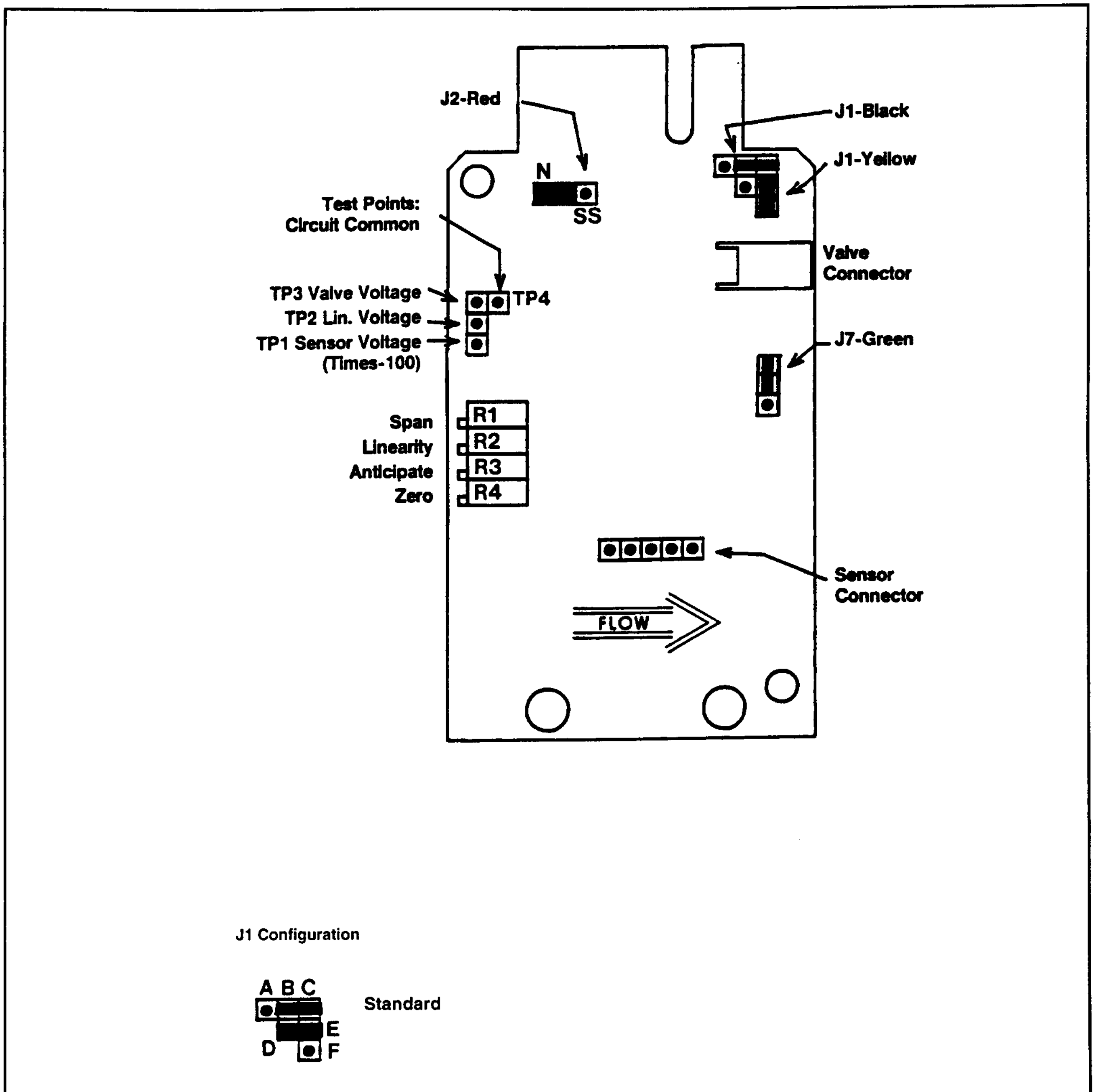


Figure 3-3. Card Edge PC Board Jumper Location & Function

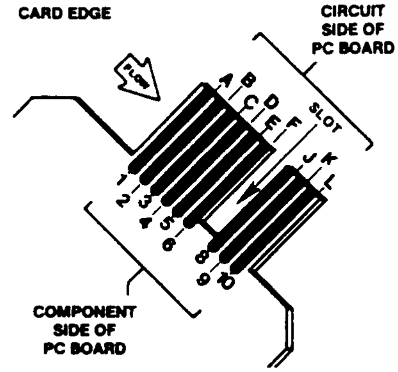


Figure 3-4. FMA-7000E Calibration Connections

3.4 Calibration Procedure

NOTE

If the valve has been disassembled and any of the following parts have been replaced the control valve adjusting procedure in Section 4.4.3 must be performed before the unit is calibrated.

- orifice
- valve stem
- plunger
- lower guide spring
- valve seat

NOTE

Calibration of the mass flow controller requires the use of a digital voltmeter (DVM) and a precision flow standard calibrator. We recommend that the calibration be performed only by trained and qualified service personnel.

NOTE

If the mass flow controller is to be used on a gas other than the calibration gas, apply the appropriate sensor conversion factor. Size the orifice for actual operating conditions.

CAUTION

For the card edge model, do not ground pin 10 with the 5 volt reference enabled. Irreparable damage to the PC Board will result.

NOTE

If OMEGA's secondary electronics are being used as a power supply during the calibration, the 5V reference must be enabled on the card edge version for proper operation. Remember to de-activate the 5V reference before installing the calibrated mass flow controller in the system where terminal 10 is grounded.

1. With the controller installed in an unpressurized gas line, apply power and allow approximately 45 minutes for warm up. During the warm-up, adjustment and calibration check procedures do not allow the control valve to open when gas flow is not present. This situation is not a normal operating mode; it will cause the control valve to heat up abnormally. A meter with an abnormally warm valve will be difficult to calibrate. This situation can be prevented by switching the valve override "closed" when there is no gas flow, or setting the command to less than 1%. Also avoid unnecessary periods with the valve override "open".

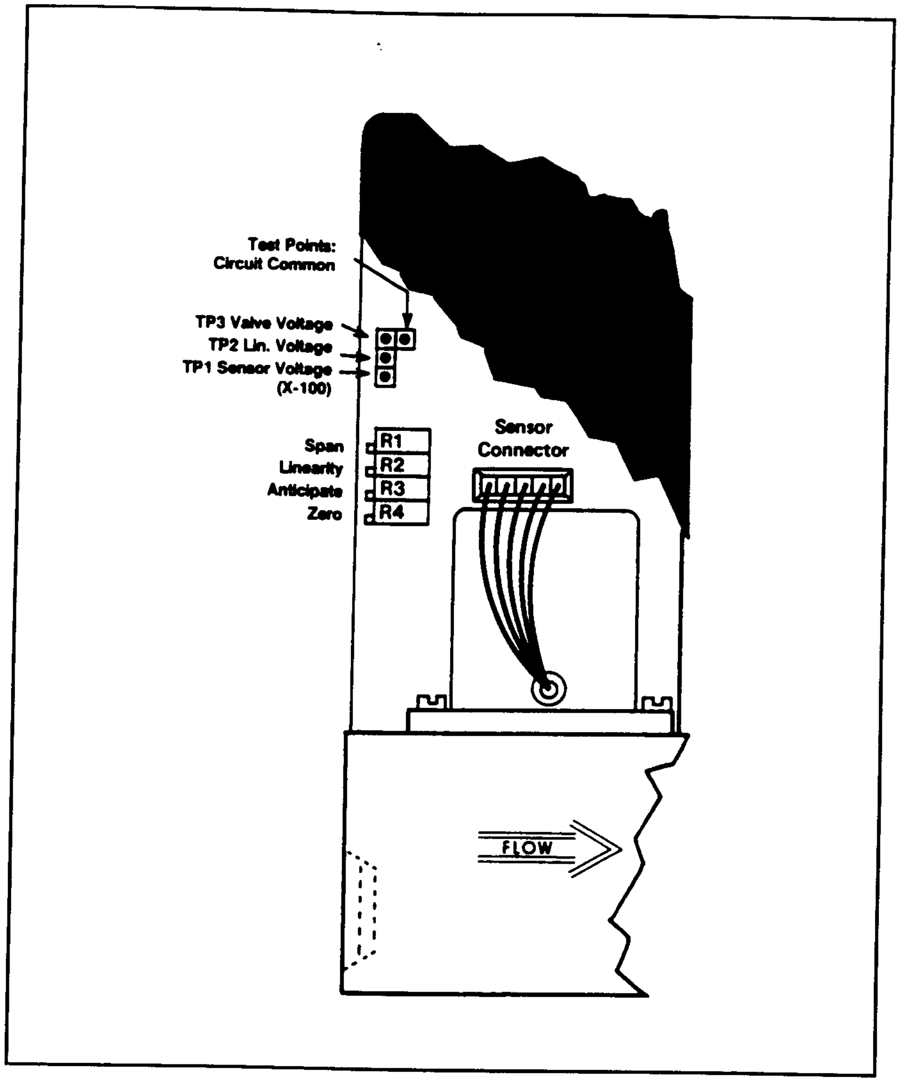


Figure 3-5. Adjustment Potentiometer Location

2. Adjust the anticipate potentiometer fully clockwise (20 turns). Then adjust the anticipate potentiometer 10 turns counterclockwise to center the potentiometer. This will provide a rough adjustment of the circuit and make the flow more stable for calibration.

3. Connect the DVM positive lead to the 0–5 V signal output (terminal 3 card edge) and the negative lead to signal common (TP4). Adjust the zero potentiometer to an output of 0 mV ±2 mV.

4. Apply pressure to the system and insure that the zero signal repeats within 2 mV of the voltage set in Step 3 above. If the zero does not repeat, check for leakage.

NOTE

Controllers supplied with special all-metal valve seats do not provide tight shut-off. A 0 to 8% leak through is typical. For metal seat controllers, close a downstream shut-off valve and observe the zero signal.

5. Set the command potentiometer (connected to terminals A, B and 10 of the card edge connector for 100% of flow (5.000 V). Connect the DVM positive lead to TP2 (linearity voltage) and the negative lead to TP4 (signal common). Adjust the linearity potentiometer for an output of 0.0 V (zero volts).
6. Connect the DVM positive lead to TP1 (−100x sensor voltage) and the negative lead to TP4 (circuit common). The command potentiometer should still be set at 100% flow (5.000 V). Measure the flow rate using suitable volumetric calibration equipment. To adjust the controller to the proper full scale flow, calculate a new TP1 voltage using the following equation.

$$\text{New TPI voltage} = \frac{\text{measured TPI voltage}}{\text{measured flow rate}} \times \text{desired flow rate}$$

Adjust the span potentiometer until the voltage at TP1 is equal to the value calculated above. Recheck the flow rate after the flow is stable (at least 2 minutes). Repeat this check and adjustment procedure until the measure flow rate is within 1% of the desired flow rate.

NOTE

The voltage at TP1 is −100 times the output voltage of the sensor. This voltage can range from −1.2 to −12 voltage; however we recommend that this voltage stay between −2.0 and −9.0 volts for proper operation. If the recommended voltage range exceeds the desired accuracy and/or signal, stability may not be achieved. If one of the limits is reached, check the orifice and restrictor sizing procedures. Refer to Sections 4.6 and 4.7, respectively.

7. Set the command potentiometer for 0% of flow. Connect the DVM positive lead to flow signal output (terminal 3 card edge) and the negative lead to TP4. Readjust the zero potentiometer for an output of 0 mV ±2 mV as necessary.

8. Set the command potentiometer for 50% of flow (2.500 V) and measure the flow rate. Calculate the error as a percentage of full scale.

$$\text{full scale error} = 100\% \frac{\text{measured flow rate} - \text{desired flow rate}}{\text{full scale flow rate}}$$

Example:

What is the percent of full scale error when full scale is equal to 100 sccm?
Measured flow rate = 48.5 sccm
Desired flow rate = 50.0 sccm

$$\text{full scale error} = 100 \frac{(48.5 - 50)}{100} = -1.5\%$$

9. Calculate the TP2 correction voltage:
(error recorded in step 8) × 0.450 volts

Example:
Error = −1.5%
TP2 correction voltage = −1.5 × 0.450 = −0.675 volts
New TP2 voltage = 0 volts + (−0.675) = −0.675 volts

10. Set the command potentiometer for 100% flow (5.000. V). Connect the DVM positive lead to TP2 and the negative lead to TP4.

11. Adjust the linearity potentiometer for an output equal to the new calculated TP2 voltage.

12. Repeat steps 6, 7 and 8.
    1. If the error recorded in step 8 is less than 0.5%, then the calibration procedure is complete.
    2. If the error is greater than 0.5% set the command potentiometer for 100% (5.000 V). Connect the DVM positive lead to TP2 (linearity voltage) and the negative lead to TP4 (circuit common). Calculate a new TP2 voltage as follows:

$$\text{New TP2 voltage} = \text{error recorded in step 9} \times 0.450\text{ V} + \text{measured TP2 voltage}$$

Example:
Controller error = 0.7%
Measured TP2 voltage = −0.567 volts

TP2 correction = 0.7 × 0.450 = 0.315 volts
New TP2 correction = 0.315 + (–0.567) = –0.252 volts
Adjust the linearity potentiometer for an output equal to the new TP2 voltage and then repeat steps 6, 7 and 8.

NOTE

The voltage at TP2 can range from –10 to +3 volts, however, it is recommended that this voltage stays between –2.5 and +2.5 volts for proper operation. If the recommended voltage range is exceeded the desired accuracy and/or signal stability may not be achieved. If one of the limits is reached, check the restrictor sizing. Refer to Section 4.7.

3.5 Response (Fast Response Adjustment)

Two methods of adjusting the step response of the mass flow controller can be used. The method described in Section 3.5.1 will get the step response close to optimum quickly and without any flow measuring equipment. This method should be used when the response time of the flow controller is not critical to overall system performance. The method described in Section 3.5.2 will allow adjustment of your mass flow controller to optimum step response performance. This method is the preferred way to adjust the step response. Adjustment of the fast response circuit will not affect the accuracy of the flow controller as adjusted in Section 3.4.

3.5.1 Fast Response Adjustment (3 seconds response specification not guaranteed)

NOTE

This procedure requires an oscilloscope, chart recorder or a DVM with a sample speed of three samples per second or greater to monitor the rate of change of the output signal.

1. Set the command potentiometer for 100% of flow (5.00 V) and wait about 45 seconds for the flow output signal to stabilize.
2. Step the command signal to 0% or activate valve override closed to stop the flow. Observe the flow signal output as it decays.

3. The behavior of the flow signal during this transition between 100% and 0% flow indicates the adjustment required of the anticipate potentiometer. Refer to Figure 3-7.
   - If the flow signal decays to −.05 to −.5 V then rises to 0 V the anticipate potentiometer is properly adjusted.
   - If the flow signal decays rapidly and goes below −.5 V before rising to 0 V the anticipate potentiometer must be adjusted clockwise and steps 1 and 2 repeated.
   - If the flow signal decays slowly and does not go below −.05 V the anticipate potentiometer must be adjusted counterclockwise and steps 1 and 2 repeated.

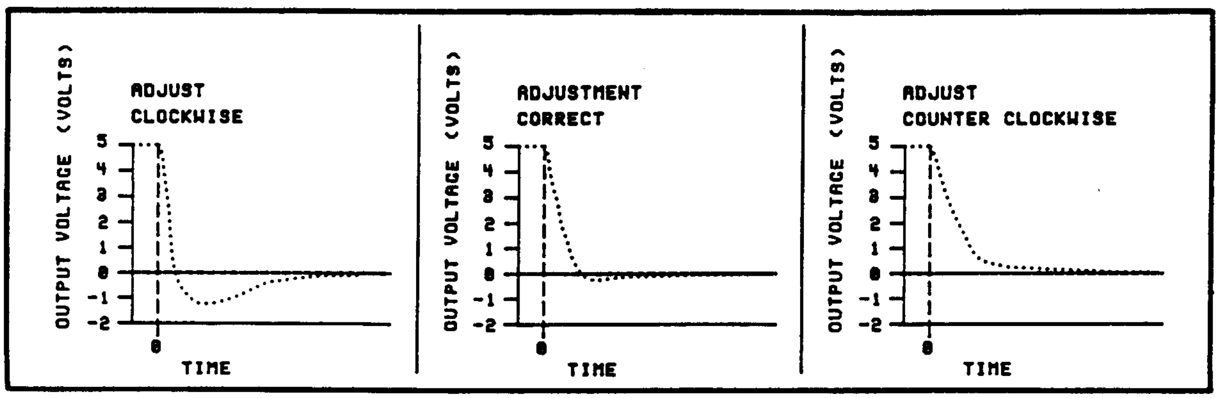


Figure 3-6. Fast Response Adjustment

3.5.2 Fast response adjustment (3 second response specification guaranteed)

Adjustment of the anticipate potentiometer to obtain a flow rate performance to be within 2% of flow rate commanded in less than 3 seconds after setpoint change requires the use of a fast response flowmeter (500 millisecond response to be within 0.2% of final value or better) in series with the mass flow controller and a storage oscilloscope or recorder.

1. Make a step in command to the controller from 0 to 100% of full scale flow and record the output signal of the fast response flowmeter.
2. If this signal shows more than 4% overshoot, adjust the anticipate potentiometer 1/2 to 1 turn counterclockwise. If the signal does not show overshoot, but is not within 2% full scale of final value after 3 seconds, adjust the anticipate potentiometer 1/2 to 1 turn clockwise. Set command potentiometer for 0% of flow.

3. Repeat steps 1 and 2 until the fast response flowmeter output signal meets the specified response requirements.

NOTE

With the above equipment, the anticipate potentiometer can be adjusted to give optimum response characteristics for any process.

Notes

4 Maintenance

4.1 General

No routine maintenance is required on the mass flow controller other than an occasional cleaning. If an in-line filter is used, the filtering element should periodically be replaced or ultrasonically cleaned.

4.2 Troubleshooting

CAUTION

It is important that this controller be serviced only by properly trained and qualified personnel.

4.2.1 System Checks

The mass flow controller is generally used as a component in gas handling systems which can be quite complex. This can make the task of isolating a malfunction in the system a difficult one. An incorrectly diagnosed malfunction can cause many hours of unnecessary downtime. If possible, make the following system checks before removing a suspected defective mass flow controller for bench troubleshooting or return, especially if the system is new.

1. Verify a low resistance common connection and that the correct power supply voltage and signals are reaching and leaving the controller.
2. Verify that the process gas connections have been correctly terminated and leak checked.
3. If the mass flow controller appears to be functioning but cannot achieve set-point, verify that sufficient inlet pressure and pressure drop are available at the controller to provide the required flow.
4. Verify that all user selectable jumpers are in their desired positions. Refer to Figures 3-3 and 3-4.

WARNING

If it becomes necessary to remove the controller from the system after exposure to toxic, pyrophoric, flammable, or corrosive gas, purge the controller thoroughly with a dry inert gas such as nitrogen before disconnecting the gas connections. Failure to correctly purge the controller could result in fire, explosion, or death. Corrosion or contamination of the mass flow controller upon exposure to air may also occur.

Bench Troubleshooting

1. Properly connect the mass flow controller to a ±15 V dc power supply, command voltage source and connect an output signal readout device (4-1/2 digit voltmeter recommended) to terminals 2 and 3 (refer to Figures 2-2 and 2-3). Apply power, set the command voltage to zero, and allow the controller to warm up for 45 minutes. Do not connect to a gas source at this time. Observe the output signal and, if necessary perform the zero adjustment procedure (Section 3.3). If the output signal will not zero properly, refer to the sensor troubleshooting section and check the sensor. If the sensor is electrically functional, the printed circuit board is defective and will require replacement.
2. Connect the controller to a source of the gas on which it was originally calibrated. Command 100% flow and adjust the inlet and outlet pressures to the calibration conditions. Verify that the output signal reaches and stabilizes at 5.00 volts. Vary the command voltage over the 2 to 100% range and verify that the output signal follows the setpoint. Apply +15 volts to the valve override input, (refer to Figure 2-3 for terminal assignments) and verify that the output exceeds 5.00 V. Apply −15 V to the valve override terminal and verify that the output signal falls below 0.100 V. If possible, connect a flow measurement device in series with the mass flow controller to observe the actual flow behavior and verify the accuracy of the mass flow controller. If the mass flow controller functions as described above, it is functioning properly and the problem may lie elsewhere.

Table 4-1 lists possible malfunctions which may be encountered during bench troubleshooting.

Trouble	Possible Cause	Check/Corrective Action
Actual flow overshoots setpoint by more than 5% full scale.	Anticipate potentiometer out of adjustment.	Adjust anticipate potentiometer. Refer to Section 3.5.
Output stays at 0 Volts regardless of command and there is no flow through the controller.	Clogged sensor	Clean sensor. Refer to cleaning procedure, Section 4.4.
	Clogged control valve	Check TP3 with the command valve at 100%. If the voltage through the controller is more negative than -11V, disassemble and repair the control valve. Refer to Sections 4.4.3 and 2-9.
	Card Edge Version Internal reference is being used as the command source and the yellow jumper is in the E-F position.	Refer to Section 2.11.
	-15 Volts applied to the valve override input.	Check valve override input. Refer to Figure 2-3 for terminal assignments.
	Defective printed circuit board	Replace printed circuit board. Refer to Section 4.4.
	Valve voltage not returned, pin L at common	Check jumper for external valve return. Refer to Section 2.11.
	"Valve-off" pin grounded	Check "Valve-off" input. Refer to Figure 2-3 for terminal assignments.
Output signal stays at +6.8V regardless of command and there is flow through the controller.	Valve stuck open or leaky	Clean and/or adjust control valve. Refer to cleaning procedure and/or Section 4.4.3.
	+15V applied to the valve override input	Check the valve override terminal. Refer to Figure 2-3 for terminal assignments.
	Defective printed circuit board	Replace printed circuit board. Refer to Section 4.4.
	Command input floating	Connect command signal. Refer to Figure 2-3 for terminal assignments.
	Pin D connected to common	Remove pin D from common.
Output signal follows setpoint at higher commands but will not go to zero.	Leaky control valve	Disassemble and repair valve. Refer to Section 4.4.3.
	Excessive resistance in valve voltage return line	Reduce wiring resistance or reconfigure controller for "External Valve Return". Refer to Section 2.11.
Output signal follows setpoint at lower commands but does not reach full scale.	Insufficient inlet pressure or pressure drop.	Adjust pressures, inspect inline filters and clear/replace as necessary.
	Partially clogged sensor	Check calibration. Refer to Section 3.4.
	Partially clogged valve	Disassemble and repair control valve. Refer to Section 4.4.
	Valve out of adjustment	Adjust valve. Refer to Section 4.4.
	Valve guide spring failure	Controller oscillates (see below).
Controller grossly out of calibration. Flow is higher than desired.	Partially clogged sensor	Clean sensor; refer to the cleaning procedure.
Controller grossly out of calibration. Flow is lower than desired.	Partially clogged restrictor	Replace restrictor. Refer to Section 4.4.
Controller oscillates.	Pressure drop or excessive inlet pressure	Adjust pressures.
	Oversized orifice	Check orifice size. Refer to Section 4.6.
	Valve out of adjustment	Adjust valve. Refer to Section 4.4.
	Anticipate potentiometer out of adjustment	Adjust anticipate potentiometer. Refer to Section 3.5.
	Faulty pressure regulator	Check regulator output.
	Defective printed circuit board.	Replace printed circuit board. Refer to Section 4.4.

Table 4-1 Bench Troubleshooting

Sensor Troubleshooting

If you suspect that the sensor coils are either open or shorted, troubleshoot using Table 4-2. If any of the steps do not produce the expected results, the sensor assembly is defective and must be replaced. Refer to Section 4.4 for the disassembly and assembly procedures to use when replacing the sensor.

NOTE

Do not attempt to disassemble the sensor.

Cleaning Procedures

Should the mass flow controller require cleaning due to deposition, use the following procedures:

1. Remove the unit from the system.
2. Refer to Section 4. 4 to disassemble the controller.

CAUTION

Do not soak the sensor assembly in a cleaning solution. If solvent seeps into the sensor assembly, it will probably damage the sensor or at least significantly alter its operating characteristics.

3. Use a hemostat or tweezers to push a 0.007" diameter piano wire through the flow sensor tube to remove any contamination. For best results, push the wire into the downstream opening of the sensor tube (end closest to the control valve). The sensor tube can be flushed with a non-residuous solvent (Freon TF† recommended). A hypodermic needle filled with solvent is a convenient means to accomplish this.

   An alternate method for flushing out the sensor is to replace the restrictor element with a low flow plug restrictor. This plug forces all the flow through the sensor and may dislodge any obstructions. With the valve orifice removed, subject the flow controller to a high differential pressure. Pressurizing the outlet of the MFC higher than the inlet may help force the obstruction upstream and out of the sensor tube.
4. Inspect the orifice for clogging by holding it in front of a light source and looking for light through the bore. Clean by soaking in a suitable non-residuous solvent and directing a stream of compressed dry nitrogen through the bore.

5. Deposits of silicon dioxide may be removed by soaking the internal parts in solution of 5% of hydrofluoric acid (5 parts hydrofluoric acid (HF), 95 parts water (H_2O)) followed by Freon TF.
6. Sintered type restrictor elements should be replaced, as it is not possible to adequately remove deposits from them. Wire mesh and A.C.L.F.E. type restrictor elements can be cleaned in an ultrasonic bath. Refer to Section 4.7 for the correct restrictor to use.
7. Blow all parts dry with dry nitrogen and reassemble. Refer to Section 4.4.2 (Assembly).
8. Purge the assembled controller with dry nitrogen.
9. Perform the calibration procedure in Section 3.4.
10. When the controller is re-installed in the system, the connections should be leak tested and the system should be purged with dry nitrogen for 30 minutes prior to startup to prevent the formation of deposits.

4.3 Sensor Tube

The sensor tube is part of a calibrated flow divider that is designed to operate within a preset gas flow range. The sensor assembly may be removed or replaced by referring to Section 4.4, Disassembly and Assembly. If the sensor assembly is cleaned and reinstalled, a calibration check should be performed. Refer to Section 3.4.

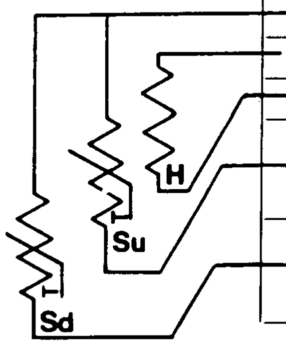
4.4 Disassembly and Assembly

You may disassemble the mass flow controller in the field for cleaning, rearranging or servicing. Disassemble and assemble the controller as follows:

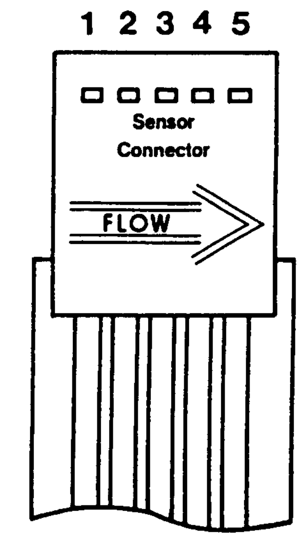
NOTE

Disassemble the mass flow controller in a clean environment to prevent particulate contamination.

SENSOR SCHEMATIC



WIRE COLOR	PIN NO.	FUNCTION
White	4	Sensor common
Yellow	1	Heater
Blue	5	Heater common
Red	2	Upstream temperature sensor (Su)
Black	3	Downstream temperature sensor (Sd)



Flex Circuit Wire Numbers

OHMMETER CONNECTION	RESULT IF ELECTRICALLY FUNCTIONAL
Yellow and white to body (ground) (Pin 1 or 4 to body)	Open circuit on ohmmeter. If either heater (yellow), or sensor common (white) are shorted, an ohmmeter reading will be obtained.
White to red (Pin 4 to Pin 2)	Nominal 1100 ohms reading.
White to black (Pin 4 to Pin 3)	Depending on temperature and ohmmeter current.
Blue to yellow (Pin 5 to Pin 1)	Nominal 1200 ohms reading

Note: Remove the sensor connector from the PC Board for this procedure.

Table 4-2 Sensor Troubleshooting

4.4.1. Disassembly

The numbers in () refer to the spare parts exploded view in Figure 5-1.

WARNING

Do not attempt to disassemble the mass flow controller until pressure has been removed and purging has been performed. Hazardous gas may be trapped in the valve assembly which could result in explosion, fire, or serious injury.

1. Remove the jam nut (1) on top of the valve assembly.
2. Unplug the valve connector from the electronics cover and remove the coil assembly (2).
3. Remove the hex socket screws (3) securing the valve retaining plate (4) attaching the valve stem assembly (6).

CAUTION

When performing the following procedure the valve stem must be removed without cocking it to prevent damage to the valve spring.

4. Carefully remove the valve stem assembly (6).
5. Remove the plunger assembly (7, 8, 9, 11).
6. Remove and note the position of the valve spring spacers (10), which may be located above and/or below the lower valve springs (8).
7. Unscrew the orifice (12) from the flow controller body (14).
8. Carefully unscrew the valve seat (11) from the plunger (7). Note the position and number of spacers (9) and springs (8) that are stacked on the threaded end of the valve seat.
9. Remove the three screws (20) attaching the electronics cover. Remove the electronics cover (23).

CAUTION

Be careful not to stress the sensor lead wire to sensor assembly junction when removing the sensor connector from the PC Board. If the sensor lead wires are stressed, an open in the sensor wiring could result.

10. Unplug the sensor connector from the PC Board. Remove the two screws securing the bracket (24) and PC Board (15). Remove the bracket and PC Board.

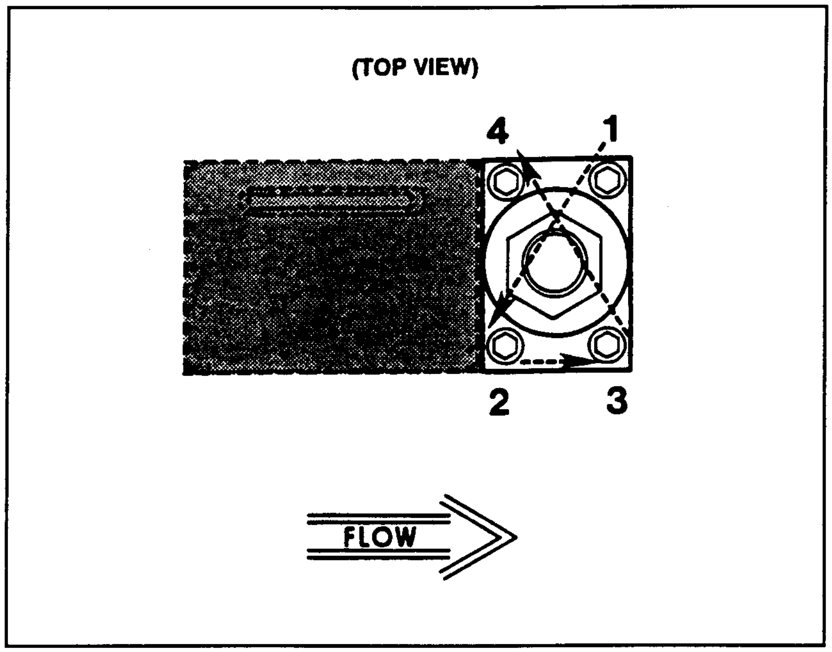


Figure 4-1. Torque Sequence for the Valve Retainer Plate

11. Remove the two screws (18) and washers (19) securing the sensor assembly (16). Remove the sensor assembly.

NOTE

Do not attempt to disassemble the sensor assembly.

CAUTION

Do not scratch the O-Ring sealing surface.

12. Remove the sensor assembly O-rings (17) from the flow controller body (14). Using the proper O-ring removal tool will help prevent scratching the sealing surface.
13. Remove the adapter fittings (27) from the flow controller body (14).
14. Remove the restrictor assembly (21) from the inlet side of the flow controller body (14) using the restrictor tool (part of the service tool kit listed in Section 5, Table 5-2).

4.4.2. Assembly

CAUTION

Do not get Halocarbon lubricant on the restrictor element (21) or hands. This is a special inert lubricant which is not easily removed.

NOTE

We recommend that you replace all O-rings during controller assembly. Lubricate all O-rings lightly with Halocarbon lubricant (part of O-ring kit, Section 5) prior to their installation.

1. Examine all parts for signs of wear or damage, replace as necessary.
2. Place the restrictor O-ring on the restrictor assembly. Screw the restrictor assembly (21) into the inlet side of the flow controller body using the restrictor tool, tighten hand tight.

CAUTION

Perform the following steps as written. Placing the O-rings on the sensor before it is installed will result in damage to the O-rings, causing a leak.

3. Press the lubricated sensor O-rings (17) into the flow controller body (14). Install the sensor assembly and secure with two screws (18) and washers (19) tightened to 15 in/lbs.
4. Install the orifice (12) and its O-ring (13), using a 3⁄8 nut driver. Insure that the orifice is fully seated, but do not overtighten.
5. Insert the valve preload spacers (10), if used, into the valve cavity in the flow controller body (14). Use care to preserve the correct order.
6. Place the spacers (9) and springs (8) on the valve seat (11) in the same order as noted in Step 8 of the disassembly. Screw the valve seat (11) into the plunger (7). Tighten the assembly until there is no looseness, but do not overtighten.
7. Install the valve plunger assembly (7, 8, 9 and 11) on the preload spacers (10). Install air gap spacers (10), if used, on top of the valve springs.
8. Install the valve stem assembly (6). Secure with the valve retaining plate (4) and four hex socket screws (3). When installing the screws, they should first make light contact with the plate. Check the plate to insure that it makes full contact around the stem assembly. Torque the screws securing the valve retaining plate in a diagonal pattern (refer to Figure 4-1) to 15 in/lbs.
9. Install the coil assembly (2) over the valve stem assembly (6) and secure with jam nut (1).
10. Install the printed circuit (PC) board (15), secure with the bracket (24) and two screws. Plug the connector from the sensor assembly onto the PC Board. The flow arrow on the connector should be pointing toward the valve assembly.
11. Install the electronics cover (23) on the controller. Secure with three screws (20). Plug the connector from the valve coil into the PC Board through the hole in the electronics cover.
12. Prior to installation, leak and pressure test to any applicable pressure vessel codes.

4.4.3 Adjusting the Control Valve

The control valve has been factory adjusted to insure proper operation. Readjustment is only required if any of the following parts have been replaced:

orifice (12)
valve stem (6)
plunger (7) lower guide springs (8)
valve seat (11)

The valve is adjusted in the mass flow controller by adding spacers (9 and 10) to the control valve assembly to vary the air gap and initial preload. Spacers are used to affect the proper adjustment because they provide a reliable and repeatable means for adjustment. Screw type adjustment mechanisms can change with pressure or vibration and introduce an additional dynamic seal that is a potential leak site and source for contamination. Refer to Figure 4-2 for spacer locations.

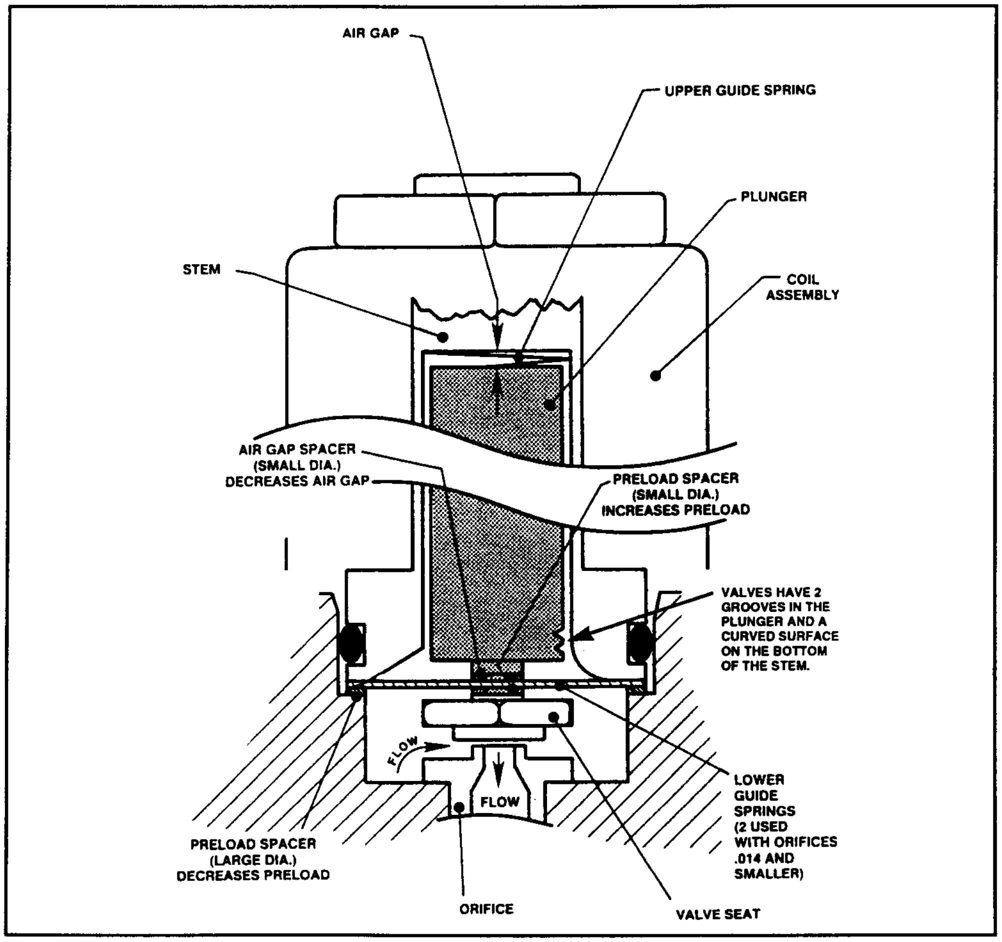


Figure 4-2. Valve Adjusting Spacer Locations

The preload determines the initial force that is required to raise the valve seat off the orifice and start gas flow. If the preload is insufficient the valve will not fully close and gas will leak through. If the preload is excessive, the magnetic force generated between the plunger and stem will be insufficient to raise the plunger and the valve will not open.

The airgap is the space between the top of the plunger and stem. The airgap determines the force between the plunger and stem at a given voltage and the total travel of the valve. If the airgap is too small, the plunger travel may be insufficient to fully open the valve; also, the magnetic force may be too high for a given valve cell voltage. If the airgap is too large, the magnetic force will be insufficient to raise the plunger and the valve will not open.

NOTE

Prior to starting the valve adjustment procedure, check to insure that the orifice is properly seated and that the valve parts are not bent or damaged.

1. Adjustment Procedure (Refer to Section 5, Spare Parts for the spacer kit)
   a. Remove the electronics cover (23) from the controller. Insure that the connector from the coil assembly (2) is properly reconnected to the PC Board after the electronics cover is removed.
   b. Perform the electrical and gas connections to the controller following the instructions in Section 2 of this manual. Use a clean dry inert gas, such as nitrogen, for this procedure. Do not apply gas pressure to the controller at this time.
   c. Disassemble the control valve following the procedure given in Section 4.4.1, above. Note the number, locations and thickness of all spacers (9 and 10).
   d. Decrease the preload of the valve by 0.005 inches by either removing a 0.005 inch small preload spacer or by adding a 0.005 inches large preload spacer. Refer to Figure 4-2.
   e. Reassemble the valve following the assembly procedure in Section 4.4.
   f. Command 0% flow, apply normal operating pressure and check for valve leak-through by observing the output signal.
   g. If the valve leaks through, increase the preload by 0.005 inch and go to Step h. If the valve does not leak through, repeat steps d, e, f and g.
   h. Apply the normal operating gas pressure and command 100% flow (5.000 volts on terminal A, pin 2).

NOTE

Due to possible heat capacity and density differences between the test gas and actual process gas for which the MFC was sized, it may be necessary to increase the inlet pressure to obtain proper control at 100% flow.

i. Measure the valve voltage by connecting a voltmeter between test point 3 (TP3) and test point 4 (TP4). Refer to Figure 4-3.

   Valve Voltage = −14.2 voltage at TP3.

j1. If the flow controller output signal is 100% (5.0 V) and the valve voltage is less than 11.5 V, the valve adjustment is complete.

j2. If the flow controller output signal is 100% (5.0 V) and the valve voltage is greater than 11.5 V, decrease the air gap with a small 0.005 inch. air gap spacer. Refer to Figure 4-2. Repeat steps h and i.

j3. If the flow controller output signal is less than 100% (5.0 V) and the valve voltage is greater than 11.5 V. This condition indicates that the inlet pressure is too low and or the orifice size is too small. First check Section 4.6 to insure that the orifice size is correct.

k. Proceed to Section 3 and perform 3-4 Calibration Procedure, if required.

4.5 Using the Conversion Tables

If a mass flow controller is operated on a gas other than the gas it was calibrated with, a scale shift will occur in the relationship between the output signal and the mass flow rate. This is due to the difference in heat capacities between the two gases. This scale shift can be approximated by using the ratio of the molar specific heat of the two gases, or sensor conversion factor. A list of sensor conversion factors is given in Table 4-3. To change to a new gas, multiply the output reading by the ratio of the gas factor for the desired gas to the gas factor for the calibration gas.

$$\begin{matrix}\text{Actual gas}\\ \text{flow rate}\end{matrix} = \begin{matrix}\text{Output}\\ \text{reading}\end{matrix} \times \frac{\text{factor of the new gas}}{\text{factor of the calibrated gas}}$$

Example:

The controller is calibrated for nitrogen.

The desired gas is carbon dioxide.

The output reading is 75 sccm when carbon dioxide is flowing.

Then 75 × 0.78 = 58.50 sccm

To calculate the conversion factor for a gas mixture, use the following formula:

$$\text{Sensor Conversion Factor Mixture} = \frac{100}{\dfrac{P_1}{\text{sensor conversion factor 1}} + \dfrac{P_2}{\text{sensor conversion factor 2}} + \dfrac{P_n}{\text{sensor conversion factor n}}}$$

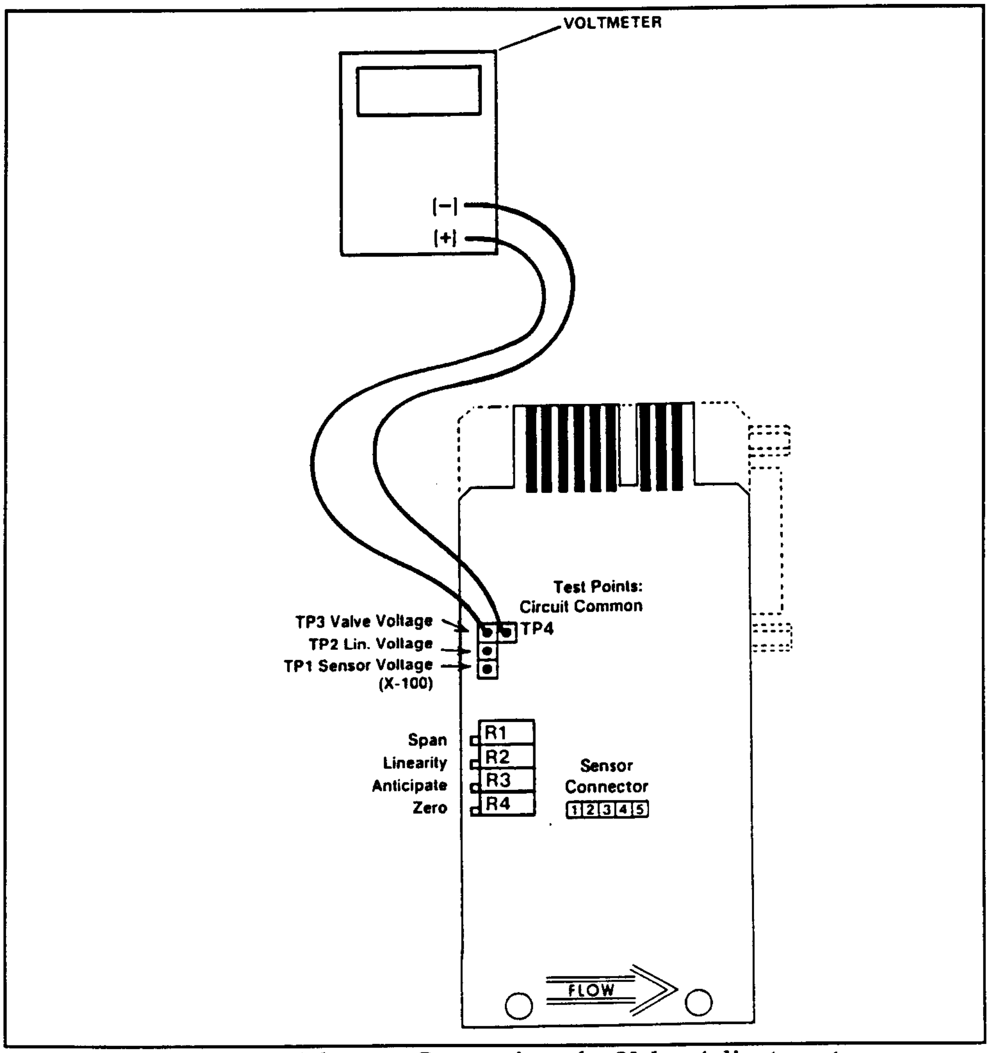


Figure 4-3. Voltmeter Connections for Valve Adjustment

Where: P1 = percentage (%) of gas 1 (by volume)

P2 = percentage (%) of gas 2 (by volume)

Pn = percentage (%) of gas n (by volume)

Example:

The desired gas is 20% Helium (He) and 80% Chlorine (Cl) by volume. The desired full scale flow rate of the mixture is 20 slpm.

Sensor conversion factor for the mixture is:

$$\text{Mixture Factor} = \frac{100}{\frac{20}{1.39} + \frac{80}{.83}} = .903$$

Air equivalent flow = 20/.903 = 22.15 slpm air

It is generally accepted that the mass flow rate derived from this equation is only accurate to ±5%. The sensor conversion factors given in Table 4-3 are calculated based on a gas temperature of 21°C and a pressure of one atmosphere. The specific heat of most gases is not strongly pressure and temperature dependent; however gas conditions that vary widely from these reference conditions may cause an additional error due to the change in specific heat due to temperature and/or pressure.

Gas	Symbol	Specific Heat Cp at 25° C and 1 Atm. J/mole K	Toxic	Flammable	Sensor Conversion Factor*	Specific Gravity (SG) at 21.1°C	Orifice Conversion Factor*$\sqrt{SG}$
Acetylene	C_2H_2	44.308	No	Yes	0.66	0.908	0.953
Air	(Mixture)	29.13	No	No	1.00	1.000	1.000
Allene	C_3H_4	60.84	No	Yes	0.48	1.385	1.177
Ammonia	NH_3	36.953	Yes	Yes	0.79	.588	.767
Argon	Ar	20.83	No	No	1.40	1.376	1.173
Arsine	A_sH_3	38.522	Yes	Yes	0.76	2.660	1.631
Boron Trichloride	BCL_3	65.655	Yes	No	0.44	4.028	2.007
Boron Trifluoride	BF_3	50.242	Yes	No	0.58	2.375	1.541
Bromine Pentafluoride	BrF_5	101.4	Yes	Yes	0.29	6.037	2.457 Liq. at 21° C
Bromine Trifluoride	BrF_3	66.65	Yes	Yes	0.44	4.726	2.174 Liq. at 21° C
Butane	C_4H_{10}	100.365	No	Yes	0.29	2.076	1.44
Butene	C_4H_8	87.329	No	Yes	0.33	1.985	1.409
Carbon Dioxide	CO_2	37.564	No	No	0.78	1.518	1.232
Carbon Monoxide	CO	29.204	Yes	Yes	0.99	0.964	0.982
Carbon Tetracloride	CCL_4	84.438	Yes	No	0.35	5.304	2.303
Carbon Tetrafluoride	CF_4	61.27	Yes	No	0.48	3.021	1.738
Carbonyl Fluoride	COF_2	108.5	Yes	Yes	0.27	2.332	1.527
Carbonyl Sulfide	COS	42.752	Yes	Yes	0.68	2.065	1.437
Chlorine	CL_2	35.317	Yes	Yes	0.83	2.462	1.569
Chloroform	$CHCL_3$	65.756	Yes	Yes	0.44	4.117	2.029
Chlorine Trifluoride	CLF_3	67.117	Yes	Yes	0.43	3.165	1.779
Cyanogen	C_2N_2	38.338	Yes	Yes	0.50	1.798	1.341
Cyclopropane	C_3H_6	57.559	Yes	Yes	0.51	1.445	1.202
Deuterium	D_2	29.204	No	Yes	1.00	0.1385	0.372
Diborane	B_2H_6	53.346	Yes	Yes	0.55	0.964	0.982
Dichlorosilane	SiH_2CL_2	65.73	Yes	Yes	0.44	3.471	1.863
Dimethylamine	$(CH_3)_2NH$	43.428	Yes	Yes	0.67	1.545	1.243
Dimethylether	$(CH_3)_2O$	49.40	Yes	Yes	0.59	1.583	1.258
Ethane	C_2H_6	53.346	No	Yes	0.55	1.038	1.019
Ethyl Chloride	C_2H_5CL	102.090	Yes	Yes	0.29	2.217	1.489
Ethylene	C_2H_4	43.428	No	Yes	0.62	0.964	0.982
Ethylene Oxide	C_2H_4O	49.40	Yes	Yes	0.59	1.514	1.231
Fluorine	F_2	31.449	Yes	Yes	0.93	1.304	1.142
Fluoroform	CHF_3	51.557	No	No	0.57	2.418	1.555
Freon 11	CCL_3F	77.613	No	No	0.38	4.858	2.204 @ 23.8°C
Freon 12	CCL_2F_2	74.469	No	No	0.39	4.248	2.061
Freon 13	$CCLF_3$	67.655	No	No	0.43	3.799	1.949
Freon 13 B1	$CBrF_3$	70.590	No	No	0.41	5.117	2.262
Freon 14	CF_4	61.271	No	No	0.475	3.021	1.738
Freon 21	$CHCL_2F$	60.994	Yes	No	0.46	3.799	1.949
Freon 22	$CHCLF_2$	57.524	No	No	0.51	3.021	1.738
Freon 23	CHF_3	51.56	No	No	0.57	2.418	1.555
Freon 113	$CCl_2F\text{-}CClF_2$	126.10	No	No	0.23	6.126	2.475
Freon 114	$CCl_2F_4\text{-}CClF_2$	112.992	No	No	0.258	5.784	2.405
Freon 115	$CClF_2\text{-}CF_3$	105.86	Yes	No	0.274	5.541	2.354
Freon 116	$CF_3\text{-}CF_3$	126.65	No	No	0.23	4.748	2.179

*Air equals 1.000 for conversion factors.

Note: The information given in the toxicity and flammability columns is intended as a general guide. The accuracy is not guaranteed and they should not be solely relied upon for establishing appropriate procedures for your operation.

Table 4-3 Conversion Factors

Gas	Symbol	Specific Heat Cp at 25° C and 1 Atm J/mole K	Toxic	Flammable	Sensor Conversion Factor*	Specific Gravity (SG) at 21.1°C	Orifice Conversion Factor*√SG
Germane	GeH_4	45.020	Yes	Yes	0.65	2.634	1.623
Helium	He	20.967	No	No	1.39	0.138	0.371
Hexamethvldisizane	HMDS	208.1	—	—	0.14	5.574	2.361
Hydrogen	H_2	28.851	No	Yes	1.01	0.070	0.264
Hydrogen Bromide	HBr	29.791	Yes	No	0.98	2.769	1.664
Hydrogen Chloride (Dry)	HCL	29.576	Yes	No	0.99	1.254	1.120
Hydrogen Fluoride	HF	16.155	Yes	No	1.00	0.689	0.830
Hydrogen Iodide	HI	30.497	Yes	Yes	0.96	4.431	2.105
Hydrogen Selenide	H_2Se	34.752	Yes	Yes	0.84	2.769	1.664
Hydrogen Sulfide	H_2S	34.218	Yes	Yes	0.85	1.184	1.088
Isobutane	C_4H_{10}	94.163	No	Yes	0.31	2.045	1.430
Isobutylene	C_4H_8	86.883	No	Yes	0.34	1.985	1.409
Krypton	Kr	21.037	No	No	1.39	2.883	1.698
Methane	CH_4	35.941	No	Yes	0.81	0.561	0.749
Methylamine	CH_3NH_2	51.460	Yes	Yes	0.57	1.080	1.048
Methyl Bromide	CH_3Br	45.020	Yes	No	0.65	3.244	1.801
Methyl Chloride	CH_3CL	42.326	Yes	Yes	0.69	1.750	1.323
Methyl Fluoride	CH_3F	38.171	No	Yes	0.76	1.171	1.082
Methyl Mercaptan	CH_4S	49.491	Yes	Yes	0.59	1.663	1.289
Neon	Ne	20.789	No	No	1.40	0.692	0.832
Nitric Oxide	NO	29.227	Yes	No	1.00	1.022	1.011
Nitrogen	N_2	28.98	No	No	1.005	0.964	0.982
Nitrogen Dioxide	NO_2	36.974	Yes	No	0.760	2.829	1.682
Nitrogen Trioxide	N_2O_3	65.618	Yes	No	0.44	2.621	1.619
Nitrogen Trifluoride	NF_3	53.371	Yes	No	0.55	2.462	1.569
Nitrous Oxide	N_2O	38.635	No	No	0.75	1.528	1.236
Oxygen	O_2	29.427	No	No	0.99	1.098	1.048
Ozone	O_3	39.238	Yes	Yes	0.74	1.654	1.286
Pentaborane	B_5H_9	100.372	—	—	0.29	2.177	1.475
n Pentane	C_5H_{12}	120.146	—	—	0.24	2.488	1.577
Perchloryl Fluoride	CLO_3F	64.733	Yes	No	0.45	3.501	1.871
Phosgene	$COCL_2$	57.693	Yes	No	0.51	3.411	1.847
Phosphine	PH_3	37.126	Yes	Yes	0.79	1.166	1.080
Phosphorus Pentafluoride	PF_5	—	Yes	No	0.35	4.289	2.071
Propane	C_3H_8	74.01	No	Yes	0.39	1.565	1.251
Propylene (Propene)	C_3H_6	62.345	No	Yes	0.47	1.468	1.212
Silane	SiH_4	42.844	Yes	Yes	0.68	1.105	1.051
Silicon Tetrachloride	$SiCl_4$	90.186	Yes	—	0.32	5.861	2.421
Silicon Tetrafluoride	SiF_4	73.492	Yes	No	0.40	3.595	1.896
Sulfur Dioxide	SO_2	39.884	Yes	No	0.73	2.253	1.501
Sulfur Hexafluoride	SF_6	97.152	No	No	0.30	5.318	2.306
Trichlorosilane	$SiCHl_3$	88.27	—	—	0.33	4.670	2.161
Trimethylamine	$(CH_3)_3N$	91.931	Yes	Yes	0.32	2.076	1.441
Tungsten Hexafluoride	WF_6	100.939	—	—	0.29	10.270	3.205
Uranium Hexafluoride	UF_6	130.789	—	—	0.22	12.139	3.484
Vinyl Bromide	C_2H_3Br	55.531	Yes	Yes	0.53	3.799	1.949
Vinyl Chloride	C_2H_3CL	53.607	Yes	Yes	0.54	2.146	1.465
Vinyl Fluoride	C_2H_3F	50.459	No	Yes	0.58	1.583	1.258
Xenon	Xe	21.012	No	No	1.39	4.584	2.141

Table 4-3 (Continued)

4.6 Using the Orifice Sizing Nomograph

The Orifice Sizing Nomograph, Table 4-4, is used to calculate the control valve's orifice size when changing any or all of the following factors from the original factory calibration.

gas
operating pressure (inlet & outlet)
flow range

The flow controller's orifice is factory-sized to a preselected gas operating pressure and flow range. Note that the orifice is marked with its size in thousandths of an inch. When changing the aforementioned factors, calculate the new orifice size by following the procedure and example outlined below.

Example: Determine the orifice size for the following conditions:

Gas	Hydrogen
Flow Rate:	2000 sccm
Outlet Pressure:	30 psig
Inlet Pressure:	50 psig

1. Determine air equivalent flow rate (Refer to Table 4-3)

$$Q_{air} = Q_{gas}\sqrt{\frac{D_{gas}}{D_{air}}} \quad \text{or}$$

$$Q_{air} = Q_{gas}\sqrt{SG_{gas}}$$

where SG_{air} = 1.00
Q_{air} = Air equivalent flow rate (sccm)
Q_{gas} = Desired flow rate of the gas (sccm) (Based on 0°C standard temperature)
D_{air} = Density of air at 70°F
D_{gas} = Density of the gas (taken at customer temperature)
SC_{gas} = Specific gravity of the gas (taken at customer temperature)

Refer to Table 4-3 for specific gravities

Example:
What is the air equivalent flow rate of 2000 sccm Hydrogen?

$$Q_{gas} = 2000 \text{ sccm}$$

$$\sqrt{SG_{gas}} = .264$$

$$Q_{air} = Q_{gas}\sqrt{SG_{gas}}$$
$$= 2000 \times .264$$
$$= 528 \text{ sccm air}$$

To calculate the orifice conversion factor when using a gas mixture, use the following formula:

$$\begin{matrix}\text{orifice}\\ \text{conversion}\\ \text{factor}\\ \text{mixture}\end{matrix} \sqrt{\frac{P_1\begin{pmatrix}\text{orifice}\\ \text{conversion}\\ \text{factor 1}\end{pmatrix}^1 + P_2\begin{pmatrix}\text{orifice}\\ \text{conversion}\\ \text{factor 2}\end{pmatrix}^2 + P_n\begin{pmatrix}\text{orifice}\\ \text{conversion}\\ \text{factor n}\end{pmatrix}}{100}}$$

Where P_1 = percentage by volume of gas 1
P_2 = percentage of volume of gas 2
P_n = percentage by volume of gas n

Example:

Find the air equivalent flow for 20 slpm of a 20% Helium and 80% Chlorine gas mixture.

$$\begin{matrix}\text{orifice}\\ \text{conversion}\\ \text{factor}\\ \text{mixture}\end{matrix} = \sqrt{\frac{20\,(.371)^2 + 80(1.573)^2}{100}}$$

$$= 1.417$$

Q Air = Q gas (orifice conversion factor)
= 20×1.417
= 28.34 slpm air

2. If inlet and outlet pressures are given in gauge pressure (psig) add 14.7 to convert to absolute pressure (psia).

   Outlet Pressure—30 psig = 14.7 = 44.7 psia
   Inlet Pressure—50 psig = 14.7 = 64.7 psia

3. Determine Critical Pressure Drop
   Critical pressure drop occurs when the outlet pressure (psia) is less than half the

   inlet pressure (psia) or $P\ \text{outlet} \frac{< P\ \text{inlet}}{2}$

   If these conditions exist, calculate the pressure drop (Δp) as follows:

   $$\Delta p = \frac{P_{in}}{2}$$

   Δp = Pressure drop (psi)
   Pin = Inlet pressure (psia)

   If these conditions do not exist, pressure drop equals the inlet pressure minus the outlet pressure.

$$\text{Is } 44.7 \text{ psia} < \frac{64.7 \text{ psia}}{2}\text{? No.}$$

Then $\Delta p = 64.7 - 44.7 = 20$ psi

4. Using the nomograph, locate the pressure drop (psi) on the vertical line marked Δp, (point A).
5. Locate the air equivalent flow rate (sccm air) on the vertical line marked Q_{air}, (point B).
6. Draw a line connecting Δp and Q_{air} and extend it to the baseline. Mark this point (C).
7. Locate inlet pressure (psia) on the vertical line marked P_{in}, (point D).
8. Draw a line connecting P_{in} (point D) and baseline (point C) and then extend this line to the vertical line marked D_o (orifice diameter, inches), (point E).
9. This point on the D_o line is the minimum orifice size for the given conditions. If this point is between two orifice sizes, select the next largest size orifice to ensure adequate flow. If the orifice selected falls below .0013, choose .0013 size orifice.

   For this example, the .007 size orifice would be selected.

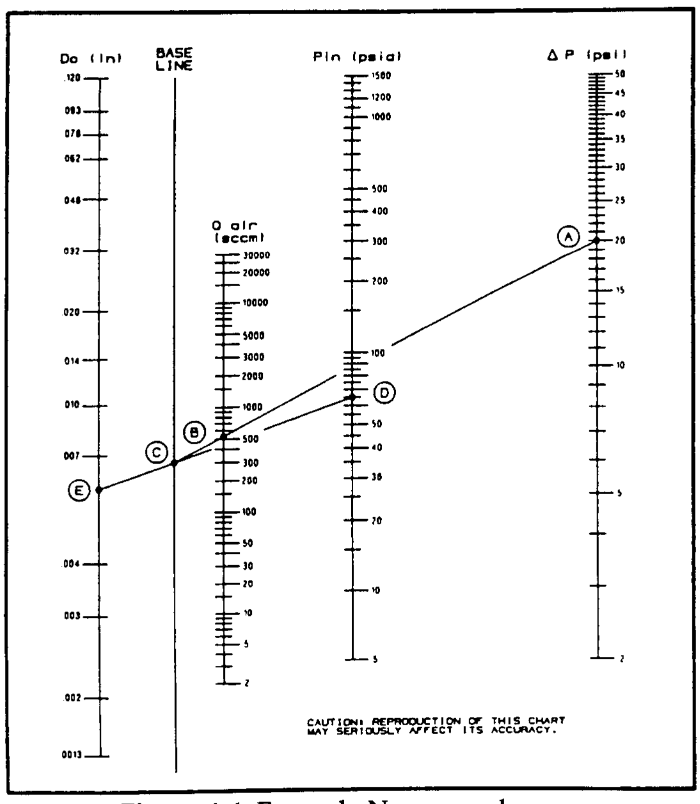


Figure 4-4. Example Nomograph

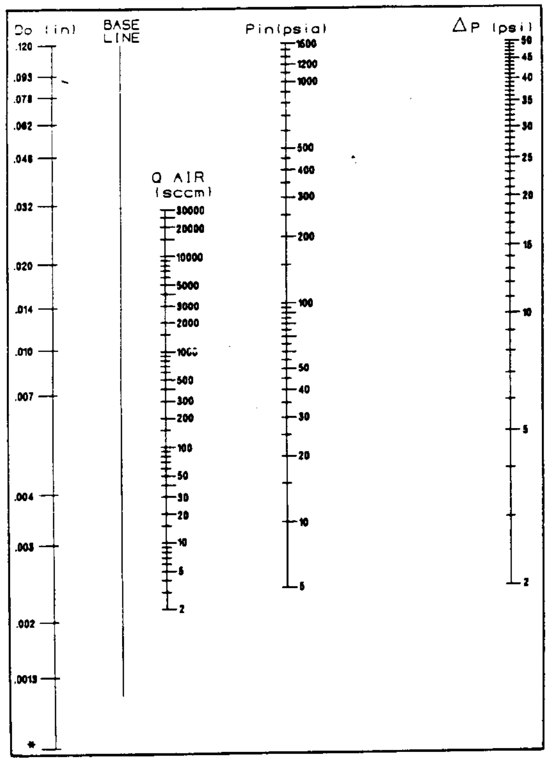


Table 4-4 Orifice Sizing Nomograph

Size	Range SCCM Air Equivalent Flow Low	High	Standard Sintered	Part Number ACLFE	Standard Wire Mesh
D	8.022	11.36	S-110-Z-296*	S-110-Z-275*	
E	11.23	15.90	S-110-Z-297	S-110-Z-276	
F	15.72	22.26	S-110-Z-298	S-110-Z-277	
G	22.01	31.17	S-110-Z-299	S-110-Z-278	
H	30.82	43.64	S-110-Z-300	S-110-Z-279	
J	43.14	61.09	S-110-Z-301	S-110-Z-280	
K	60.40	85.53	S-110-Z-302	S-110-Z-281	
L	84.56	119.7	S-110-Z-303	S-110-Z-282	
M	118.4	167.6	S-110-Z-304	S-110-Z-283	
N	165.7	234.7	S-110-Z-305	S-110-Z-284	
P	232.0	328.6	S-110-Z-306	S-110-Z-285	
Q	324.8	460.0	S-110-Z-307	S-110-Z-286	
R	454.8	644.0	S-110-Z-308	S-110-Z-287	
S	636.7	901.6	S-110-Z-309	S-110-Z-288	
T	891.4	1262.	S-110-Z-310	S-110-Z-289	
U	1248.	1767.	S-110-Z-311	S-110-Z-290	
V	1747.	2474.	S-110-Z-312	S-110-Z-291	
W	2446.	3464.	S-110-Z-313	S-110-Z-292	
X	3424.	4849.			S-110-Z-319*
Y	4794.	6789.			S-110-Z-321
1	6711.	9504.			S-110-Z-317
2	9396.	13310.			S-110-Z-228
3	13150.	18630.			S-110-Z-226
4	18420.	30000.			S-110-Z-224

*Materials: BMT = 316 Stainless Steel (ACLFE only)
CVA = Hastelloy C (ACLFE and sintered)
DCA = Monel R (ACLFE and sintered)
BMA = Sintered 316 Stainless Steel (wire mesh and sintered)

Note: For flow rates less than 8 sccm use the low flow plug, P/N 618-K-019-BMT in place of a restrictor assembly and install a low flow filler ring P/N 724-Z-363-BMT in the valve cavity after the orifice is installed.

Table 4-5 FMA-7000E Restrictors

4.7 Restrictor Sizing

The restrictor assembly is a ranging device for the sensor portion of the controller. It creates a pressure drop which is linear with flow rate. This diverts a sample quantity of the process gas flow through the sensor. Each restrictor maintains the ratio of sensor flow to restrictor flow; however, the total flow through each restrictor is different. Different restrictors (micron porosity and active area) have different pressure drops and produce controllers with different full scale flow rates. For a discussion of the interaction of the various parts of the controller, review Section 3.1 (Theory of Operation).

If the restrictor assembly has been contaminated with foreign matter, the pressure drop versus flow characteristics will be altered and it must be cleaned or replaced. It may also be necessary to replace the restrictor assembly when the mass flow controller is to be calibrated to a new flow rate.

Restrictor assembly replacement should be performed only by trained personnel. The tools required for the removal/replacement procedure are as follows:

Appropriate size wrench for the removal of the inlet process connection

Restrictor removal tool (contained in service tool kit P/N S-778-D-017-AAA)

Restrictor O-ring (refer to Spare Parts Section 5 for the correct part number)

4.7.1 Restrictors

The mass flow controller uses three types of restrictor assemblies depending on full scale flowrate and expected service conditions.

- Porous sintered metal for air equivalent flow rates up to and including 9.5 slpm. The porosity ranges from 1–40 microns. This type of assembly is least expensive and should be used when the gas stream will not contain any particulate matter.
- Sintered wire mesh for air equivalent flow rates above 3.5 slpm. These restrictor assemblies are made from a cylinder of sintered wire mesh and are easily cleaned if they become contaminated in service.
- Anti-Clog Laminar Flow Element (ACLFE). This type of restrictor assembly is used for air equivalent flow rates less than 3.4 slpm. The ACLFE is much more tolerant to particulate contamination than the sintered metal assembly. This is especially important when handling semiconductor gases that tend to precipitate particles. The ACLFE will also improve accuracy when operating at very low pressures. The ACLFE can be field-installed to replace a sintered restrictor. After installation, we recommend recalibrating the unit. Without recalibration accuracy will be from 3–6% of full scale.

4.7.2 Sizing

All FMA-7000E Series Restrictor Assemblies are factory adjusted to provide a 115 mm water column pressure drop for a specific flow rate. This corresponds to the desired full scale flow rate. A list of restrictor assemblies used in the FMA-7000E Series Mass Flow Controllers is shown in Table 4-5.

Example:

The desired gas is Silane (SiH4).

The desired full scale flow rate is 200 sccm.

Sensor conversion factor is 0.68 from Table 4-3.

Air equivalent flow = 200/0.68 = 294.1 sccm air.

In the example above, a size P restrictor would be selected. Both the sintered metal and ACLFE are available for this size. Either type will work; however, since Silane is known to precipitate silicon dioxide particles when contaminated, an anti-clog laminar flow element should be selected for this application.

NOTE

If the calculated flow rate is such that two different size restrictors could be used, always select the larger size.

If a mixture of two or more gases is being used, the restrictor selection must be based on the air equivalent flow rate of the mixture.

Example:

The desired gas is 20% Helium (He) and 80% Chlorine (Cl) by volume. The desired full scale flow rate of the mixture is 20 slpm.

Sensor conversion factor for the mixture is:

$$\text{Mixture Factor} = \frac{100}{\frac{20}{1.39} + \frac{80}{.83}} = .903$$

Air equivalent flow = 20/.903 = 22.15 slpm air.

In this example, a size 4 wire mesh assembly would be selected.

Notes

5 Parts List

5.1 General

When ordering parts, please specify: OMEGA Serial Number, Model Number, Part Description, Part Number, and Quantity. (Refer to Figure 5-1 and Tables 5-1 and 5-2).

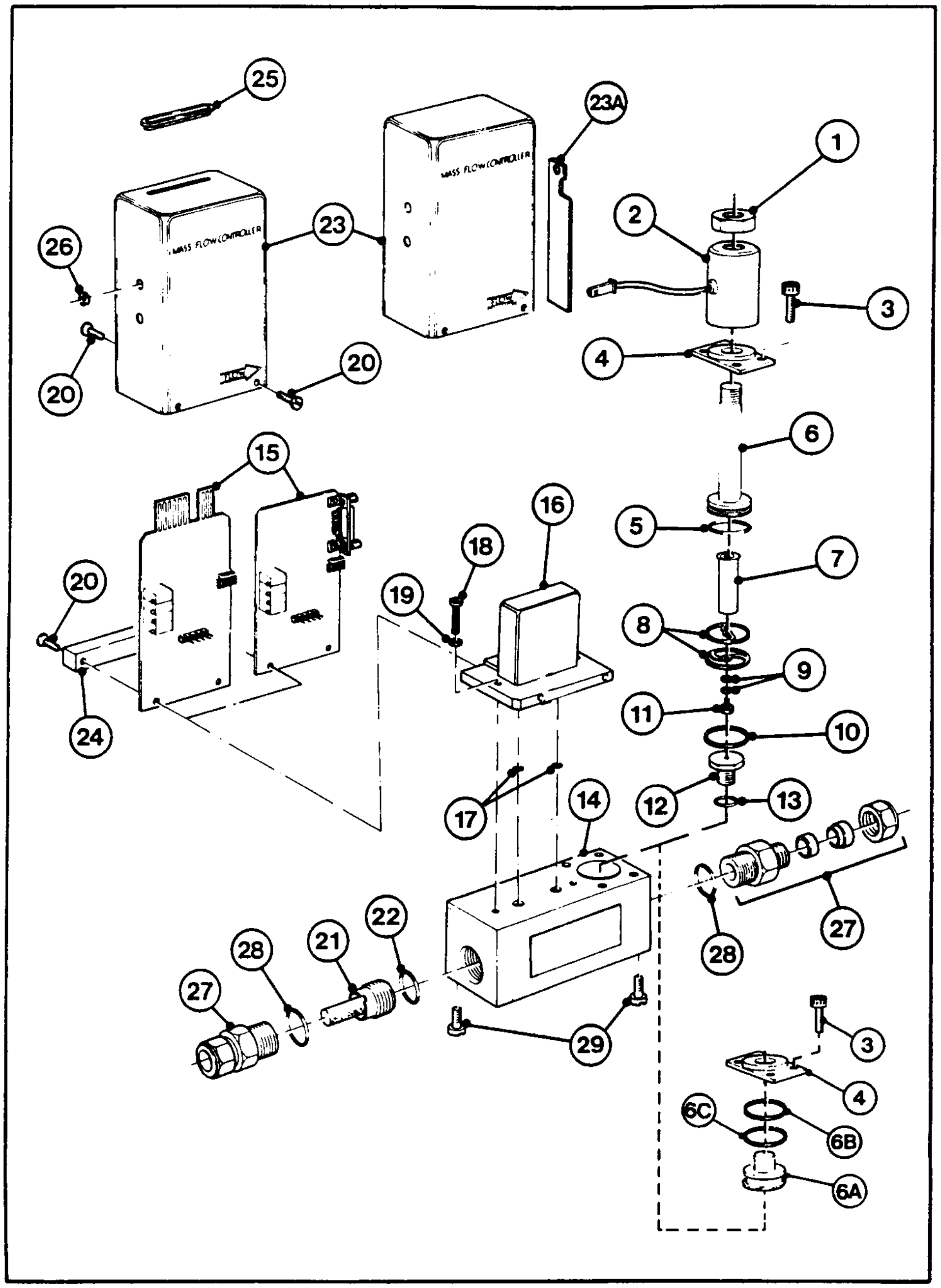


Figure 5-1. FMA-7000E Parts Drawing

Item No.	Qty.	Description		Part Number	
1	1	Jam Nut		573-B-027-ACK	
2	1	Coil Assembly		S-185-Z-271-AAA	
3	4	Screw, Valve		751-C-322-AWA	
4	1	Retaining Plate		715-Z-169-CZ%	
5	1	O-Ring, Valve Stem, Size 016		375-B-016-•••	
6	1	Valve Stem, Corrosion Resistant*		949-Z-203-QOA	
6A	1	Valve Plug		953-Z-068-BMT	
6B	1	Valve Ring		763-Z-064-•••	
6C	1	Valve O-ring		375-B-016-•••	
7	1	Valve Plunger Assy., Corrosion Resistant*		S-622-Z-165-AAA	
8	1 or 2	Lower Guide Spring, see Section 4-4C		820-Z-083-BMA	
9	AR	Small Valve Spacer, 0.005" Thick		810-A-362-BMA	
9	AR	Small Valve Spacer, 0.010" Thick		810-A-363-BMA	
10	AR	Large Valve Spacer, 0.005" Thick		810-A-368-BMA	
10	AR	Large Valve Spacer, 0.010" Thick		810-A-361-BMA	
11	1	Valve Seat with Viton† Insert		S-715-Z-051-AAA	
		Valve Seat with Buna† Insert		S-715-Z-050-AAA	
		Valve Seat with Kalrez† Insert		S-715-Z-163-AAA	
		Valve Seat Solid 316 Stainless Steel		715-Z-181-BNT	
				Stainless	Hastalloy
12	1	Orifice	ID 0.0013"	577-Z-375-BMT	577-Z-404-CVA
			ID 0.002"	577-Z-376-BMT	577-Z-405-CVA
			ID 0.003"	577-Z-377-BMT	577-Z-406-CVA
			ID 0.004"	577-Z-378-BMT	577-Z-407-CVA
			ID 0.007"	577-Z-381-BMT	577-Z-410-CVA
			ID 0.010"	577-Z-383-BMT	577-Z-412-CVA
			ID 0.014"	577-Z-385-BMT	577-Z-414-CVA
			ID 0.020"	577-Z-387-BMT	577-Z-416-CVA
			ID 0.032"	577-Z-391-BMT	577-Z-420-CVA
			ID 0.048"	577-Z-393-BMT	577-Z-422-CVA
			ID 0.062"	577-Z-395-BMT	577-Z-424-CVA
			ID 0.078"	577-Z-397-BMT	577-Z-426-CVA
		(Refer to Section 4-6	ID 0.093"	577-Z-398-BMT	577-Z-427-CVA
		for sizing)	ID 0.116"	577-Z-399-BMT	577-Z-428-CVA
			ID 0.120"	577-Z-400-BMT	577-Z-429-CVA
13	1	O-ring, Orifice, Size 008		375-B-008-•••	
14	1	Controller Body		092-Z-768-BM%	
15	1	PC Board Assembly (Card Edge)		S-097-Y-824-AAA	
		(D-connector)		S-097-Y-847-AAA	
16	1	Sensor Assembly		S-774-Z-607-AAA	
17	2	O-ring, Sensor, Size 004		375-B-004-•••	
18	2	Screw Sensor-Body		753-B-269-AWA	
19	2	Lock Washer, Sensor		962-D-006-AWA	
20	5	Screw, Sensor-PC Board-Cover		753-L-056-AWZ	
21	1	Restrictor Assembly and Components (Refer to Section 4-7 for sizing)			
22	1	O-Ring, Restrictor, Size 109		375-B-109-•••	
23	1	Electronics Cover Can (Card Edge)		219-Z-376-EA%	
		(D-Connector)		219-Z-377-EA%	
23A	1	Cover Plate (D-Con. Version Only)		852-Z-209-EA%	
24	1	PC Board Mounting Bracket		079-Z-135-EAA	
25	1	Centrating Ring (Card Edge Only)		106-D-073-MDQ	
				106-D-072-MDQ	
26	2	Pot Hole Plug		620-Z-434-SXA	

••• QTA-Viton, SUA-Buna, TTA-Kalrez AR As required NS Not shown

Table 5-1 Replacement Parts List

Item No.	Qty.	Description	Length	Part Number
		Fittings:		
27	2	1/4" Compression, Swagelok		320-B-136-BMA
28	2	O-ring, Fitting, Size 906		375-B-906- •••
		Interconnecting Cables:	Length	Card Edge
NS	1	Connector on one end with no termination on other end	5 Feet 10 Feet 25 Feet 50 Feet	S-124-Z-469-AAA S-124-Z-470-AAA S-124-Z-471-AAA S-124-Z-472-AAA
				Card Edge
NS		Connector on one end with Connector for 5870 Series Secondary Electronics on other end	5 Feet 10 Feet 25 Feet 50 Feet	S-124-Z-669-AAA S-124-Z-539-AAA S-124-Z-562-AAA S-124-Z-670-AAA
29	2	8-32 Mounting Screw		Customer Supplied

••• QTA-Viton, SUA-Buna, TTA-Kalrez
AR As required
NS Not shown

Table 5-1 Replacement Parts List (Continued)

FMA-7000E Service Tool Kit P/N S-778-D-017-AAA Permits the complete disassembly of the unit for servicing Contains: 1 — O-Ring Removal Tool 1 — Potentiometer Adjustment Tool 1 — Ball Point Allen Wrench 1 — Phillips Screw Driver 1 — Nut Driver for Orifice 1 — Restrictor Removal Tool 1 — Common Screw Driver	**FMA-7000E O-Ring Service** P/N S-375-Z-278-*** Contains: 1 — Orifice O-Ring 1 — Restrictor O-Ring 1 — Valve O-Ring 2 — Sensor O-Rings 2 — Adapter O-Rings 1 — Syringe with Halocarbon Grease 1 — Information Sheet
FMA-7000E Break Out Board Assembly P/N S-273-Z-649-AAA Card Edge Version Installs directly between mass flow controller and interconnecting cable. Allows convenient access to all signals for easy troubleshooting of system Contains: 1 — Break Out PC Board 1 — 5 foot Extension Cable 1 — Terminal PC Board	**FMA-7000E Valve Shim Kit** P/N S-810-A-372-BMA Contains: 1 — .010" Large Spacer 2 — .005" Large Spacers 1 — .010" Small Spacer 2 — .005" Small Spacers
FMA-7000E Calibration Cover - Edge Card P/N 909-Z-011-EAD	

*** QTA-Viton, SUA-Buna, TTA-Kalrez

Table 5-2 FMA-7000E Tool and Spare Parts Kit

WARRANTY

OMEGA warrants this unit to be free of defects in materials and workmanship and to give satisfactory service for a period of **13 months** from date of purchase. OMEGA Warranty adds an additional one (1) month grace period to the normal **one (1) year product warranty** to cover handling and shipping time. This ensures that our customers receive maximum coverage on each product. If the unit should malfunction, it must be returned to the factory for evaluation. Our Customer Service Department will issue an Authorized Return (AR) number immediately upon phone or written request. Upon examination by OMEGA, if the unit is found to be defective it will be repaired or replaced at no charge. However, this WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion; or current, heat, moisture or vibration; improper specification; misapplication; misuse or other operating conditions outside of OMEGA's control. Components which wear or which are damaged by misuse are not warranted. These include contact points, fuses, and triacs.

We are glad to offer suggestions on the use of our various products. Nevertheless, OMEGA only warrants that the parts manufactured by it will be as specified and free of defects.

OMEGA MAKES NO OTHER WARRANTIES OR REPRESENTATIONS OF ANY KIND WHATSOEVER, EXPRESSED OR IMPLIED, EXCEPT THAT OF TITLE AND ALL IMPLIED WARRANTIES INCLUDING ANY WARRANTY OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE HEREBY DISCLAIMED.

LIMITATION OF LIABILITY: The remedies of buyer set forth herein are exclusive and the total liability of OMEGA with respect to this order, whether based on contract, warranty, negligence, indemnification, strict liability or otherwise, shall not exceed the purchase price of the component upon which liability is based. In no event shall OMEGA be liable for consequential, incidental or special damages.

Every precaution for accuracy has been taken in the preparation of this manual; however, OMEGA ENGINEERING, INC. neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damages that result from the use of the products in accordance with the information contained in the manual.

SPECIAL CONDITION: Should this equipment be used in or with any nuclear installation or activity, buyer will indemnify OMEGA and hold OMEGA harmless from any liability or damage whatsoever arising out of the use of the equipment in such a manner.

RETURN REQUESTS / INQUIRIES

Direct all warranty and repair requests/inquiries to the OMEGA ENGINEERING Customer Service Department. Call toll-free in the USA and Canada: 1-800-622-2378, FAX: 203-359-7811; International: 203-359-1660, FAX: 203-359-7807.

BEFORE RETURNING ANY PRODUCT(S) TO OMEGA, YOU MUST OBTAIN AN AUTHORIZED RETURN (AR) NUMBER FROM OUR CUSTOMER SERVICE DEPARTMENT (IN ORDER TO AVOID PROCESSING DELAYS). The assigned AR number should then be marked on the outside of the return package and on any correspondence.

FOR **WARRANTY** RETURNS, please have the following information available BEFORE contacting OMEGA:

1. P.O. number under which the product was PURCHASED,
2. Model and serial number of the product under warranty, and
3. Repair instructions and/or specific problems you are having with the product.

FOR **NON-WARRANTY** REPAIRS OR **CALIBRATION**, consult OMEGA for current repair/calibration charges. Have the following information available BEFORE contacting OMEGA:

1. Your P.O. number to cover the COST of the repair/calibration,
2. Model and serial number of product, and
3. Repair instructions and/or specific problems you are having with the product.

OMEGA's policy is to make running changes, not model changes, whenever an improvement is possible. This affords our customers the latest in technology and engineering.

OMEGA is a registered trademark of OMEGA ENGINEERING, INC.

† TRADEMARKS

Buna ............................E.I. DuPont de Nemours & Co.
Freon TF........................E.I. DuPont de Nemours & Co.
Kalrez ...........................E.I. DuPont de Nemours & Co.
VCO...Cajon
VCR...Cajon
Viton .....................E.I. DuPont de Nemours & Co.

OMEGA... Your Source for Process Measurement and Control

TEMPERATURE

- Thermocouple, RTD & Thermistor Probes, Connectors, Panels & Assemblies
- Wire: Thermocouple, RTD & Thermistor
- Calibrators & Ice Point References
- Recorders, Controllers & Process Monitors
- Infrared Pyrometers

PRESSURE/STRAIN FORCE

- Transducers & Strain Gages
- Load Cells & Pressure Gauges
- Displacement Transducers
- Instrumentation & Accessories

FLOW/LEVEL

- Rotameters, Gas Mass Flowmeters & Flow Computers
- Air Velocity Indicators
- Turbine/Paddlewheel Systems
- Totalizers & Batch Controllers

pH/CONDUCTIVITY

- pH Electrodes, Testers & Accessories
- Benchtop/Laboratory Meters
- Controllers, Calibrators, Simulators & Pumps
- Industrial pH & Conductivity Equipment

DATA ACQUISITION

- Data Acquisition and Engineering Software
- Communications-Based Acquisition Systems
- Plug-in Cards for Apple, IBM & Compatibles
- Datalogging Systems
- Recorders, Printers & Plotters

HEATERS

- Heating Cable
- Cartridge & Strip Heaters
- Immersion & Band Heaters
- Flexible Heaters
- Laboratory Heaters

ENVIRONMENTAL MONITORING AND CONTROL

- Metering & Control Instrumentation
- Refractometers
- Pumps & Tubing
- Air, Soil & Water Monitors
- Industrial Water & Wastewater Treatment
- pH, Conductivity & Dissolved Oxygen Instruments

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