User's Guide

OMEGA
An OMEGA Technologies Company

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FMA-8500 SERIES
Mass Flowmeters

omega.com®

OMEGA®

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FMA-8500 Series
Mass Flowmeters

SECTION 1 INTRODUCTION

The OMEGA® FMA-8500 Series Mass Flowmeters are designed for accurate measurement and control of gas flow, and consist of a flow sensor and an integral electronic signal conditioner. This combination produces a stable gas flow indication that eliminates the need to continuously monitor and compensate for changing gas pressures and temperatures. The meters feature fast response, superior repeatability, and produce a 0 to 5 VDC output signal linear to the mass flow rate for use in recording, indicating, and/or control purposes.

AVAILABLE MODELS

MODEL	RANGE
FMA-8500	0-10 SCCM
FMA-8501	0-20 SCCM
FMA-8502	0-50 SCCM
FMA-8503	0-100 SCCM
FMA-8504	0-200 SCCM
FMA-8505	0-500 SCCM
FMA-8506	0-1000 SCCM
FMA-8507	0-2000 SCCM
FMA-8508	0-5000 SCCM
FMA-8509	0-10 SLM
FMA-8510	0-20 SLM

SECTION 2 INSTALLATION

2.1 Unpacking

Remove the packing list and verify that all equipment has been received. If there are any questions about the shipment, please call OMEGA Customer Service Department at 1-800-622-2378 or (203) 359-1660.

Upon receipt of the shipment, inspect the container and equipment for any signs of damage. Take particular note of 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

If intermediate or long-term storage is required, it is recommended that equipment be stored in a sheltered area, with an ambient temperature of approximately 70° F and 45% relative humidity.

Upon removal from storage, visually inspect the condition of the equipment. If it has been in storage in excess of 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 FMA-8500 Series are 1/4" compression fittings for flow rates up to 10 SLPM, and 3/8" compression fittings for higher flow rates.

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

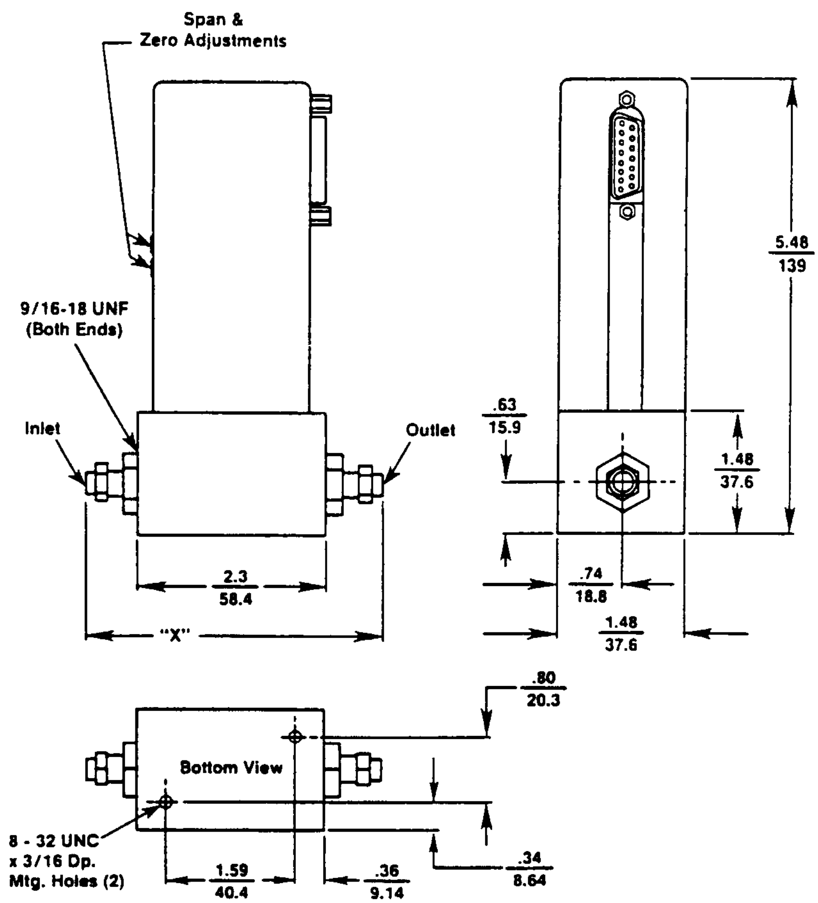
2.4 Installation Procedure (Refer to Figures 2-1 and 2-2)

WARNING

When used with a reactive or toxic gas, contamination or corrosion may occur as a result of plumbing leaks or improper purging. Plumbing should be checked carefully for leaks and the controller purged with dry nitrogen before use.

1. The flowmeter should be located in a clean, dry atmosphere relatively free from shock and vibration.
2. Leave sufficient room for access to the electrical components.
3. Install in such a manner that permits easy removal if the instrument requires cleaning.
4. The flowmeter can be installed in any position. However, mounting orientations other than the original factory calibration will result in ±0.5% maximum full scale shift after re-zeroing.
5. When installing flowmeters with full scale flow rates of 10 SLPM or greater, 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 flowmeter.

INCHES/MILLIMETERS



Connection	"X" Dim.
1/4" Compression Fitting	4.32 / 109.7
1/4" Tube VCO	3.86 / 98.0
1/4" Tube VCR	4.18 / 106.2
3/8" Compression Fitting	4.44 / 112.8

Figure 2-1. FMA-8500 Series Dimensions

2.5 In-Line Filter

It is recommended that an in-line filter be installed upstream from the flowmeter to prevent the possibility of any foreign material entering the flow sensor or control valve. The filtering element should be periodically replaced or ultrasonically cleaned.

Table 2-1 lists the maximum recommended porosity for each flow range. The minimum micron porosity that does not limit the full scale flowrate should be used.

TABLE 2-1
MAXIMUM POROSITY

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

2.6 Electrical Connections

To insure proper operation, the FMA-8500 must be connected as shown in Figure 2-2. The following minimum electrical connections must be made for new installations: Chassis Ground; 0-5 Volt Signal Common; 0-5 Volt Signal Output; +15 VDC Supply; -15 VDC Supply.

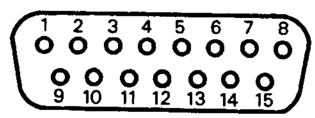


Figure 2-2. "D" Type Connector Pin Arrangement

PIN NO.	FUNCTION	COLOR CODE
2	0-5 Volt Signal Output	White
3	Supply Common	Red
5	+15 Vdc Supply	Orange
6	-15 Vdc Supply	Blue
9	Supply Voltage Common	Grn/Blk
10	0-5 Volt Signal Common	Org/Blk
14	Chassis Ground	Grn/White

Note: 1. Cable shield is tied to chassis ground in meter connector. Make no connection on customer end.
2. All power leads must be connected to power supply.

SECTION 3 OPERATION

3.1 Theory of Operation

The thermal mass flow sensing technique used in the FMA-8500 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:

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

Where:
T = 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 (S^2-°K^2/kJ^2)

A bridge circuit interprets the temperature difference and a differential amplifier generates a linear 0-5 VDC 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 meters with different full scale flow rates. The span adjustment in the electronics affects the fine adjustment of the meter's full scale flow.

The FMA-8500 has the following features incorporated in the integral signal conditioning 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.
- Removable cleanable sensor permits the user to clean or replace the sensor.
- Output limiting prevents possible damage to delicate data acquisition devices by limiting the output to +6.8 VDC and -.7 VDC.

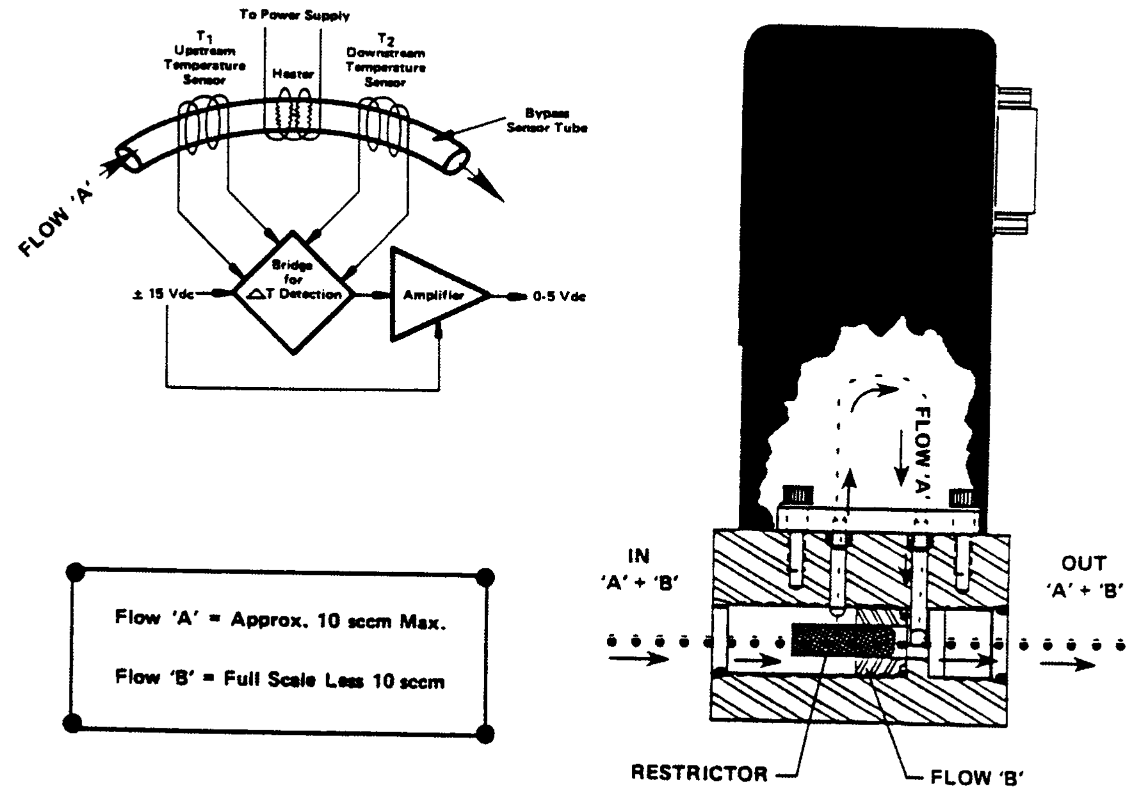


Figure 3-1. Flow Sensor Operational Diagram

3.2 Operating Procedure

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

3.3 Zero Adjustment

Each FMA-8500 is factory adjusted to provide a 0 ±10 mVdc signal at zero flow. The adjustment is made in a calibration laboratory which is temperature controlled to 70° F ±2° F (21.2° C). 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 the laboratory and final installation. The zero flow reading can also be affected to a small degree by changes in line pressure and mounting attitude.

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

3.4 Calibration Procedure

Calibration of the FMA-8500 requires the use of a digital voltmeter (DVM), a flow control valve or mass flow controller to set the flow rate, and a precision flow standard calibrator. It is recommended that calibration be performed only by trained and qualified service personnel.

If the flowmeter is to be used on a gas other than the calibration gas, apply the appropriate sensor conversion factor.

1. Adjust the anticipate potentiometer fully clockwise (20 turns). Then adjust the anticipate potentiometer 10 turns clockwise to center the potentiometer. This will provide a rough adjustment of this circuit and make the flow signal stable for calibration.
2. Connect the DVM positive lead to the 0-5V signal output (terminal 3 card edge, pin 2 D-type) and the negative lead to signal common (TP4). Adjust the zero potentiometer for an output of 0 mV ±2mV.

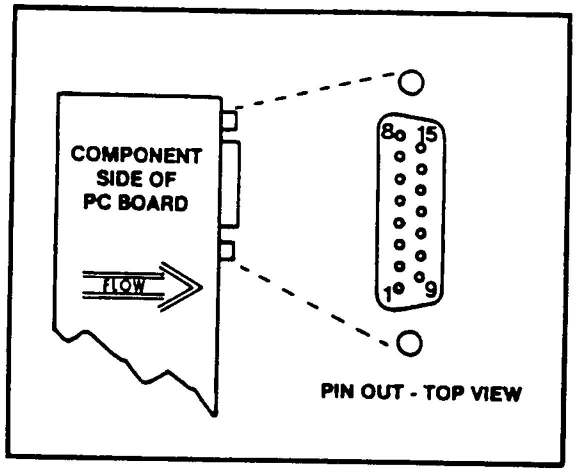


Figure 3-2. Calibration Connections

3. Increase the flow rate until the flow signal output equals 5.000V. Connect the DVM positive lead to the 0-5V signal output (pin 2 of the D-connector) and the negative lead to TP4. 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 0.0V (zero volts).
4. Connect the DVM positive lead to the 0-5V signal output (pin 2 of D-Connector) and the negative lead to TP4 (circuit common). Measure the flow rate using suitable volumetric calibration equipment. Adjust the flow rate to the proper full scale flow.

   $$\text{Flow signal voltage} = \frac{\text{measured flow rate}}{\text{full scale flow rate}} \times 5.000$$

   Adjust the span potentiometer until the voltage at pin 2 is 5.000V.
5. Measure the voltage at TP1. The voltage at TP1 is -100 times the output voltage of the sensor. This voltage can range from -1.2 to -12 volts, however it is recommended that this voltage stay between 2.0 and 9.0 volts for proper operation. If the recommended voltage range exceeds this, then 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 4-6.
6. Shut off the flow. Connect the DVM positive lead to flow signal output (terminal 3 card edge, pin 2 D-type) and the negative lead to TP4. Readjust the zero potentiometer for an output of 0 mV ± 2mV as necessary.

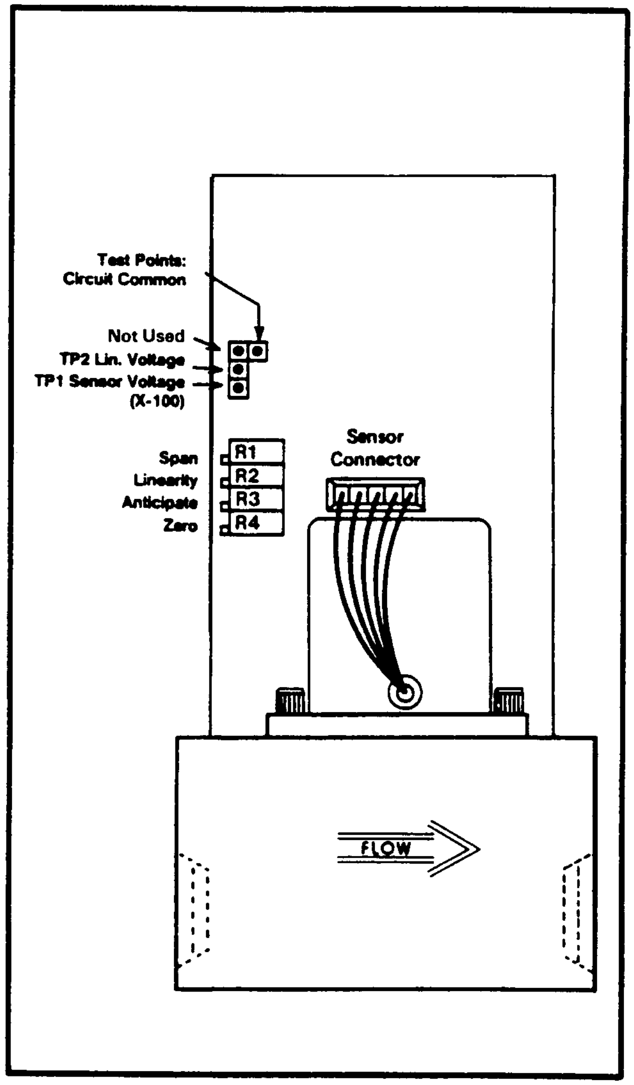


Figure 3-3. Location of Adjustment Potentiometers

7. Set flow rate for a flow signal output of 50% (2.500V) and measure the actual flow rate. Calculate the error as a percentage of full scale.

$$\text{Full Scale error} = 100\% \frac{\text{Indicate flow rate} - \text{Measured flow rate}}{\text{Full scale flow rate}}$$

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

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

8. Calculate the TP2 correction voltage:
(error recorded in step 7) x 0.450 volts

Example: Error = -1.5%
TP2 correction voltage = 1.5 x 0.450 = -0.675 volts.
New TP2 voltage = 0 volts + (-0.675) = -0.675 volts

9. Set flow rate for a flow signal output of 100% (5.000V). Connect the DVM positive lead to TP2 and the negative lead to TP4.

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

11. Repeat steps 4, 5, 6, and 7.

a) If the error recorded in step 7 is less than 0.5%, then the calibration procedure is complete

b) If the error is greater than 0.5%, set the flow rate for a flow signal output of 100% (5.000V): Connect the DVM positive lead to TP2 (linearity voltage) and the negative lead to TP4 (circuit common). Calculate a new TP2 voltage as follows:

New TP2 voltage = error recorded x 0.450V + measured TP2 voltage in step 9

Example: Sensor error = 0.7%
Measured TP2 voltage = -0.567 volts
TP2 correction = 0.7 x 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 stay 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 4.6.

3.5 Response (Flow Output Signal)

To achieve the proper response characteristics, the response compensation circuit must be adjusted. This adjustment is performed by observing the meter's output signal when flow is suddenly stopped.

Place a metering valve upstream of the FMA-8500 to control the flow rate. Also place a fast-acting shut-off valve immediately downstream of the flowmeter. A solenoid valve is ideal for this, but a manual toggle valve will do. Keep the length of interconnecting tubing as short as possible between the valves and the FMA-8500, since the tubing can have a dampening effect on the flow and the gas may not stop flowing the instant the downstream valve is closed as desired. Adjustment of the fast response circuit will not alter the steady state accuracy of the flowmeter as adjusted in Section 3.4.

This procedure requires an oscilloscope, chart recorder, or DVM with a sample speed of three samples per second or greater to monitor the rate of change of the output signal during the test. Monitor the output signal at pin 2 of D-connector. TP4 may be used for ground.

1. With the shut-off valve open, adjust the metering valve so that the output voltage of the FMA-8500 is 4.050 to 5.000 VDC. Allow the output to become stable at this setting.
2. Close the shut-off valve to stop the flow. Observe the output signal as it decays.
3. The behavior of the output signal during the transition between 100% and 0% flow indicates the adjustment required of the anticipated potentiometer. Refer to Figure 3-4.
   a. If the flow singal decays to -0.05 to -.05V, then rises to 0.0V, the anticipate potentiometer is properly adjusted.
   b. If the flow signal decays rapidly and goes below – 0.5V before rising to 0.0V, the anticipated potentiometer must be adjusted clockwise and steps 1 and 2 repeated.
   c. If the flow signal decays slowly and does not go below -0.05V, the anticipate potentiometer must be adjusted counterclockwise and steps 1 and 2 repeated.

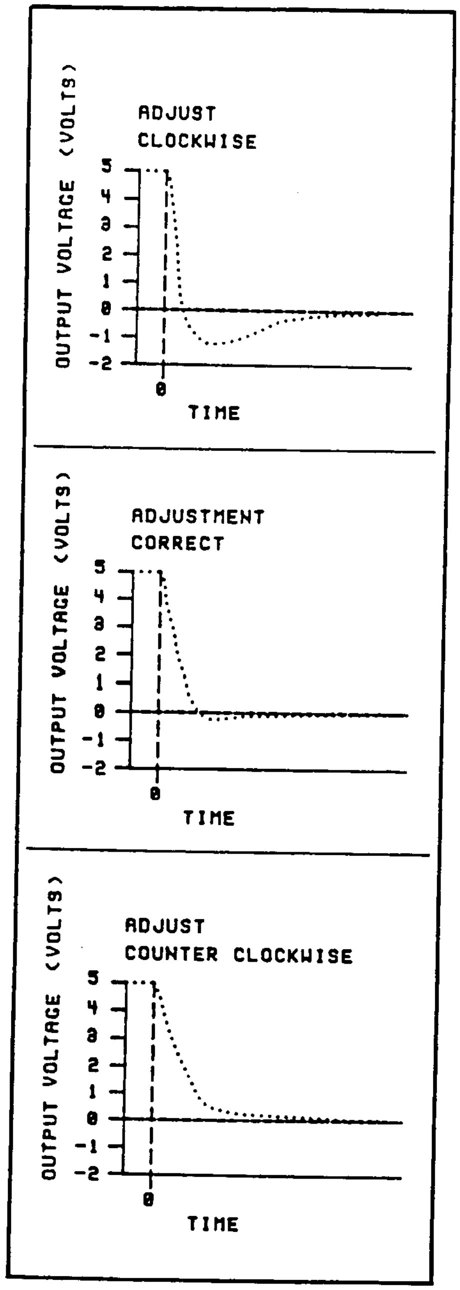


Figure 3-4. Fast Response Adjustment

SECTION 4 MAINTENANCE

4.1 General

No routine maintenance is required on the FMA-8500 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

4.2.1 System Checks

The FMA-8500 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.

WARNING

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

4.2.2 Bench Troubleshooting

1. Properly connect the mass flowmeter to a ±15 VDC power supply, and connect an output signal readout device ($4^1/_2$ digit voltmeter recommended) to terminals 2 and 3 (D-type pins 2 and 10). Refer to Figure 2-2. Apply power, and allow the flowmeter 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.

CAUTION

The FMA-8500 contains electronic components that are susceptible to damage by static electricity. Proper handling procedures must be observed during the removal, installation, or other handling of internal circuit boards or devices. Power to unit must be removed, and personnel must be grounded before any printed circuit card is installed, removed or adjusted. Printed circuit cards must be transported in a conductive bag or container.

2. Connect the flowmeter to a source of the gas on which it was originally calibrated. Increase the flow until 100% indication (5.00 VDC) is achieved. Vary the flow rate over the 2 to 100% range and verify that the output signal follows the flow rate. If possible, connect a flow measurement device in series with the mass flowmeter to observe the actual flow behavior and verify the accuracy of the mass flowmeter. If the mass flowmeter 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.

TABLE 4-1
BENCH TROUBLESHOOTING

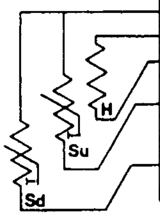
Problem	Possible Cause	Corrective Action
Output stays at 0 volts regardless of flow.	Clogged sensor	Clean sensor, Refer to cleaning procedure.
Output signal stays at +6.8V and there is flow through meter.	Defective printed circuit board	Replace printed circuit board.
	Defective sensor	Replace sensor assembly.
Meter grossly out of calibration, flow is higher than indicated	Partially clogged sensor	Clean sensor.
Meter grossly out of calibration, flow is lower than indicated	Partially clogged restrictor	Replace restrictor.
Meter output oscillates	Anticipate potentiometer out of adjustment	Adjust anticipate potentiometer. Refer to Section 3.4.
	Faulty pressure regulator	check regulator output.
	Defective printed circuit board	Replace printed circuit board. Refer to Section 4.4.

4.2.3 Sensor Troubleshooting

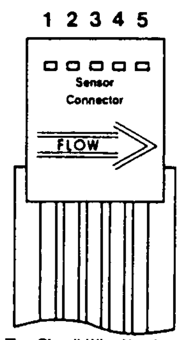
It is believed that the sensor coils are either open or shorted, troubleshoot using Table 4-2. If any of the steps do not produce the expected results, the sensor assembly is defective and must be replaced. Refer to Section 4.4. for the removal and assembly procedures to use when replacing the sensor.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

TABLE 4-2
SENSOR TROUBLESHOOTING

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 ohm reading.

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

4.2.4 Cleaning Procedures

If the flowmeter requires cleaning, use the following procedure.

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 damage the sensor, or significantly alter its operating characteristics.

3. Use tweezers to push a 0.007" dia. 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 is recommended). A hypodermic needle filled with solvent can be used for this purpose.

   An alternate method for flushing out the sensor is to replace the restrictor element with a low flow plug resistor. This plug forces all the flow through the sensor and may dislodge any obstructions. Subject the flowmeter to a high differential pressure. Pressurizing the outlet of the flowmeter higher than the inlet may help force the obstruction upstream and out of the sensor tube.
4. 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, followed by Freon TF).
5. 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 4.6 for the correct restrictor to use.
6. Blow all parts dry with dry nitrogen and reassemble. Refer to Section 4.4.
7. Purge the assembled flowmeter with dry nitrogen.
8. Perform the calibration procedure in Section 3.4.
9. When the flowmeter 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. If the sensor assembly is cleaned and reinstalled, a calibration check should be performed. Refer to Section 3.4.

4.4 Disassembly and Assembly (Refer to Figure 5.2)

The FMA-8500 may be disassembled in the field by the user for cleaning, a re-ranging or servicing. The flowmeter should be disassembled and assembled in a clean environment to prevent particulate contamination. Disassemble and assemble as follows:

WARNING

Do not attempt to disassemble the mass flowmeter 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.

A. DISASSEMBLY

1. Remove the three screws attaching the electronics cover and loosen the upper jack post on the D-Connector. Remove the electronics cover.

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 opening in the sensor wiring could result.

2. Unplug the sensor connector from the PC Board. Remove the two screws securing the bracket and PC Board. Remove the bracket and PC Board.
3. Remove the two screws and washers securing the sensor assembly. Remove the sensor assembly. Do not attempt to disassemble the sensor assembly.
4. Remove the back-up rings and the sensor assembly O-rings from the flowmeter body. **CAUTION:** Do not scratch the O-ring sealing surface; using an O-ring removal tool will help prevent this.
5. Remove the adapter fittings from the flowmeter body.
6. Remove the restrictor assembly from the inlet side of the flowmeter body.

B. ASSEMBLY

It is recommended that all O-rings be replaced during assembly. All O-rings should be lightly lubricated with Halocarbon lubricant prior to their installation.

CAUTION

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

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 into the inlet side of the flowmeter body, tighten hand tight.

CAUTION

The steps that follow must be performed in this order. 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-ring into the flowmeter body. Press the back-up rings into the O-ring cavity above the O-rings. Be sure that the O-rings are seated squarely and the back-up rings are below the surface of the body.
4. Install the sensor assembly as shown in Figure 5-2 and secure with the two socket head cap screws and washers. Tighten the screws to 28 in-lbs.
5. Install the printed circuit board, secure with bracket, and two screws. Plug the connector from the sensor assembly onto the PC board. The flow arrow on the connector should be pointing in the direction of the flow.
6. Install the electronics cover on the controller and secure with three screws. Tighten the upper jack post on the D-connector.
7. Prior to installation, leak and pressure test the flowmeter to any applicable vessel codes.

4.5 Using the Conversion Tables

If a mass flowmeter 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.

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

Example: The flowmeter is calibrated for nitrogen. The desired gas is carbon dioxide. The output reading is 75 SCCM when carbon dioxide is flowing.
75 x 0.78 = 58.50 SCCM

In order to calculate the conversion factor for a gas mixutre, the following formula should be used:

$$\text{Sensor Conversion Factor Mixture} = \frac{100}{\dfrac{P1}{\text{sensor conversion factor 1}} + \dfrac{P2}{\text{sensor conversion factor 2}} + \dfrac{Pn}{\text{sensor conversion factor n}}}$$

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:

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

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 are 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 from temperaure and/or pressure.

TABLE 4-3
CONVERSION FACTORS

Gas	Symbol	Specific Heat Cp at 25° C and 1 Atm. j/mole K	Toxic	Flammable	Sensor Conversion Factor*
Acetylene	C_2H_2	44.308	No	Yes	0.66
Air	(Mixture)	29.13	No	No	1.00
Allene	C_3H_4	60.84	No	Yes	0.48
Ammonia	NH_3	36.953	Yes	Yes	0.79
Argon	Ar	20.83	No	No	1.40
Arsine	A_5H_3	38.522	Yes	Yes	0.76
Boron Trichloride	BCL_3	65.655	Yes	No	0.44
Boron Trifluoride	BF_3	50.242	Yes	No	.058
Bromine Pentafluoride	BrF_5	101.4	Yes	Yes	.029
Bromine Trifluoride	BrF_3	66.65	Yes	Yes	.044
Butane	C_4H_{10}	100.365	No	Yes	0.29
Butene	C_4H_8	87.329	No	Yes	0.33
Carbon Dioxide	CO_2	37.564	No	No	0.78
Carbon Monoxide	CO	29.204	Yes	Yes	0.99
Carbon Tetracloride	CCL_4	84.438	Yes	No	0.35
Carbon Tetrafluoride	CF_2	61.27	Yes	No	0.48
Carbonyn Fluoride	COF_2	108.5	Yes	Yes	0.27
Carbonyl Sulfide	COS	42.752	Yes	Yes	0.68

TABLE 4-3 (CONT'D)
CONVERSION FACTORS

Gas	Symbol	Specific Heat Cp at 25° C and 1 Atm. j/mole K	Toxic	Flammable	Sensor Conversion Factor*
Chlorine	CL_2	35.317	Yes	Yes	0.83
Chlorine Trifluoride	CLF_3	67.117	Yes	Yes	0.43
Chloroform	$CHCL_3$	65.756	Yes	Yes	0.44
Cyanogen	C_2N_2	38.338	Yes	Yes	0.50
Cyclopropane	C_3H_6	57.559	Yes	Yes	0.51
Deuterium	D_2	29.204	No	Yes	1.00
Diborane	B_2H_6	53.346	Yes	Yes	0.55
Dichlorosilane	SiH_2CL_2	65.73	Yes	Yes	0.44
Dimethylamine	$(CH_3)_2NH$	42.428	Yes	Yes	0.67
Dimethylether	$(CH_3)_2O$	49.40	Yes	Yes	0.59
Ethane	C_2H_6	53.346	No	Yes	0.55
Ethyl Chloride	C_2H_5CL	102.090	Yes	Yes	0.29
Ethylene	C_2H_4	43.428	No	Yes	0.62
Ethylene Oxide	C_2H_4O	49.40	Yes	Yes	0.59
Fluorine	F_2	31.339	Yes	Yes	0.93
Fluoroform	CHF_3	51.557	No	No	0.57
Freon 11	CCL_3F	77.613	No	No	0.38
Freon 12	CCL_2F_2	74.469	No	No	0.39

Freon 13	$CCLF_3$	67.655	No	No	0.43
Freon 13 B1	$CBrF_3$	70.590	No	No	0.41
Freon 14	CF_4	61.271	No	No	0.475
Freon 21	$CHCL_2F$	60.994	Yes	No.	0.46
Freon 22	$CHCLF_2$	57.524	No	No	0.51
Freon 23	CHF_3	51.56	No	No	0.57
Freon 113	$CCl_2F\text{-}CClF_2$	126.10	No	No	0.23
Freon 114	$CCl_2F_4\text{-}CClF_2$	112.992	No	No	0.258
Freon 115	$CClF_2\text{-}CF_3$	105.86	Yes	No	0.274
Freon 116	$CF_3\text{-}CF_3$	126.65	No	No	0.23
Germane	GeH_4	45.020	Yes	Yes	0.65
Helium	He	20.967	No	No	1.39
Hexamethyldisizane	HMDS	–	–	–	0.14
Hydrogen	H_2	28.851	No	Yes	1.01
Hydrogen Bromide	HBr	29.791	Yes	No	0.98
Hydrogen Chloride (Dry)	HCL	29.576`	Yes	No	0.99
Hydrogen Fluoride	HF	16.155	Yes	No	1.00
Hydrogen Iodide	HI	30.497	Yes	Yes	0.96
Hydrogen Selenide	H_2Se	34.752	Yes	Yes	0.84
Hydrogen Sulfide	H_2S	34.218	Yes	Yes	0.85
Isobutane	C_4H_{10}	94.163	No	Yes	0.31
Isobutylene	C_4H_8	86.883	No	Yes	0.34
Kypton	Kr	21.037	No	No	1.39

TABLE 4-3 (CONT'D)
CONVERSION FACTORS

Gas	Symbol	Specific Heat Cp at 25° C and 1 Atm. j/mole K	Toxic	Flammable	Sensor Conversion Factor*
Methane	CH_4	35.941	No	Yes	0.81
Methylamine	CH_3NH_2	51.460	Yes	Yes	0.57
Methyl Bromide	CH_3Br	45.020	Yes	No	0.65
Methyl Chloride	CH_3CL	42.326	Yes	Yes	0.69
Methyl Fluoride	CH_3F	38.171	No	Yes	0.76
Methyl Mercaptan	CH_4S	49.491	Yes	Yes	0.59
Neon	Ne	20.789	No	No	1.40
Nitric Oxide	NO	29.227	Yes	No	1.00
Nitrogen	N_2	29.98	No	No	1.005
Nitrogen Dioxide	NO_2	36.974	Yes	No	0.760
Nitrogen Trioxide	N_2O_3	65.618	Yes	No	0.44
Nitrogen Trifluoride	NF_3	53.371	Yes	No	0.55
Nitrous Oxide	N_2O	38.635	No	No	0.75
Oxygen	O_2	29.427	No	No	0.99
Ozone	O_3	39.238	Yes	Yes	0.74
Pentaborane	B_5H_9	100.372	–	–	0.29
n Pentane	C_5H_{12}	120.146	–	–	0.24
Perchloryl Fluoride	CLO_3F	64.733	Yes	No	0.45

Phosgene	$COCL_2$	57.693	Yes	No	0.51
Phosphine	PH_3	37.126	Yes	Yes	0.79
Phosphorus Pentafluoride	PF_5	–	Yes	No	0.35
Propane	C_3H_8	74.01	No	Yes	0.39
Propylene (Propene)	C_3H_6	62.345	No	Yes	0.47
Silane	SiH_4	42.844	Yes	Yes	0.68
Silicon Tetrachloride	$SiCl_4$	90.186	Yes	–	0.32
Silicon Tetrafluoride	SiF_4	73.492	Yes	No	0.40
Sulfur Dioxide	SO_2	39.884	Yes	No	0.73
Sulfur Hexafluoride	SF_6	97.152	No	No	0.30
Trichlorosilane	$SiHCL_3$	–	–	–	0.33
Trimethylamine	$(CH_3)_3N$	91.931	Yes	Yes	0.32
Tungsten Hexafluoride	WF_6	100.939	–	–	0.29
Uranium Hexafluoride	UF_6	130.789	–	–	0.22
Vinyl Bromide	C_2H_3Br	55.531	Yes	Yes	0.53
Vinyl Chloride	C_2H_3CL	53.607	Yes	Yes	0.54
Vinyl Fluoride	C_2H_3F	50.459	No	Yes	0.58
Xenon	Xe	21.012	No	No	1.39

*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.

4.6 Restrictor Sizing

The restrictor assembly is a ranging device for the sensor portion of the flowmeter. 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 meters with different full scale flow rates.

If the restrictor assembly has been contaminated with foreign matter, the pressure drop vs. 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 flowmeter is to be calibrated to a new full scale flow rate.

Restrictor assembly replacement should be performed only by trained personnel. The FMA-8500 flowmeters use three types of restrictor assemblies, depending on full scale flowrate and expected service conditions.

1. 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.
2. 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.
3. 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.

All restrictor assemblies are factory adjusted to prove a 115mm 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 flowmeter is shown in Table 4-4.

Example: The desired gas is Silane (SiH_4).
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 this example, a size P restrictor would be selected. Both 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 laminate flow element should be selected for this application.

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 are 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.

TABLE 4-4
STANDARD RESTRICTIONS

Size	Range sccm Air Equivalent Flow Low	High	Part Number Sintered	ACLFE	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-314		S-110-Z-319*
Y	4794.	6789.	S-110-Z-208		S-110-Z-321
1	6711.	9504.	S-110-Z-192		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)

SECTION 5 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: (Flow Output Signal)	Less than 3 seconds response to within 2% of full scale final value with a 0 to 100% flow step.
Power Requirements:	±15 Vdc, 35 mA, 1 watt power consumption
Ambient Temperature Limits:	Operating: 40 to 150° F (5 to 65° C) Non-operating: -13 to +212° F (-25 to 100° C)
Working Pressure:	4500 psi (31.03 MPa) maximum
Output Signal:	0-5 Vdc into 2000 ohms or greater. Maximum ripple 3mV.
Temperature Sensitivity:	Zero: less than ±0.075% F.S. per ° C Span: less than ±1% F.S. shift over 10-50° C
Power Supply Sensitivity:	±0.09% full scale per % power supply voltage variation
Mounting Attitude Sensitivity:	±0.5% maximum full scale deviation after re-zeroing
Leak Integrity:	1×10^{-9} Atm. scc/sec Helium
Usable Range:	50 to 1
Electrical Connection:	D-type, 15-pin connector
Pressure Coefficient:	±.03%/psi up to 200 psi of N

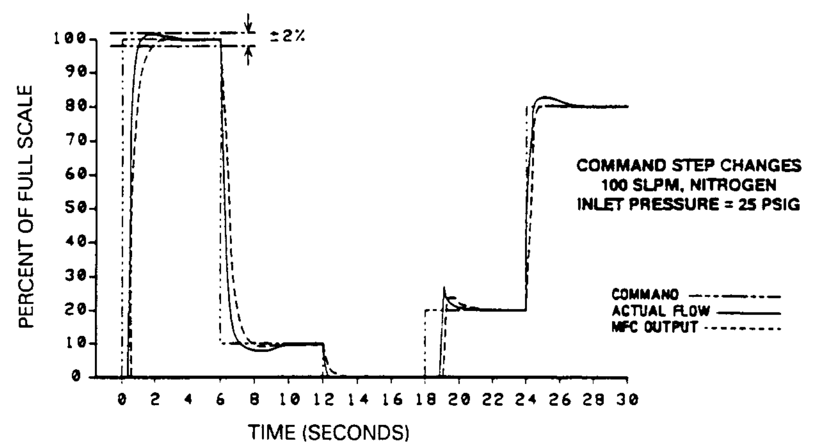


Figure 5-1. Typical Response to Flow Step Changes

5.1 Parts List

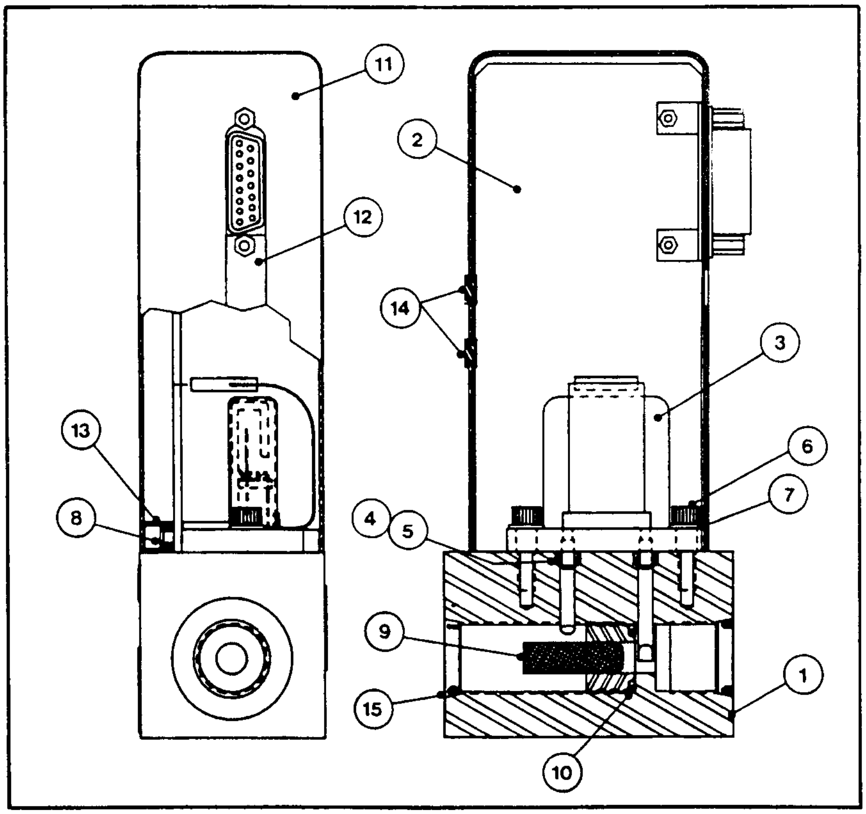


Figure 5-2. FMA-8500 Series Parts Drawing

TABLE 5-1
REPLACEMENT PARTS LIST

Item No.	Description	Length	Part Number
1	Flowmeter Body		092-Z-773-BM%
2	PC Board Assembly (D-Connector)		S-097-Y-847-AAA
3	Sensor Assembly		S-774-Z-607-AAA
4	O-ring, Sensor, Size 004		375-B-004-***
5	Back-Up Ring, Sensor		962-A-027-NZA
6	Screw Sensor-Body		751-Z-107-AA0
7	Lock Washer, Sensor		926-D-006-AWA
8	Screw, Sensor-PC Board-Cover		753-L-056-AWZ
9	Restrictor Assembly and Components (Refer to Section 4.6 for size)		
10	O-ring, Restrictor, Size 109		375-B-109-***
11	Electronics Cover Can (D-Connector)		219-Z-392-EA%
12	Cover Plate		852-Z-213-EA%
13	PC Board Mounting Bracket		079-Z-135-EAA
14	Pot Hole Plug		620-Z-434-SXA
	Fittings:		
NS	1/4" Compression, Swagelok		320-B-136-BMA
	1/4" Male VCR, Cajon		315-Z-036-BMA
	1/4" Male VCO, Cajon		315-Z-035-BMA
15	O-ring, Fitting, Size 906		375-B-906-***
NS	O-ring, VCO Gland, Size 010		375-B-010-***
	Interconnecting Cables:	Length	D-type
NS	Connector on one end with no termination on other end	5 Feet	S-124-Z-191-AAA
		10 Feet	S-124-Z-362-AAA
		25 Feet	S-124-Z-346-AAA
		50 Feet	S-124-Z-442-AAA
NS	Connector on one end with Connector for FMA-8500 Series Secondary Electronics on other end	5 Feet	S-124-Z-576-AAA
		10 Feet	S-124-Z-577-AAA
		25 Feet	S-124-Z-578-AAA
		50 Feet	S-124-Z-579-AAA
NS	8-32 Mounting Screw		Customer Supplied

*** QTA-Viton, SUA-Buna, TTA-Kalrez
NS Not shown

NOTES

WARRANTY/DISCLAIMER

OMEGA ENGINEERING, INC. warrants this unit to be free of defects in materials and workmanship 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 OMEGA's customers receive maximum coverage on each product.

If the unit should malfunction, it must be returned to the factory for evaluation. OMEGA's 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. OMEGA's WARRANTY does not apply to defects resulting from any action of the purchaser, including but not limited to mishandling, improper interfacing, operation outside of design limits, improper repair, or unauthorized modification. 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 are not warranted, including but not limited to contact points, fuses, and triacs.

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RETURN REQUESTS / INQUIRIES

Direct all warranty and repair requests/inquiries to the OMEGA Customer Service Department. BEFORE RETURNING ANY PRODUCT(S) TO OMEGA, PURCHASER MUST OBTAIN AN AUTHORIZED RETURN (AR) NUMBER FROM OMEGA'S 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.

The purchaser is responsible for shipping charges, freight, insurance and proper packaging to prevent breakage in transit.

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 relative to the product.

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

1. P.O. number to cover the COST of the repair,
2. Model and serial number of product, and
3. Repair instructions and/or specific problems relative to the product.

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