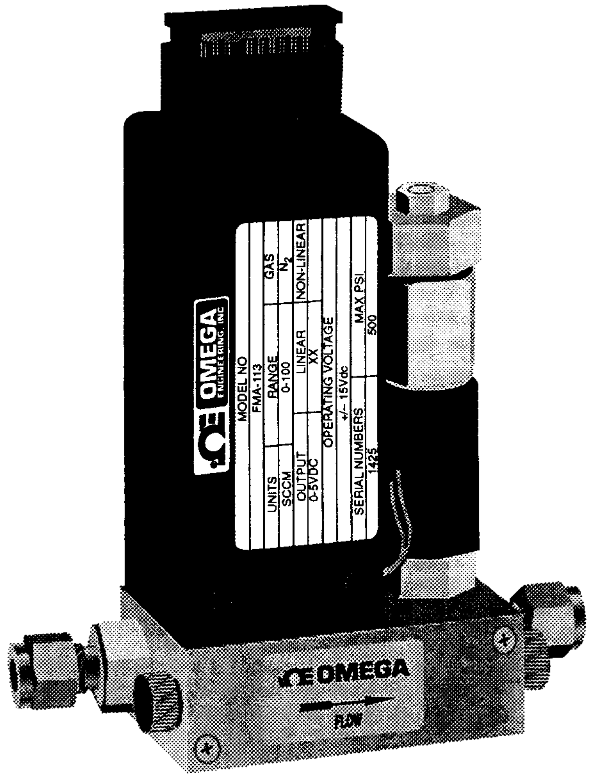
FMA-100, -200

Mass Flow Controller & Mass Flow Meter



OMEGA®
An OMEGA Technologies Company

Operator's Manual

OMEGA®

An OMEGA Technologies Company

Servicing USA and Canada: Call OMEGA Toll Free

USA	Canada
One Omega Drive, Box 4047	976 Bergar
Stamford, CT 06907-0047	Laval (Quebec) H7L 5A1
Telephone: (203) 359-1660	Telephone: (514) 856-6928
FAX: (203) 359-7700	FAX: (514) 856-6886

Sales Service: 1-800-826-6342 / 1-800-TC-OMEGA℠
Customer Service: 1-800-622-2378 / 1-800-622-BEST℠
Engineering Service: 1-800-872-9436 / 1-800-USA-WHEN℠
TELEX: 996404 EASYLINK: 62968934 CABLE OMEGA

Servicing Europe: United Kingdom Sales and Distribution Center

25 Swannington Road, Broughton Astley, Leicestershire
LE9 6TU, England
Telephone: 44 (0455) 285520 FAX: 44 (0455) 283912

The OMEGA Complete Measurement and Control Handbooks & Encyclopedias

- Temperature
- Pressure, Strain & Force
- Flow and Level
- pH and Conductivity
- Data Acquisition Systems
- Electric Heaters
- Environmental Monitoring and Control

Call for Your FREE Handbook Request Form Today: (203) 359-RUSH

Oxygen Service Caution

CAUTION

OMEGA is not liable for any damages or personal injury whatsoever resulting from the use of flow meters or controllers for oxygen gas. Although OMEGA does clean its mass flow meters and controllers prior to shipment, we make no claim or warranty that their cleanliness renders them safe for oxygen service. Customers must clean mass flow meters or controllers to the degree that they require for their oxygen flow applications.

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.

TABLE OF CONTENTS

1. Introduction 1-1

1.1 Purpose 1-1
1.2 Principle of Operation 1-2
1.3 Specifications 1-5
1.3.1 FMA-200 Mass Flow Meters 1-5
1.3.2 FMA-100 Mass Flow Controllers 1-7

2. Installation 2-1

2.1 Mechanical Installation 2-1
2.2 Plumbing Connections 2-1
2.3 Electrical Connections 2-3
2.3.1 20-Pin Edge Card Connector Pin Assignments 2-5

3. Operation 3-1

3.0.1 Over-Range Indication 3-1
3.0.2 Cold Sensor Lockout Circuit 3-1
3.1 Output Options, Meters and Controllers 3-2
3.2 Control Operation 3-2
3.2.1 Set Point Input Signal 3-2
3.2.1.1 Local Set Point Potentiometer 3-3
3.2.2 Auto Shut-Off 3-3
3.2.3 Valve Off, TTL Compatible (Pin J) Electromagnetic Valves 3-4
3.2.4 Valve Monitor Purge Function (Pin D) 3-4
3.2.5 Soft Start Option, Electromagnetic Valves 3-5

4. K Factors and Gas Tables 4-1

4.1 For a Single Gas 4-1
4.2 For Dual-Gas Mixtures 4-4

5. Maintenance 5-1

5.1 Electronics Maintenance 5-1
5.2 Flow Path Maintenance 5-1
5.2.1 Laminar Flow Element 5-1
5.2.2 Sensor Maintenance 5-2
5.2.3 Valve Maintenance 5-5

TABLE OF CONTENTS

6. Calibration Procedure 6-1

- 6.1 FMA-200 Mass Flow Meter Calibration Procedure 6-1
- 6.2 FMA-100 Calibration Procedure 6-3
- 6.2.1 Piston Tube Calibration Procedure..6-4
- 6.2.2 Transfer Standard Calibration Procedure............................6-5
- 6.3 Response Adjustment 6-6

7. Trouble-Shooting 7-1

- 7.1 General 7-1
- 7.2 Trouble-Shooting Guide 7-1

Index of Appendix

- A. FMA-200 Schematic A-1
- B. FMA-100 Schematic B-1
- C. FMA-100 Low Flow Exploded View, Mechanical C-1
- D. List of Bypasses and Orifice Sizes, Low Flow D-1
- E. Mounting Dimensions, Mass Flow Meters and Controllers...E-1
- F. Recommended Wire Gauges for Flow Meters and Controllers...F-1
- G. Conversion of Flow Rate to Other T and P Conditions G-1

1 Introduction

This manual covers operation and maintenance of the OMEGA® FMA-100 Mass Flow Controller and FMA-200 Mass Flow Meter. Read the sections on Specifications, Installation, Operation and Maintenance *before* attempting to operate the device.

Calibration of these instruments is performed on a primary standard calibration system. Sections pertaining to K-factors and Calibration are not essential reading, but may offer insight into how the instrument operates. If you are attempting to use a primary standard calibration device to re-calibrate your flow meter or controller yourself, an understanding of these sections will be essential.

A Trouble-Shooting Section is included to assist you with any difficulties either in the initial installation or maintenance of your instrument. Using this section will often save you time and effort, and lead you directly to the problem. If it does become necessary to contact us, having read the Trouble-Shooting Section prior to the call will facilitate our communication.

NOTE

We do not recommend the use of a transfer standard method of calibration with any of these instruments, as this will make an accurate calibration of less than 1% (of full scale) technically impossible. For the device to operate at peak performance, it must be calibrated on a primary standard.

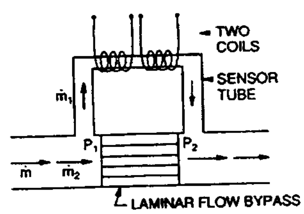
1.1 Purpose

The FMA-100 and FMA-200 are designed for the measurement and control of gas mass flow. These flow meters and controllers rely on a large diameter thermal mass flow sensor which is virtually clog-proof. The unique straight sensor tube has access ports at either end, permitting easy cleaning. All wetted surfaces are constructed of 316 stainless steel. Viton seals are standard. Controllers incorporate an electromagnetic proportional control valve.

These instruments utilize precision analog circuitry with a five breakpoint linearizer, providing highly accurate calibration specifications. Available in a card-edge configuration, the FMA-100 and FMA-200 series has proven it can operate in a variety of exacting and extreme conditions.

1.2 Principle of Operation

The operating principle of the FMA-100/200 is based on heat transfer and the first law of thermodynamics. The process gas enters the instrument's flow body and divides into two flow paths, one through the sensor tube, the other through the laminar flow element.



$$\dot{m} = \dot{m}_1 + \dot{m}_2$$
$$\dot{m} = \dot{m}_1 (1 + \dot{m}_2/\dot{m}_1) = k\,\dot{m}_1$$

Figure 1-1 Flow Paths

Here, a pressure drop P_1-P_2 is created, forcing a small fraction of the total flow to pass through the sensor tube (m1), which is then monitored. A straight sensor tube is mounted on the side of the laminar flow path.

Two resistance temperature detector (RTD) coils around the sensor tube direct a constant amount of heat (H) into the gas stream.

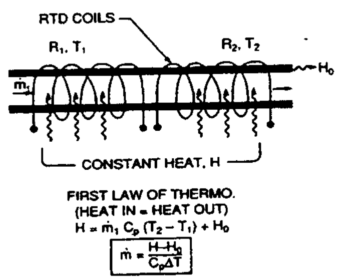


Figure 1-2 Measuring Sensor Flow

In actual operation, the gas mass flow carries heat from the upstream coil to the downstream coil. The resulting temperature difference (ΔT) is detected by the RTD coils.

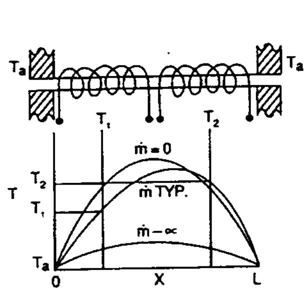


Figure 1-3 Sensor Temperature Distribution

Figures 1-2 and 1-3 show the mass flow through the sensor tube as inversely proportional to the temperature difference of the coils. The coils are legs of a bridge circuit with an output voltage in direct proportion to the difference in the coils' resistance; the result is the temperature difference (ΔT). Two other parameters, heat input (H) and coefficient of specific heat (C_p) are both constant. Although the output is not intrinsically linear with mass flow, as is often claimed, it is nearly linear over the normal operating range. The FMA-100/200 provides precision circuitry with a five breakpoint linearizer to assure a 0.5% full scale linearity specification.

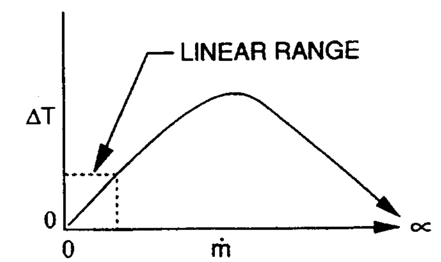


Figure 1-4 Output Signal

In the case of a mass flow controller, once the gas flows through the monitoring section, it is then controlled by the built-in servo-control valve, a proprietary high-efficiency electromagnetic valve. The normally closed valve is similar to an on/off solenoid valve, except that the current to the valve coil—and hence the magnetic field—is modulated so that the ferromagnetic valve armature (or valve plug) assumes the exact height above the valve's orifice required to maintain the valve's command flow. The result is nearly infinite resolution. All controllers can be provided with a 'Soft-Start' option for those processes that require it.

1.3 Specifications

(All specifications are subject to change without notice, due to continuous improvements in design and manufacture.)

1.3.1 FMA-200 Mass Flow Meters

Flow Ranges [1]

Low Flow Body	0-10 SCCM to 0-10 SLM[2]

Gases

Specify when ordering.

Output Signal

Linear 0-5 Vdc standard; 1000 ohms minimum load resistance

Input Power

FMA-200 Transducer:	+15 Vdc at 80 mA, 1.2 Watts; -15 Vdc at 10 mA, 0.15 Watts

Accuracy

±1% of full scale including linearity over 15-25°C and 10-60 psia (0.70 to 2.8 kg/cm^2); ±2% of full scale including linearity over 5-50°C and 5-150 psia (0.35 to 10 kg/cm^2), special calibration with ±1% full scale accuracy at a specific temperature and pressure is available

Repeatability

±0.2% of full scale

Temperature Coefficient

0.1% of full scale per 1°C, or better

Pressure Coefficient

0.1% of full scale per 1 psi (0.07 kg/cm^2), or better

Response Time

300 ms time constant; 1 second (typical) to within ±2% of final value over 25 to 100% of full scale

Pressure Drop

0.08 psi (0.006 kg/cm², 6 cm of water) differential maximum

Gas Pressure

500 psi (35 kg/cm²) gauge maximum; 30 psi (2 kg/cm²) gauge optimum.

Leak Integrity

5 x 10^{-9} SCCS helium maximum to outside environment

Temperature Range

5 to 50°C, gas and ambient

Wetted Materials

316 stainless steel; Viton O-rings standard; Neoprene and 4079 Kal-Rez O-rings optional, others on special order

Gas Fittings

Swagelok, in 1/4", 3/8", 1/2" sizes

Net Weight

1.41 lb (3.11 kg)

(1) Flow ranges specified are for an equivalent flow of N_2 at 760 mm Hg and 21.1°C or 70°F.

(2) For certain gases only. Confirm with factory.

Trademarks: Viton, Neoprene, Kal-Rez–E.I. DuPont de Nemours and Co.; Swagelok, VCO, VCR-Crawford Fitting Co.

1.3.2 Model FMA-100 Mass Flow Controllers

Flow Ranges[1]

Low Flow Body 0-10 SCCM to 0-10 SLM[2]

Gases

Specify when ordering.

Output Signal

Linear 0-5 Vdc standard; 1000 ohms minimum load resistance

Input Power

FMA-100 Controller: +15 Vdc at 80 mA, 1.2 Watts and
-15 Vdc at 175 mA, 2.6 Watts

Accuracy

±1% of full scale including linearity over 15-25°C and 10-60 psia (0.70 to 2.8 kg/cm²); ±2% of full scale including linearity over 5-50°C and 5-150 psia (0.35 to 10 kg/cm²), special calibration with +1% full scale accuracy at a specific temperature and pressure is available

Repeatability

±0.2% of full scale

Temperature Coefficient

0.1% of full scale per 1°C, or better

Pressure Coefficient

0.01% of full scale per 1 psi (0.07 kg/cm²), or better

Response Time

300 ms time constant; 1 second (typical) to within ±2% of final value over 25 to 100% of full scale; 1.5 second time constant

ΔP Required

5-50 psi (0.35–3.5 kg/cm²) differential standard; 30 psi (2 kg/cm²) differential optimum

Gas Pressure

500 psi (35 kg/cm²) gauge maximum, 30 psi (2 kg/cm²) gauge optimum

Leak Integrity

5 x 10^{-9} SCCS helium maximum to outside environment

Temperature Range

5 to 50°C, gas and ambient

Wetted Materials

316 stainless steel; Viton O-rings and valve seats standard; Neoprene and 4079 Kal-Rez optional; PFA Teflon valve seats optional; others on special order

Gas Fittings

Swagelok, in 1/4", 3/8", 1/2" sizes

Net Weight

2.00 lb (4.41 kg)

Control Valve Orifice Diameter

Low Flow Bodies: 0.010, 0.020, 0.040, 0.055, 0.063, 0.073, 0.094, 0.125 in.

Command Signal

0.5 Vdc; greater than 20 Megohms input impedance

Control Range

2-100% of full scale; auto shut-off below 2% (other shut off values available); shut off circuit may be disabled (consult factory)

Valve Leak Rate

1×10^{-4} SCCS helium maximum

(1) Flow ranges specified are for an equivalent flow of N_2 at 760 mm Hg and 21.1°C or 70°F.

(2) For certain gases only. Confirm with factory.

Trademarks: Viton, Neoprene, Kal-Rez–E.I. Dupont de Nemours and Co.; Swagelok, VCO, VCR–Crawford Fitting Co.

Notes

2 Installation

2.1 Mechanical Installation

To ensure a successful installation, inlet and outlet tubing should be in a clean state prior to plumbing the transducer into the system. The shipping caps covering the inlet/outlet fittings should not be removed until immediately prior to installation.

Do not locate the transducer in areas subject to sudden temperature changes, drafts, or near equipment radiating significant amounts of heat. Allow adequate space for cable connectors and wiring. **Be sure the arrow on the side of the transducer points in the direction of flow.** If the flow meter or controller is to be mounted in any position other than horizontal and was not calibrated specifically for your application, the transducer will require a zero adjustment for proper operation. Contact OMEGA for instructions on how to proceed, or follow zero adjust in Section 6.1.

2.2 Plumbing Connections

Flow meters and controllers using the Low Flow Body have specially constructed inlet fittings containing a filter screen and threads for mounting the laminar flow element. These fittings should not be removed or exchanged unless the transducer is to be cleaned and re-calibrated. See Figure 2-1.

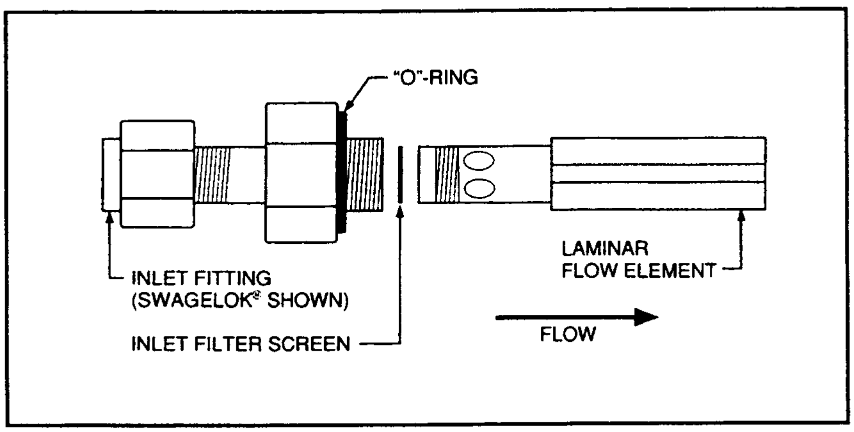


Figure 2-1 Low Flow LFE

Transducers are supplied with 1/4" compression fittings. For the first installation of 1/4" to 1" (6 mm to 25 mm) Swagelok fittings:

1. Insert the tubing into the fitting. Make sure that the tubing rests firmly on the shoulder of the fitting and that the nut is finger tight.

2. Scribe the nut at the 6 o'clock position. While holding the fitting body steady with a backup wrench, tighten the nut 1-1/4 turns, watching the scribe mark make one complete revolution and continue to the 9 o'clock position. For 1/16", 1/8" and 3/16" (2, 3 and 4 mm) sizes, tighten 3/4 turn from finger tight. After initial installation, reconnect fittings using a wrench so that the nut seats tightly against the fitting.

CAUTION

Do not mix or interchange parts of tube fittings made by different manufacturers.

3. Finally, check the system's entire flow path thoroughly for leaks before proceeding to the Operations Section.

WARNING

If the gas contains any particulate matter, an in-line filter is recommended. When installing flow controllers, there can be *no restrictions* (such as valves, tubing or piping internal diameters, reducers, etc.) *upstream or downstream of the FMA-100 less than the valve orifice diameter.* Failure to comply with this requirement will result in severely impaired performance and possible oscillations in flow controllers.

CAUTION

All instruments are leak-tested prior to shipping. To check your installation, test fittings only. If liquid enters the sensor compartment or flow body, your warranty may be found invalid.

Flow Ranges Relative to N_2	Minimum Restriction Diameter (Valve Orifice Diameter), Inches
Electromagnetic Valves:	
0-10 to 0-1000 SCCM	0.020
0-2 to 0.5 SLM	0.040
0-10 SLM	0.040

2.3 Electrical Connections

Meters and controllers require a +15 Vdc and a -15 Vdc power supply and a readout device. Additionally, controllers require a 0-5 Vdc setpoint input.

Meters and controllers are connected to the power supply, setpoint control and readout signals through a 20-pin card-edge connector.

Many installations will include a power supply/readout display (with front-panel mounted setpoint controls when required). This insures a high quality, integrated system for flow monitoring and control. Moreover, all functions will be easily accessible to you, providing you with the most versatile system available.

CASE	1	A	SET
COM	2	B	COM
VOUT	3	C	COM
+15	4	D	TEST
V REF	6	F	–15
	7	G	
+15	8	H	
4-20	9	I	
COM	10	J	OFF

Figure 2-2 Pin Assignments

0-5Vdc

2.3.1 20-Pin Edge Card Connector Pin Assignments

PIN NO.	DESCRIPTION
1	Chassis Ground
2	Common/Output Low
3	Output High
4	+15 Vdc Supply
5	No Connection
6	+5 Vdc for Local setpoint
7	Not Available-Connector Key
8	+15 Vdc Supply
9	**No Connection**
10	Common
A	Command Setpoint Input (0-5 Vdc)
B	Common
C	Common
D	Valve Test Point (Electromagnetic Valve) Purge
E	**No Connection**
F	-15 Vdc Supply
G	Not Available-Connector Key
H	**No Connection**
I	**No Connection**
J	Valve Off what valve (like an emergency switch manually shut off) See page 3-4 3.2.3

Voltage input as a setpoint
0 or 4 volts

Notes

3 Operation

3.0.1 Over-Range Indication

Once the transducer has been installed and the system has undergone a complete leak check, apply power and allow at least 15 minutes of warm-up time prior to use.

NOTE

When power is first applied, the output signal from the transducer will remain fixed at a much higher than normal level until the sensor warms up to its normal range of operating temperature. When the sensor reaches its minimum operating temperature, the output signal will resume a normal zero reading. See Section 3.0.2 for further details.

Once the sensor has been allowed to properly warm up, the transducer is ready for operation. Since the output signal is linear, flow can be read directly. The normal response time of a transducer is 1 second to within 2% of final value.

In systems using mass flow meters, where it is possible for overflow conditions to occur, insert a valve or critical orifice in the line to limit the flow to approximately 25% above the full scale range of the meter. Doing this greatly decreases the recovery time from overflow conditions.

3.0.2 Cold Sensor Lockout Circuit

The mass flow meter and the mass flow controller incorporate an over-range circuit. In the case of a controller, if a fault condition is detected that could result in uncontrolled flow (with the valve wide open), the safety circuit will automatically close the valve. The circuit operates by monitoring the temperature of the sensor elements and forcing the output signal to a fixed high level when temperature falls below a preset limit. There are several conditions under which this could occur:

- Operation at a temperature below that for which the instrument is rated

- Power failure while running at or near full scale. Upon resumption of power, the valve will remain closed until minimum operating temperature is again reached.
- Sensor failure

The operation of this circuit can be verified by observing the signal output during power up. In some instances, this circuit may be undesirable. The cold sensor lock-out circuit and/or over-range indicator can be disabled by removing CR1 from the main circuit board (refer to Appendices A, B and C).

3.1 Output Options, Meters and Controllers

Standard output for FMA-100/200 meters and controllers is a 0-5 Vdc signal, which directly corresponds to the 0-100% mass flow full scale range.

3.2 Control Operation

3.2.1 Setpoint Input Signal

The setpoint input signal is a direct linear representation of 0-100% of the mass flow full scale value. (A 0 Vdc setpoint will cause a condition of 0% flow to occur and a 5.00 Vdc setpoint will cause a flow condition equivalent to 100% of flow to occur.)

When the command (setpoint) signal is applied, the flow controller will respond to changes in the setpoint in 1 second to within 2% of final value. The standard setpoint command is 0-5 Vdc.

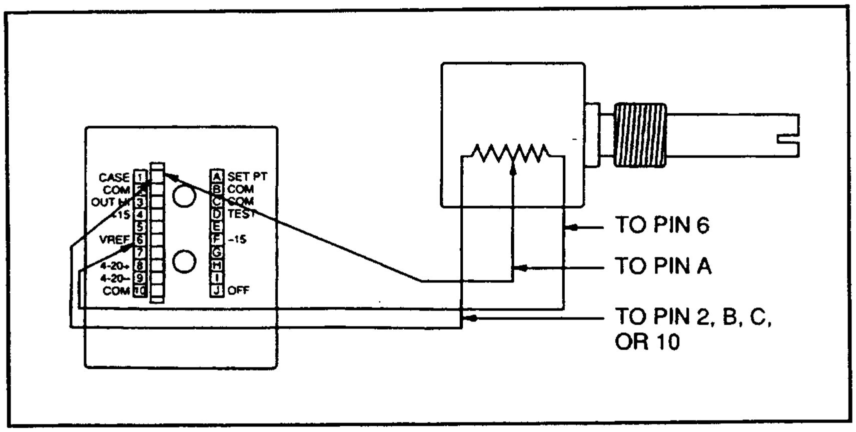


Figure 3.1 Local Setpoint Potentiometer

3.2.1.1 Local Setpoint Potentiometer

A highly regulated +5 Vdc output signal is available at Pin 6 of the 20-pin card-edge connector for the connection of a local (stand alone) setpoint potentiometer.

Any potentiometer value between 5K and 100K may be used. One leg of the potentiometer is connected to the +5 Vdc reference (VREF), the other leg is connected to common (Pin B), and the wiper of the potentiometer is connected to the setpoint input (Pin A).

NOTE

If the setpoint input is not connected to some type of command control device, the valve on/off switch must be activated in the off position. If no setpoint command is present on a controller when powered-up and the valve is not switched off, the valve will drift wide open.

3.2.2 Auto Shut-Off

All flow controllers are normally provided with an Auto Shut-Off feature that will close the valve at a command signal level of 2% of full scale, or less.

3.2.3 Valve Off, TTL Compatible (Pin J) Electromagnetic Valves

For all models equipped with an electromagnetic valve, on/off control is provided via a TTL level switch. This option can be utilized manually by connecting an on/off switch between Pins 10 and J of the 20-Pin card-edge connector. Normal operation resumes when Pin J is brought high or left floating.

3.2.4 Valve Monitor Purge Function (Pin D)

During normal operation, the mass flow controller's valve voltage can be monitored by connecting a voltmeter between Pin D and Pin F of the 20-Pin card-edge connector. The voltage at Pin D is normally negative. The valve purge function will be activated when Pin D is connected to ground. When this occurs, the valve is driven fully open regardless of the setpoint input. Furthermore, the purge function will override any valve-off function.

Purging non-reactive gases:

Purge the FMA-100/200 with clean, dry nitrogen or argon for a minimum of 2 hours.

Purging reactive gases:

One of the following methods may be used:

Cycle purge. This is done by alternately evacuating and purging the FMA-100/200 for 2 to 4 hours with clean, dry nitrogen or argon.

or

Purge the FMA-100/200 with clean, dry nitrogen or argon for 8 to 24 hours

or

Evacuate the FMA-100/200 for 8 to 24 hours.

4 K-Factors and Gas Tables

The following tables provide K-factors and thermodynamic properties of gases commonly used with mass flow controllers and meters. The purpose of these tables is two-fold:

4.1 For a Single Gas

- Calibrating an "actual" gas with a reference gas. This is particularly useful if the actual gas is not a common gas or if it is toxic, flammable, corrosive, etc.
- Interpreting the reading of a flow meter or flow controller which has been calibrated with a gas other than the actual gas.

In applying the tables, the following fundamental relationship is used:

$$Q_1/Q_2 = K_1/K_2 \tag{1}$$

Where:

Q = The volumetric flow rate of the gas referenced to standard conditions of 0°C and 760 mm Hg (SCCM or SLM),

K = The "D" factor defined in equation (6) below,

$(\,)_1$ = Refers to the "actual" gas, and

$(\,)_2$ = Refers to the "reference" gas.

The K-factor is derived from the first law of thermodynamics applied to the sensor tube, as described in Figure 1.2, page 3:

$$H = \frac{\dot{m}\, C_p \Delta T}{N} \tag{2}$$

Where:

H = The constant amount of heat applied to the sensor tube,

$\dot{m}$ = The mass flow rate of the gas (gm/min),

C_p = The coefficient of specific heat of the gas (Cal/gm); C_p is given in the Table (at 0°C),

ΔT = The temperature difference between the downstream and upstream coils, and

N = A correction factor for the molecular structure of the gas given by the following table:

Flow Ranges Relative to N_2	Minimum Restriction Diameter (Valve Orifice Diameter), Inches
Electromagnetic Valves:	
0-10 to 0-1000 SCCM	0.020
0-2 to 0.5 SLM	0.040
0-10 SLM	0.040

The mass flow rate, $\dot{m}$, can also be written as:

$$\dot{m} = \rho Q \tag{3}$$

Where:

ρ = the gas mass density at standard conditions (g/l); ρ is given in the tables (at 0°C, 760 mm Hg).

Furthermore, the temperature difference, ΔT, is proportional to the output voltage, E, of the mass flow meter, or:

$$\Delta T = aE \tag{4}$$

Where:

a = A constant.

If we combine equations (3) and (4), insert into equation (2), and solve for Q, we get:

$$Q = (bN/\rho C_p) \tag{5}$$

Where:

b = H/aE = a constant if the output voltage is constant.

For our purposes, we want the ratio of the flow rate, Q_1, for an actual gas to the flow rate of a reference gas, Q_2, which will produce the same output voltage in a particular mass flow meter or controller.

We get this by combining equations (1) and (5):

$$Q_1/Q_2 = K_1/K_2 = (N_1/\rho_1 C_{p1})(N_2/\rho_2 C_{p2}) \qquad (6)$$

Please note that the constant B cancels out. Equation (6) is the fundamental relationship used in the accompanying tables. For convenience, the tables give "relative" K-factors, which are the ratios K_1/K_2, instead of the K-factors themselves.

In the third column of the tables, the relative K-factor is $K_{actual}/K_{reference}$, where the reference gas is a gas very close molecularly to the actual gas. In the fourth column, the relative K-factor is K_{actual}/KN_2 where the reference gas is the commonly used gas, nitrogen (N_2). The remaining columns give C_p and ρ, enabling you to calculate K_1/K_2 directly using Equation (6). In some instances, K_1/K_2 from the tables may be different from that which you calculate directly. The value from the tables is preferred because in many cases it was obtained by experiment.

Each OMEGA FMA-100/200 mass flow meter and controller is calibrated with primary standards using the actual gas or a molecularly equivalent reference gas. The calibration certificate accompanying your instrument will cite the reference gas used.

Example 1

An FMA-100/200 is calibrated for nitrogen (N_2), and the flow rate is 1000 SCCM for a 5.000 Vdc output signal. The flow rate for carbon dioxide at a 5.000 Vdc output is:

$$Q_{CO2}/Q_{N1} = K_{CO2}/K_{N2}, \text{ or}$$

$$Q_{CO2} = (0.74/1.000)1000 = 740 \text{ SCCM}$$

Example 2

An FMA-100/200 is calibrated for hydrogen (H_2), and the flow rate is 100 SCCM for a 5.000 Vdc output signal. The flow rate for nitrous oxide (N_2O) is found as follows:

$$Q_{N2O}/Q_{H2} = K_{N2O}/K_{H2}, \text{ or}$$

$$Q_{N2O} = (0.71/1.101)\ 100 = 70.3 \text{ SCCM}$$

Note that the K-factors relative to nitrogen must be used in each case.

Example 3

We want an FMA-100/200 to be calibrated for use with dichlorosilane (SiH_2CL_2) at a 100 SCCM full scale flow. We wish to use the preferred reference gas Freon-14 (CF_4). What flow of CF_4 must we generate to do the calibration?

$$Q_{SiH2CL2}/Q_{CF4} = K_{SiH2CL2}/K_{CF4}$$

$$100/Q_{CF4} = 0.869$$

$$Q_{CF4}=100/0.869 = 115 \text{ SCCM}$$

4.2 For Dual-Gas Mixtures

Equation (6) is used for gas mixtures, but we must calculate $N/\rho\ C_p$ for the mixture. The equivalent values of ρ, C_p, and N for a dual gas mixture are given as follows:

The equivalent gas density is:

$$\rho = (\dot{m} / \dot{m}_T)\ \rho_1 + (\dot{m}_2 / \dot{m}_T)\ \rho_2$$

Where:

$\dot{m}_T=$	$\dot{m}_1 + \dot{m}_2$ = Total mass flow rate (gm/min),
$(\ )_1 =$	Refers to gas #1, and
$(\ )_2 =$	Refers to gas #2.

The equivalent specific heat is:

$$C_P = F_1C_{p1} + F_2C_{p2}$$

Where:

$$F_1 = (\dot{m}_1 \rho_1)/(\dot{m}_T \rho) \text{ and}$$

$$F_2 = (\dot{m}_2 \rho_2)/(\dot{m}_T \rho).$$

The equivalent value of N is:

$$N = (\dot{m}_1 / \dot{m}_T) N_1 + (\dot{m}_2 / \dot{m}_T) N_2$$

The equivalency relationships for ρ, C_P, and N for mixtures of more than two gases have a form similar to the dual-gas relationship given above.

CAUTION

Please note that if you have a mass flow meter calibrated for a gas such as methane and wish to use the K-factors to measure a gas such as air, that the inaccuracy of the measurement can range from ±5 to 10%. The use of K-factors is, at best, only a rough approximation and should not be used in applications that require better than ±5 to 10% accuracies.

Also certain gases, in similar "families" will work exceptionally well with K-factors; however, those instances are only true when similar thermal properties of the gas are present.

Actual Gas	Ref. Gas	KFactor Rel. to Ref. Gas	KFactor Relative N2	Cp (Cal/g)	Density (g/ℓ) @ 0°C	Elastomer O-Ring*	Elastomer Valve Seat
Acetylene C_2H_2	C_2H_4	.973	.58	.4036	1.162		
Air	N_2	1.00	1.00	.240	1.293		
Allene (Propadiene) C_3H_4	$CHClF_2$	.934	.43	.352	1.787		KR
Ammonia NH_3	N_2O	1.028	.73	.492	.760	NEO	NEO
Argon Ar	Ar	1.000	1.45	.1244	1.782		
Arsine AsH_3	N_2O	.943	.67	.1167	3.478		KR
Boron Trichloride BCl_3	$CHClF_2$	.891	.41	.1279	5.227	KR	KR
Boron Trifluoride BF_3	$CHClF_2$	1.108	.51	.1778	3.025		KR
Bromine Br_2	N_2O	1.140	.81	.0539	7.130		
Boron Tribromide Br_3	$CHClF_2$	.826	.38	.0647	11.18		KR
Bromine Pentafluoride BrF_5	$CHClF_2$	.565	.26	.1369	7.803		KR
Bromine Trifluoride BrF_3	$CHClF_2$	.826	.38	.1161	6.108		KR
Bromotrifloromethane (Freon-13 B1) $CBrF_3$	$CHClF_2$	.804	.37	.1113	6.644		
1,3-Butadiene C_4H_6	$CHClF_2$	.695	.32	.3514	2.413		
Butane C_4H_{10}	$CHClF_2$	.565	.26	.4007	2.593	NEO	KR
1-Butane C_4H_8	$CHClF_2$	.652	.30	.3648	.2.503	NEO	KR
2-Butane C_4H_8 CIS	$CHClF_2$	.704	.324	.336	2.503	NEO	KR
2-Butane C_4H_8 TRANS	$CHClF_2$	.632	.291	.374	2.503		
Carbon Dioxide CO_2	N_2O	1.042	.74	.2016	1.964		
Carbon Disulfide CS_2	C_2H_4	1.007	.60	.1428	3.397		
Carbon Monoxide CO	N_2	1.000	1.00	.2488	1.250		
Carbon TetrachlorideCCl_4	$CHClF_2$	.673	.31	.1655	6.860		KR
Carbon Tetrafluoride (Freon-14) CF_4	$CHClF_2$	1.000	.42	.1654	3.926		KR
Carbonyl Fluoride COF_2	C_2H_4	.907	.54	.1710	2.945		
Carbonyl Sulfide COS	N_2O	.929	.66	.1651	2.680		
Chlorine CL_2	N_2	.860	.86	.114	3.163		KR
Chlorine Trifluoride ClF_3	$CHClF_2$	.869	.40	.1650	4.125		KR
Chlorodifluoromethane (Freon-22) $CHClF_2$	$CHClF_2$	1.000	.46	.1544	3.858		KR
Chloroform $CHCl_3$	$CHClF_2$	.847	.39	.1309	5.326		KR
Chloropentafluoroethane (Freon-115) C_2ClF_5	$CHClF_2$	.521	.24	.164	6.892		KR
Chlorotrifluromethane (Freon-13) $CClF_3$	$CHClF_2$	.826	.38	.153	4.660		KR
Cyanogen C_2N_2	C_2H_4	.7526	.61	.2613	2.322		
Cyanogen Chloride ClCN	C_2H_2	1.024	.61	.1739	2.742		KR
Cychlopropane C_3H_5	$CHClF_2$	1.00	.46	.3177	1.877		KR
Deuterium D_2	N_2	1.00	1.00	.1722	1.799		
Diborane B_2H_6	$CHClF_2$	.956	.44	.508	1.235		KR
Dibromodifluoromethane	$CHClF_2$	.413	.19	.15	9.362		KR
CBr_2F_2	$CHClF_2$	1.021	.47	.075	7.76		KR
Dichlorodifluoromethane (Freon-12) CCl_2F_2	$CHClF_2$	.760	.35	.1432	5.395		KR
Dichlorofluoromethane (Freon-21) $CHCl_2F$	$CHClF_2$	.913	.42	.140	4.952		KR
Dichloromethylsilane $(CH3)_2SiCl_2$	$CHClF_2$	.543	.25	.1882	5.758		KR
Dichlorosilane SiH_2Cl_2	$CHClF_2$	.869	.40	.150	4.506		KR
Dichlorotetrafluoroethane (Freon-114) $C_2Cl_2F_4$	$CHClF_2$	.478	.22	.1604	7.626		KR
1,1-Difluoroethylene (Freon-1132A) $C_2H_2F_2$	$CHClF_2$	.934	.43	.224	2.857		KR

Actual Gas	Ref. Gas	KFactor Ref. to Ref. Gas	KFactor Relative N2	Cp (Cal/g)	Density (g/ℓ) @ 0°C	Elastomer O-Ring*	Valve Seat
Dimethylamine $(CH_3)_2NH$	$CHClF_2$	.804	.37	.366	2.011		KR
Dimeyl Ether $(CH_3)_2O$	$CHClF_2$	.847	.39	.3414	2.055		KR
2,2-Dimethylpropane C_5H_{12}	$CHClF_2$	.423	.22	.3914	3.219		KR
Ethane C_2H_6	$CHClF_2$	1.086	.50	.4097	1.342		
Ethanol C_2H_6O	$CHClF_2$	.856	.39	.3395	2.055		KR
EthylAcetylene C_4H_6	$CHClF_2$	.703	.32	.3513	2.413		KR
Ethyl Chloride C_2H_5Cl	$CHClF_2$	.84	.39	.244	2.879		KR
Ethylene C_2H_4	C_2H_4	1.000	.60	.1365	1.251		
Ethylene Oxide $C_2H_4)$	$CHClF_2$	1.130	.52	.268	1.965		KR
Fluorine F_2	N_2	.980	.98	.1873	1.695		KR
Fluoroform (Freon-23) CHF_3	$CHClF_2$	1.086	.50	.176	3.127		KR
Freon-11 CCl_3F	$CHClF_2$	.717	.33	.1357	6.129		KR
Freon-12 CCl_2F_2	$CHClF_2$	.760	.35	.1432	5.395		KR
Freon-13 $CClF_3$	$CHClF_2$	.826	.38	.153	4.660		KR
Freon-13 B1 $CFrF_3$	$CHClF_2$	.804	.37	.1113	6.644		KR
Freon-14 CF_4	$CHClF_2$	1.000	.42	.1654	3.926		
Freon-21 $CHCl_2F$	$CHClF_2$	.913	.42	.140	4.952		KR
Freon-22 $CHClF_2$	$CHClF_2$	1.000	.46	.1544	3.858		KR
Freon-113 CCl_2FCClF_2	$CHClF_2$	.434	.20	.161	8.360		KR
Freon-114 $C_2Cl_2F_4$	$CHClF_2$	.478	.22	.160	7.626		KR
Freon-115 C_2ClF_5	$CHClF_2$	.521	.24	.164	6.892		KR
Freon-C318 C_4F_8	$CHClF_2$	.369	.17	.185	8.397		KR
Germane GeH_4	C_2H_4	.950	.57	.1404	3.418		
Germanium Tetrachloride $GeCL_4$	$CHClF_2$	.586	.27	.1071	9.565		KR
Helium He	He	1.000	1.454	1.241	.1786		
Hexafluoroethane C_2F_6 (Freon-116)	$CHClF_2$	.521	.24	.1834	6.157		KR
Hexane C_6H_{14}	$CHClF_2$	.391	.18	.3968	3.845		KR
Hydrogen H_2	H_2	1.000	1.01	3.419	.0899		
Hydrogen Bromide HBr	N_2	1.000	1.00	.0861	3.610		KR
Hydrogen Chloride HCl	N_2	1.000	1.00	.1912	1.627	KR	KR
H MOS	N_2	1.000	1.00				KR
Hydrogen Cyanide HCN	N_2	1.070	.76	.3171	1.206		KR
Hydrogen Fluoride HG	N_2	1.000	1.00	.3479	.893	KR	KR
Hydrogen Iodide HI	N_2	1.000	1.00	.0545	5.707		KR
Hydrogen Selenide H_2Se	N_2O	1.112	.79	.1025	3.613		KR
Hydrogen Sulfide H_2S	N_2O	1.126	.80	.2397	1.520		KR
Iodine Pentafluoride IF_5	$CHClF_2$	.543	.25	.1108	9.90		KR
Isobutane $CH(CH_3)_3$	$CHClF_2$	.586	.27	.3872	2.67		KR
Isobutylene C_4H_8	$CHClF_2$	.630	.29	.3701	2.503		KR
Krypton Kr	Ar	1.002	1.453	.0593	3.739		
Methane CH_4	N_2O	1.014	.72	.5328	.715		
Methanol CH_3OH	C_2H_4	.976	.58	.3274	1.429		
Methyl Acetylene C_3H_4	$CHClF_2$	.94	.43	.3547	1.787		KR
Methyl Bromide CH_2Br	C_2H_4	.966	.58	.1106	4.236		
Methyl Chloride CH_3Cl	C_2H_4	1.050	.63	.1926	2.253		KR
Methyl Fluoride CH_3F	C_2H_4	.957	.68	.3221	1.518		KR
Methyl Mercaptan CH_3SH	$CHClF_2$	1.130	.52	.2459	2.146		KR
Methyl Trichlorosilane $(CH_3)\ SiCl_3$	$CHClF_2$	.543	.25	.164	6.669		KR
Molybdenum Hexafluoride MoF_6	$CHClF_2$	.456	.21	.1373	9.366		KR
Monoethylamine $C_2H_5NH_2$	$CHClF_2$	.760	.35	.387	2.011		KR
Monomethylamine CH_3NH_2	$CHClF_2$	.850	.51	.4343	1.386		KR

Actual Gas	Ref. Gas	KFactor Rel. to Ref. Gas	KFactor Relative N2	Cp (Cal/g)	Density (g/ℓ) @ 0°C	Elastomer O-Ring*	Elastomer Valve Seat
Neon NE	Ar	1.006	1.46	.246	.900		
Nitric Oxide NO	N_2	.990	.99	.2328	1.339		
Nitrogen N_2	N_2	1.000	1.00	.2485	1.25		
Nitrogen Dioxide NO_2	N_20	1.042	.74	.1933	2.052		
Nitrogen Trifluoride NF_3	$CHClF_2$	1.043	.48	.1797	3.168		KR
Nitrosyl Chloride NOCl	C_2H_4	1.016	.61	.1632	2.920		KR
Nitrous Oxide N_2O	N_2O	1.000	.71	.2088	1.964		
Octafluorocyclobutane (Freon-C318) C_4F_8	$CHClF_2$	.369	.17	.185	8.397		KR
Oxygen Difluoride OF_2	C_2H_4	1.050	.63	.1917	2.406		
Oxygen O_2	N_2	1.000	1.00	.2193	1.427		
Ozone O_3	N_2	.446	.446	.3	2.144		
Pentaborane B_5H_9	$CHClF_2$	.565	.26	.38	2.816		KR
Pentane C_5HI_2	$CHClF_2$	.456	.21	.398	3.219		KR
Perchloryl FluorideClO_3F	$CHClF_2$	.847	.39	.1514	4.571		KR
Perfluoropropane C_3F_8	$CHClF_2$	.369	.174	.197	8.388		KR
Phosgene $COCl_2$	$CHClF_2$	.956	.44	.1394	4.418		KR
Phosphine PH_3	N_2O	1.070	.76	.2374	1.517		KR
Phosphorous Oxychloride $POCl_3$	$CHClF_2$	.782	.36	.1324	6.843		KR
Phosphorous Pentafluoride PH_5	$CHClF_2$	.652	.30	.1610	5.620		KR
Phosphorous Trichloride PCl_3	$CHClF_2$	.652	.30	.1250	6.127		KR
Propane C_3H_8	$CHClF_2$	.782	.36	.3885	1.967		KR
Propylene C_3H_6	$CHClF_2$	.891	.41	.3541	1.877		KR
Silane SiH_4	C_2H_4	1.000	.60	.3189	1.433		KR
Silicon Tetrachloride $SiCl_4$	$CHClF_2$	.608	.28	.1270	7.580		KR
Silicon Tetrafluoride SiF_4	$CHClF_2$	.760	.35	.1691	4.643		KR
Sulfur Dioxide So_2	N_20	.900	.69	.1488	2.858	EPDM	KR
Sulfur Hexafluoride SF_6	$CHClF_2$	.565	.26	.1592	6.516		KR
Sulfuryl Fluoride SO_2F_2	$CHClF_2$	.847	.39	.1543	4.562		KR
Teos	N_2	.090	.090			KR	KR
Tetrafluorahydrazine N_2F_4	$CHClF_2$	.695	.32	.182	4.64		KR
Trichlorofluormethane (Freon-11)CCl_3F	$CHClF_2$	.717	.33	.1357	6.129		KR
Trichlorisilane $SiHCl_3$	$CHClF_2$	.717	.33	.1380	6.043		KR
1,1,2-Trichloro-1,2,2 Trifluorethane (Freon-113) CCl_2FCClF_2	$CHClF_2$	.434	.20	.161	8.360		KR
Trisobutyl Aluminum $(C_4H_9)Al$	$CHClF_2$	.132	.061	.508	8.848		KR
Titanium Tetrachloride $TiCl_4$	$CHClF_2$	.586	.27	.120	8.465		KR
Trichloro Ethylene C_2HCl_3	$CHClF_2$	.695	.32	.163	5.95		KR
Trimethylamine $(CH_3)_3N$	$CHClF_2$	.608	.28	.3710	2.639		KR
Tungsten Hexasfuoride WF_6	$CHClF_2$	.552	.25	.0810	13.28	KR	Teflon PFA
Uranium Hexafluoride UF_6	$CHClF_2$	.434	.20	.0888	15.70		KR
Vinyl Bromide CH_2CHBr	$CHClF_2$	1.000	.46	.1241	4.772		KR
Vinyl Chloride CH_2CHCl	$CHClF_2$	1.043	.48	.12054	2.788		KR
Xenon Xe	Ar	.993	1.44	.0378	5.858		

5 Maintenance

5.1 Electronics Maintenance

The electronic components in both the FMA-100 and FMA-200 essentially require no maintenance. If repair or recalibration is needed, return the instrument to OMEGA. This is usually the most cost effective and reliable means.

5.2 Flow Path Maintenance

The flow path of the FMA-100/200 is a 316 stainless steel (wetted magnetic parts of solenoid valve are 430F stainless steel) with Viton, Neoprene, or Kal-Rez seals. Inspect and clean flow path periodically as required.

WARNING

When toxic or corrosive gases are used, purge unit thoroughly with inert dry gas before disconnecting from gas line. Never return a gas mass flowmeter/controller to OMEGA or any other repair/calibration facility without fully neutralizing any toxic gases trapped inside. If the unit is to be returned to the factory and has been used with a toxic or corrosive gas, enclose a MSDS (Material Safety Data Sheet) with the unit upon its return. (Please see Section 3.2 for purge methods).

5.2.1 Laminar Flow Element

The laminar flow element (LFE) is a precision flow divider which diverts a preset amount of flow through the sensor tube. The LFE is made of precision machined 316 stainless steel. The particular LFE used depends on the gas and flow range of the instrument and is identified by the number scribed on its downstream end.

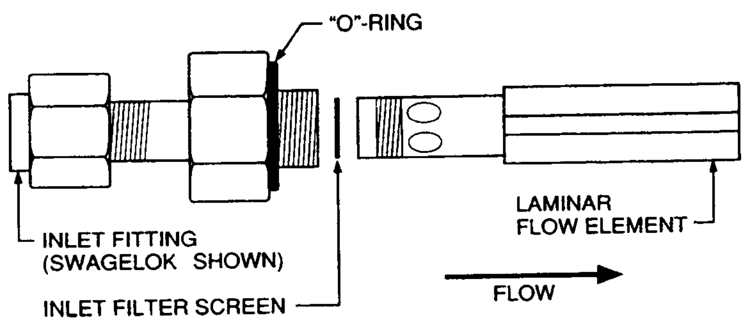


Figure 5-1 Low Flow LFE

Low Flow Body LFE—For low flow transducers, the LFE may be accessed by unscrewing the main inlet fitting and removing it from the flow body. The LFE is screwed into the inlet fitting, which has been specially machined for this purpose. An inlet filter screen is held in place in the inlet fitting by the LFE. Disassemble by holding the fitting steady with a wrench and unscrewing the LFE with a medium flat-tipped screwdriver.

5.2.2 Sensor Maintenance

The FMA-100/200 sensor tube is straight and has a relatively large 0.031" I.D., thus making inspection and cleaning much easier than the small-I.D., U-shaped sensor tubes commonly used in other flow controllers.

CAUTION

Do not remove the sensor compartment cover plate except for sensor or O-ring replacement; doing so can alter calibration.

Sensor maintenance consists of inspecting the sensor flow path and checking the sensor for proper electrical function.

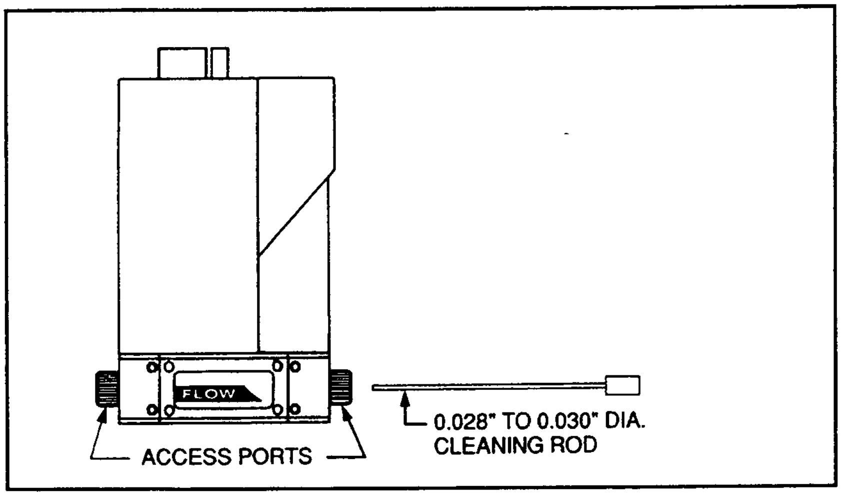


Figure 5.2 Sensor Cleaning Ports

To access the sensor for inspection or cleaning:

1. Remove the two socket head access port plugs with a $^1/_4$" Allen wrench. Visually inspect the sensing ports and sensor.
2. Rod out the sensor using a 0.020" to 0.028" diameter piece of piano wire. In cases where solids are deposited in the sensor, return the unit to the factory for complete cleaning and recalibration.
3. We recommend a final flush with Freon TF and drying with dry nitrogen.

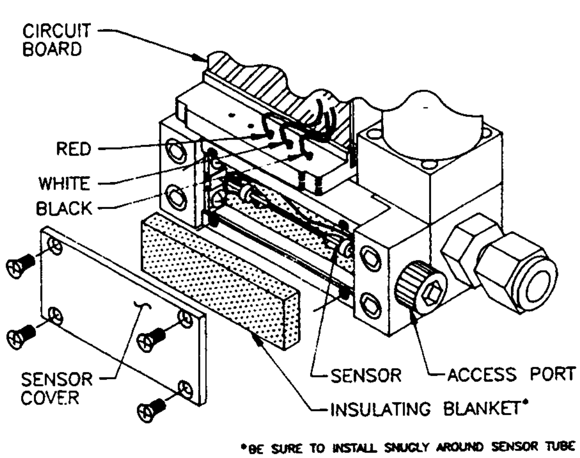


Figure 5-3 Sensor Compartment

To check the electrical integrity of the sensor windings:

1. Remove the two 4-40 Phillips head screws located on top of the electronics enclosure and slide the enclosure up and off.
2. Locate the black, red, and white wires connecting the sensor to the main circuit board. Connect one lead of an ohm meter to the white wire and measure the resistance between the red and white wires and the black and white wires. These readings should each be approximately 40 ohms. Low or zero ohms on either reading indicates a short circuit. High or infinite ohms readings indicates an open circuit.
3. Measure the resistance between the case (metal part of the flow body) and any one of the sensor wires. This reading should be two Megohms or greater. Incorrect readings will require sensor replacement and re-calibration.

5.2.3 Valve Maintenance

The FMA-100/200 electromagnetic valve requires no maintenance under normal operating conditions other than an occasional cleaning. Use of certain corrosive gases may require frequent replacement of the valve plug and O-rings. This indicates a need for a different elastomer. Viton is standard, with Neoprene, Kal-Rez, and PFA Teflon offered as options. Please contact OMEGA if you encounter media compatibility problems.

CAUTION

Do not attempt any valve adjustments while the meter is "on-line" with any dangerous gas. Thoroughly leak-test the FMA-100 following valve adjustment.

Low Flow Body Valve—Cleaning can often be accomplished by opening the valve, using the purge function and flushing in both directions. Alternatively, manually open the valve by loosening the 6-32 lock nut on top of the valve and turning the adjustment screw fully counterclockwise. Read the valve adjustment section in Section 6.0, Calibration.

Disassemble the electromagnetic valve as follows:

1. Refer to Appendix D, Model FMA-100 Exploded View, for help in locating valve parts.
2. To disassemble the low and medium flow valve, remove the two 4-40 Phillips head screws on top of the enclosure. Remove the enclosure by sliding it up and off.
3. Remove the metal cap on top of the valve by inserting a flat tip screwdriver into the slots provided and prying upward.

CAUTION

If the $5/8$" nut (item 27, page 49) is not plastic, call OMEGA at once for a free plastic replacement nut. Do not tighten the $5/8$" nut with more than 10 in lbs torque.

4. Using a $5/8$" nut driver, loosen and remove the $5/8$" nut at the top of the valve. Remove the coil, coil enclosure and warp washer. The small circuit board may be separated from the main one to ease removal of the coil. To separate, first remove the plastic #4 mounting screw located in the center of the main circuit board and carefully pull the two boards apart.
5. Remove the four 4-40 socket head cap screws at the base of the valve. Separate the valve from the flow body. There are three O-rings sealing the valve assembly: one between the base and the flow body, one under the valve seat (orifice), and one on the top adjusting screw inside the valve. Inspect the O-rings for damage and replace as necessary. It is good practice to replace all O-rings whenever the valve is disassembled.
6. Inspect the valve seat and plug for corrosion or roughness and replace as necessary. Re-assemble in reverse order of disassembly and leak check before placing the FMA-100 back in operation.

6 Calibration Procedure

Calibration of flow meters and controllers, in keeping with the requirements of Mil Std 45662-A, requires a calibration standard of at least four times better than the desired claimed accuracy. This leaves one to choose calibration devices with an accuracy of better than 0.25%. Most calibrations can be done using dry nitrogen and the "K" factor tables included in this manual.

The calibration procedure is essentially the same for both meters and controllers. Flow meters require a metering valve for setting a constant flow rate; controllers are calibrated while in the control mode.

In the following procedures, please refer to the Appendix.

6.1 FMA-200 Mass Flow Meter Calibration Procedure

Calibration checks and minor adjustments to the zero and span may be made via the access ports in the enclosure. To adjust linearity (such as when installing a different bypass to change range) go to Step 4.

1. **Warm Up:** Plug in the instrument to be calibrated and allow at least 30 minutes warm up time before attempting any adjustments.
2. **Zero Adjust:** Rotate to open the zero and span access doors. Using a voltmeter connected to the meter output pins, adjust the zero potentiometer (R5) for zero volts at zero flow (4 mA for 4-20 mA outputs).
3. **Check Full Scale:** Generate full scale flow using a metering valve in line with the unit under test. Compare the indicated flow rate with the flow standard reading. If they agree to within ±10%, adjust the span potentiometer (R10) for exact agreement. If the readings do not agree within ±10%, attempt to determine the cause of disagreement. Possibilities are:
   - Leaks in the system or in the flow meter
   - Wrong or improper use of "K" factor

- Wrong or improper correction for temperature and pressure
- Partially clogged or dirty sensor tube
- Replacement of parts in the flow signal path

This completes the calibration procedure. To adjust linearity, go to Step 4.

4. **Adjusting Linearity:** Remove the two black 4-40 Phillips head screws on the top of the meter enclosure near the edge connector. Pull the enclosure up and off the meter. Orient the meter so that the component side of the circuit board is facing you. Plug in the meter and allow to warm up for at least 30 minutes.
5. **Zero Adjust:** Connect a voltmeter to the meter output pins and adjust the zero potentiometer (R5) for zero volts at zero flow (4 mA for 4-20 mA outputs).
6. **Calibrate 25%:** Use the calibration standard to set a flow rate of 25% of full scale. Adjust R10 for 1.25 volts (8 mA outputs) at the output of the meter.
7. **Calibrate 50%:** Increase the flow rate to 50% of full scale. If the output is 2.5 volts ±25 mV or 12 mA ±0.08 mA, no adjustment is necessary. If the output is beyond these limits, adjust R23 for the proper reading. (See Figure 6-1)
8. **Calibrate 75% and 100%:** Set the flow to 75% of full scale. If the output is outside the limits set in Step 7, adjust R25 for the correct reading. Repeat this procedure for 100% flow using R27. Repeat Steps 6 through 8 at least one more time.

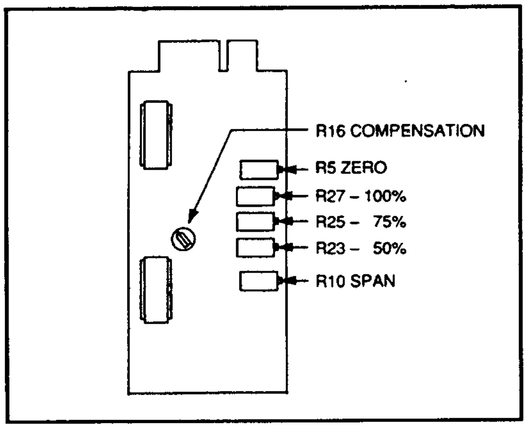


Figure 6-1 Potentiometer Location

6.2 FMA-100 Calibration Procedure

There are two ways a flow controller can be calibrated, depending on the type of calibration standard used. Transfer standards normally give a continuous real time readout of the flow rate. This allows calibration of a flow controller in a minimum amount of time. Transfer standards are not the most accurate calibrators available, but they are adequate in some cases.

Primary standards such as positive displacement piston-tubes and bubble meters are extremely accurate but have several disadvantages when manually operated. They are difficult to use, require manual temperature and pressure corrections, and give the flow readout after the fact. This presents a problem for flow controllers, since an unknown flow has to be measured, adjusted and measured again until the desired accuracy is achieved. The following procedures detail the steps necessary to calibrate an FMA-100 using each type of these standards.

NOTE

Inlet and outlet pressures must be set up to match actual operating conditions.

6.2.1 Piston Tube Calibration Procedure

1. **Disable Valve:** Open the electromagnetic valve by turning the valve adjustment screw counterclockwise until it stops. The mass flow controller can then be calibrated as a flow meter. Follow Steps 1 through 8, FMA-100 Calibration Procedure and then continue with Step 2 below.

2. **Adjust Valve:** (Complete Steps 1 through 8, FMA-100 Calibration Procedure, before beginning this step.)

   Generate a small flow through the mass flow controller and close the valve by turning the adjustment screw clockwise until the flow just stops. Connect a voltmeter negative lead to P_2 (-15) and positive lead to pin 8 of U_2 on the FMA-100 printed circuit. With an upstream pressure of 30 PSIG, apply a 0.50 volt setpoint and adjust the valve screw for 5.50 volts on the voltmeter. Apply a 5.00 volt setpoint and check that the valve voltage does not exceed 11.0 volts across P_1 and P_2. This value will vary depending on the full scale flow rate.

3. **Check Full Scale:** Adjust the setpoint for 5.00 volts and measure the flow rate. Adjust R_{10} if necessary and check full scale again.

NOTE

In the control mode, turn R10 clockwise to DECREASE the flow; turn counterclockwise to INCREASE the flow. Record the final value on the calibration sheet.

4. **Calibrate 25%:** Turn the setpoint down to 1.25 volts (25% of full scale). Measure the flow. It should be within ±50 millivolts of the setpoint value. Re-adjust R_{10} only if necessary.

5. **Calibrate 50%:** Increase the setpoint to 2.50 volts (50% of full scale). Measure the flow. Adjust R23 if necessary.

6. **Calibrate 75% and 100%:** Repeat Step 5 for 75% and 100%, adjusting R25 and R27 respectively, if the readings are out of tolerance. Record the measured values on the calibration sheet. This completes the Piston Tube Calibration Procedure.

6.2.2 Transfer Standard Calibration Procedure

This procedure assumes that the transfer standard provides a continuous real time readout of flow and is of sufficient quality to maintain the unit being calibrated at its specified accuracy.

Calibration checks and minor adjustments to the zero and span may be made via the access ports in the enclosure. If the linearity needs adjustment (as in changing range), remove the enclosure.

1. **Warm Up:** Plug in the MFC to be calibrated and allow at least 30 minutes warm up time before attempting any adjustments.

2. **Zero Adjust:** Rotate to open the zero and span access doors. Using a voltmeter connected to the meter output pins, adjust the zero potentiometer (R5) for zero volts at zero flow (4 mA for 4-20 mA outputs).

3. **Adjust Valve:** Generate a small flow through the mass flow controller and close the valve by turning the adjustment screw clockwise until the flow just stops. Connect a voltmeter negative lead to P_2 (-15) and positive lead to pin 8 of U_2 on the FMA-100 printed circuit. With an upstream pressure of 30 PSIG, apply a 0.50 volt setpoint and adjust the valve screw for 5.50 volts on the voltmeter. Apply a 5.00 volt setpoint and check that the valve voltage does not exceed 11.0 volts across P_1 and P_2. This value will vary depending on the full scale flow rate.

NOTE

All medium and some high flow valves operate from 10 to 22 volts across P_1 and P_2 depending on the gas and full scale range.

4. **Check Full Scale:** Adjust the setpoint for 5.00 volts and read the flow rate from the transfer standard. Adjust R10 if necessary.

NOTE

In the control mode, turn R10 clockwise to DECREASE the flow; turn counterclockwise to INCREASE the flow. Record the final value on the calibration sheet.

5. **Calibrate 25%:** Turn the setpoint down to 1.25 volts (25% of full scale). Allow 30 seconds for unit to stabilize. Read the flow from the transfer standard. It should be within ±50 millivolts of the setpoint value. Re-adjust R10 only if necessary.
6. **Calibrate 50%:** Increase the setpoint to 2.50 volts (50% of full scale). Allow 30 seconds for unit to stabilize. Read the flow from the transfer standard. Adjust R23 if necessary. Record the final value on the calibration sheet.
7. **Calibrate 75% and 100%:** Repeat Step 6 for 75% and 100%, adjusting R25 and R27 respectively, if the readings are out of tolerance. Record the measured values on the calibration sheet. This completes the calibration procedure. Repeat Steps 5 through 7 at least one more time.

6.3 Response Adjustment

Speed of response can be adjusted using R16. This adjustment is primarily for trimming the shape of the output to more closely approximate a square wave. This adjustment is similar to trimming an oscilloscope probe for best response. The purpose of the response adjustment is to match the 0-5 Vdc output signal to the actual flow.

The response is set at the factory and in most cases needs no further adjustment. Response adjustment is not recommended unless done by qualified service personnel with proper equipment. For special cases please consult the factory service department.

Equipment Required:

- Digital Storage Oscilloscope or Two Channel Strip Chart Recorder with a response of better than 0.33 seconds to within ± 1% of full scale
- Delta P-producing Laminar Flow Element (Sized for the flow range of interest)
- Pressure Transducer with voltage output to monitor Laminar Flow Element (Transducer response better than 0.1 sec to ±1% of full scale)
- Bypass Valve Manifold to produce step response in flow to meter under test
- Flow Metering Valve
- Source of compressed gas (Type of gas depends upon application)

Basic Adjustment Procedure, Flow Meter:

1. Using the Bypass Valve Manifold, apply a step change in flow (0 to 63% of full scale) to the meter under test and observe the shape of the output signal.
2. To correct for overshoot, turn the adjustment potentiometer counterclockwise. To correct for undershoot, turn clockwise.

NOTE

Turning the adjustment pot fully in either direction may cause the output signal to "latch-up". Begin with the pot in the center position and adjust out in small increments.

Basic Adjustment Procedure, Flow Controller:

Apply a step change in flow by raising the setpoint to 63% of full scale or by using the Valve-Off function, (see Section 3.2.3). Observe the output signal of both the flow controller and the pressure transducer/laminar flow element (located directly downstream of the flow controller under test). Adjust R16 for the best response of both signals.

NOTE

Turning the adjustment pot fully in either direction may cause the output signal to "latch-up". Begin the procedure with the pot in center position and adjust out in small increments.

Due to the interaction of the control valve and sensor, increasing the speed of the sensor signal (clockwise rotation of R16) has the effect of slowing the valve response. The effect may not be observable in the DC output signal, but can be seen in the pressure transducer/ laminar flow element output signal.

7 Trouble-Shooting

7.1 General

When you suspect that the mass flow controller or meter is not operating correctly, make these few simple checks before dismantling for repair:

1. Ensure that there are no leaks in the line.
2. Ensure that all cables are plugged in and are in good condition.
3. Ensure that the power supply is of the correct polarity and voltage.
4. Check for adequate pressure differential across the controller.
5. Double check connector pinouts when replacing another manufacturer's mass flow controller.

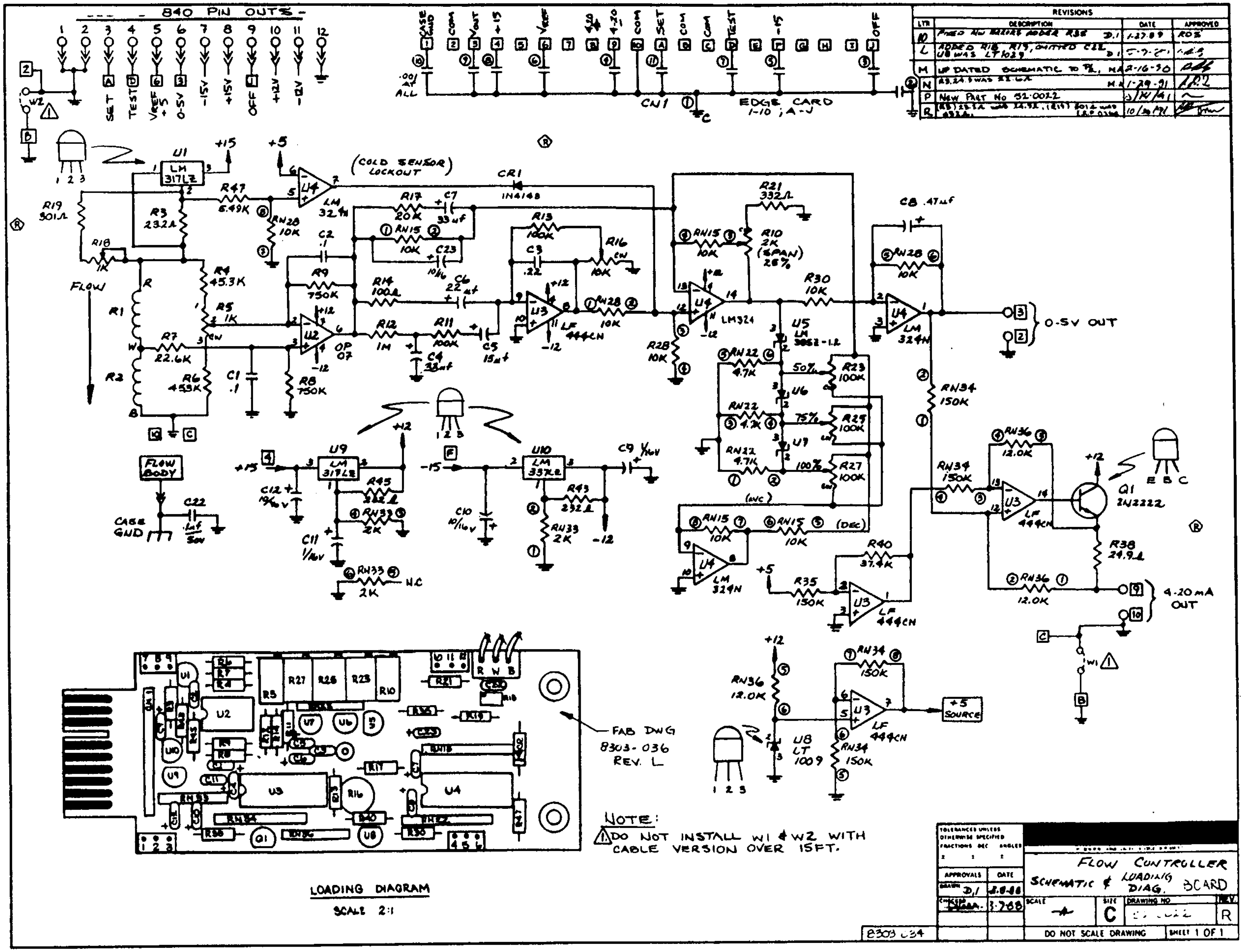
7.2 Trouble-Shooting Guide

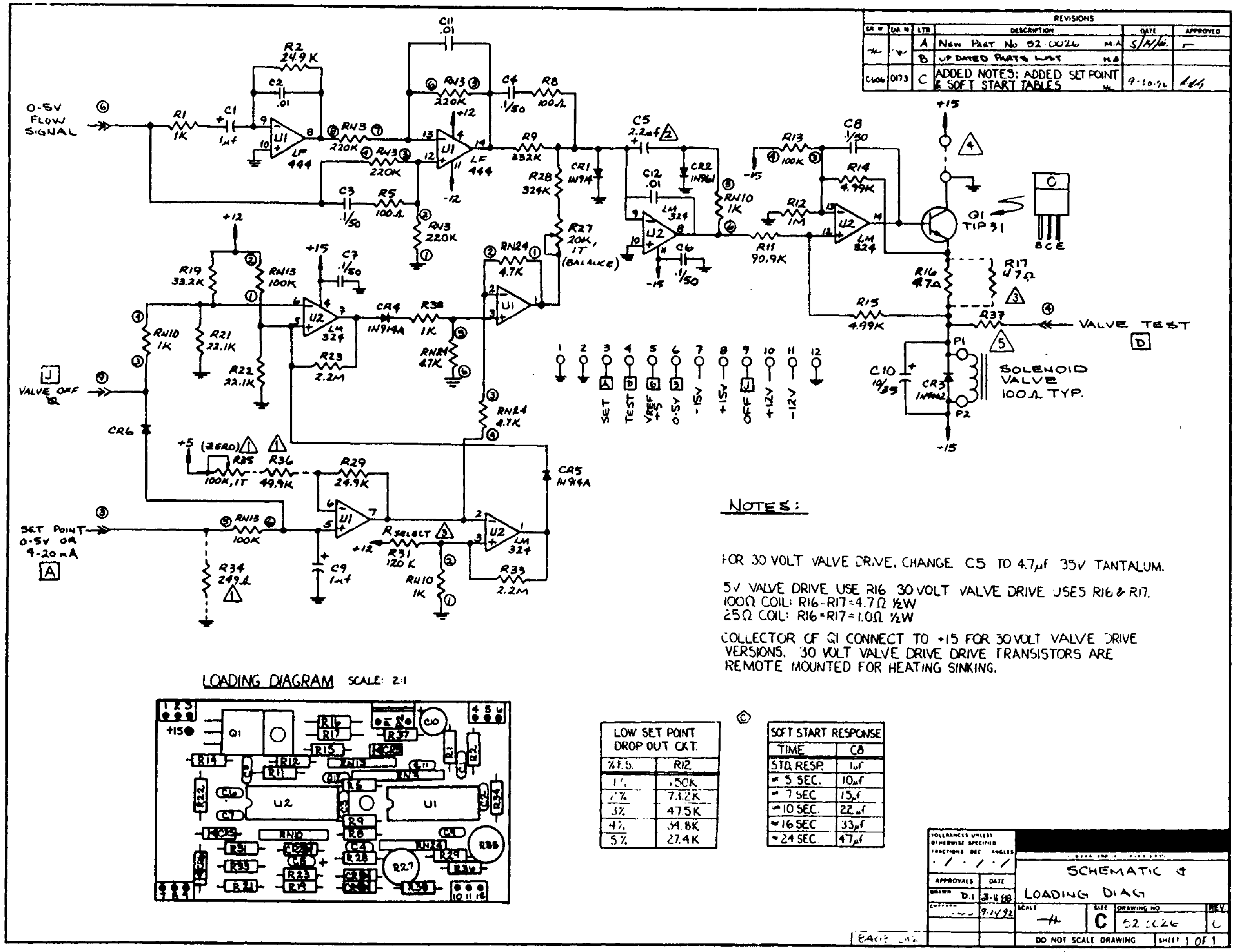
This guide is provided to help locate the section of the controller at fault. It is not intended to be an all inclusive repair manual. In the case of major repairs, return the unit to the factory for service.

FMA-100s & FMA-200s With Electro-Magnetic Valves

Symptom	Possible Cause	Corrective Action
Doesn't respond to set point	Low or no gas pressure	Set correct gas pressure
	Faulty cable or connector	Correct or replace
	Set point is below 2% of full scale	Increase set point or disable auto shut-off circuit (see Section 3.2)
Flow does not match set point	No gas pressure	Set correct gas pressure
	Inlet filter screen clogged	Clean or replace
	Ground loop	Separate signal and power commons
	Out of adjustment	Adjust R22 balance on the FMA-100. Consult factory
No output	Clogged sensor	Clean or replace sensor
	PCB defective	Repair or replace PCB
	Inlet filter screen	Clean or replace screen
Will not zero	Gas leak	Find and correct leaks
	Application requires high pressure and non-horizontal mounting	Re-zero meter
	PCB defective	Repair or replace PCB
Reads full scale with no flow or with valve shut	Defective sensor	Return to factory for replacement
	Gas leak	Find and correct leaks
Out of calibration	Dirty or clogged sensor	Clean or replace sensor
	Change in composition of gas	See "K" factor tables
	Gas leak	Find and correct leaks
	PCB defective	Repair or replace PCB
	LFE dirty	Clean LFE
	Inlet filter screen clogged	Clean or replace screen
	Incorrect inlet conditions (high flow and NPT models only)	Re-plumb meter correctly (see Section 2.4)

A FMA-200 Schematic





REVISIONS

		LTR	DESCRIPTION		DATE	APPROVED
		A	New Part No 52-0026	M.A.		
		B	UP DATED PARTS LIST			
	0173	C	ADDED NOTES; ADDED SET POINT & SOFT START TABLES		9-10-92	

NOTES:

FOR 30 VOLT VALVE DRIVE, CHANGE C5 TO 4.7µf 35V TANTALUM.

5V VALVE DRIVE USE R16 30 VOLT VALVE DRIVE USES R16 & R17.
100Ω COIL: R16-R17=4.7Ω ½W
25Ω COIL: R16-R17=1.0Ω ½W

COLLECTOR OF Q1 CONNECT TO +15 FOR 30 VOLT VALVE DRIVE VERSIONS. 30 VOLT VALVE DRIVE TRANSISTORS ARE REMOTE MOUNTED FOR HEATING SINKING.

LOW SET POINT DROP OUT CKT.	
%F.S.	R12
1%	150K
2%	73.2K
3%	47.5K
4%	34.8K
5%	27.4K

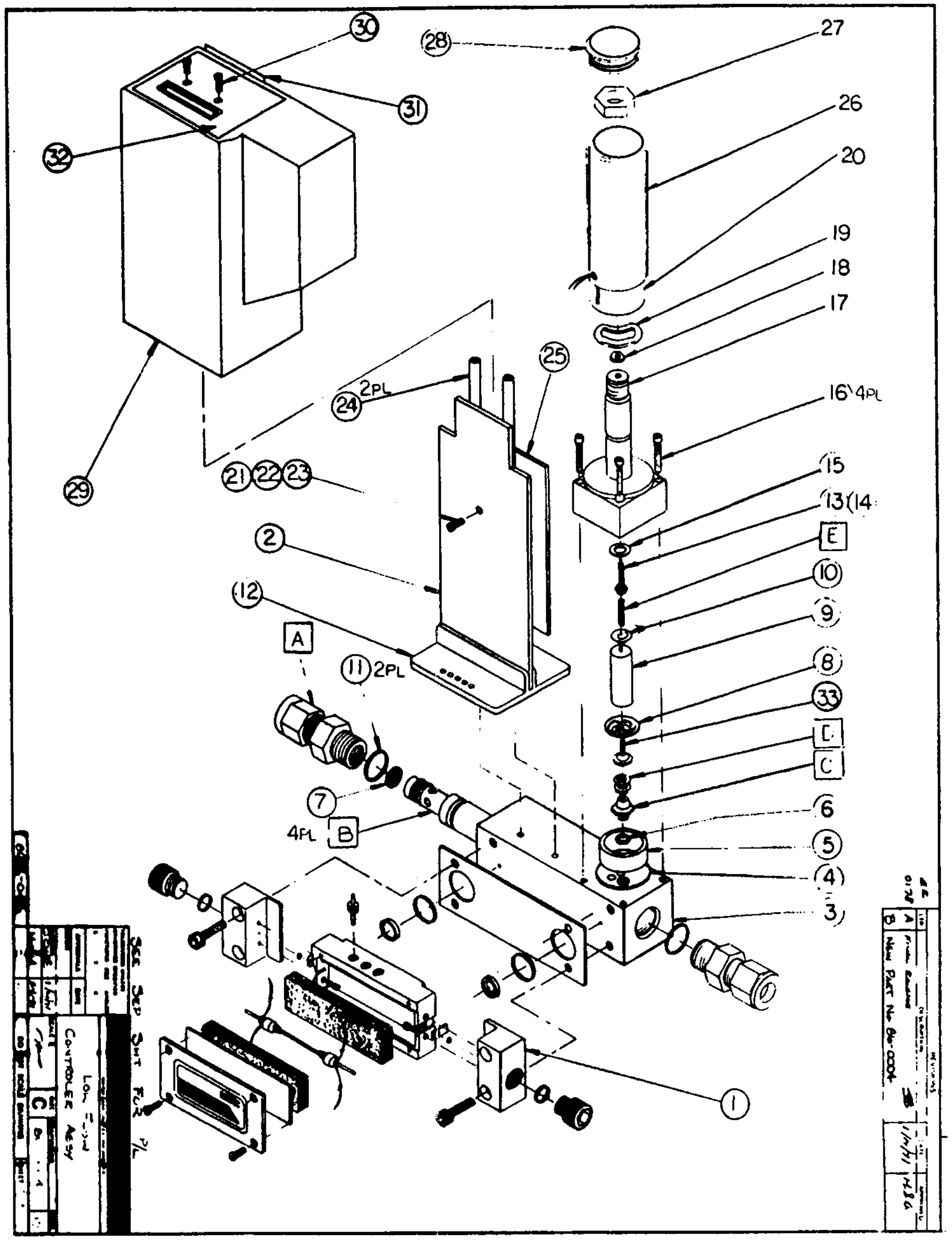
SOFT START RESPONSE	
TIME	C8
STD. RESP.	1µf
≈5 SEC.	10µf
≈7.5 SEC.	15µf
≈10 SEC.	22µf
≈16 SEC.	33µf
≈24 SEC.	47µf

SCHEMATIC & LOADING DIAG
SIZE C DRAWING NO. 52-0026 REV C
DO NOT SCALE DRAWING SHEET 1 OF 1

FMA-100 Low Flow Exploded View, Mechanical

ITEM NO.	OMEGA PART NO.	DESCRIPTION
1	86-003	Sensor Compartment Sub Assembly
2	52-0061	Circuit Board
3	41-0485	Flow Body
4	31-001-018	"O"-Ring
5	41-0018	Sleeve
6	31-0001-008	"O"-Ring
7	40-0074	Inlet Filter
8	41-0350	Spider Spring
9	41-0019-01	Valve Plug
10	41-0017	Helical Spring
11	31-0001-906	"O"-Ring
12	42-0027	PCB Base Plate
13	41-0016	Adjustment Screw
14	31-0001-003	"O"-Ring
15	41-0015	Spacer
16	35-0149	Soc. Hd. Cap Screw
17	41-0022	Valve Assembly
18	35-0347	Hex Nut
19	35-0055	Warp Washer
20	29-0105	Coil
21	35-0339	Pan Hd. Phil. Screw
22	35-0236	Standoffs
23	35-0101	Hex Hd. Nut
24	41-0021	Standoff
25	52-0060	Printed Circuit Board
26	41-0006	Coil Enclosure
27	45-0015	Hex Nut
28	42-0026	Valve Cap
29	42-0095	Electronics Enclosure
30	35-0028	Pan Hd. Phil Screws
31	47-0009	Cable
32	47-0123	Cable
33	84-0001-01	Valve Plug Asm

ITEM NO.	DESCRIPTION
A	Fitting
B	Laminar Flow Element
C	Valve Seat
D	Valve Spring, Bottom
E	Valve Spring, Top



D List of Bypasses and Orifice Sizes, Low Flow

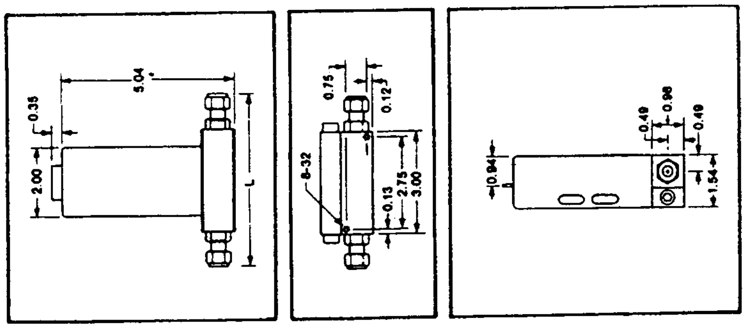
LFE and Valve Orifice Sizes for Mass Flow Controllers

Low Flow Body

LFE, Part No.	Maximum Flow, SCCM of N_2 at 21°C, 760mm Hg	Orifice Size, Inches	
		Part No.	Orifice Size, Inches
41-0023-011	15	41-0012-01/02	0.010 or 0.020
41-0023-021	30	41-0012-01/02	0.010 or 0.020
41-0023-031	41	41-0012-01/02	0.010 or 0.020
41-0023-041	68	41-0012-01/02	0.010 or 0.020
41-0023-051	106	41-0012-01/02	0.010 or 0.020
41-0023-061	134	41-0012-01/02	0.010 or 0.020
41-0023-071	191	41-0012-01/02	0.010 or 0.020
41-0023-081	279	41-0012-01/02	0.010 or 0.020
41-0023-091	569	41-0012-02	0.020
41-0023-101	710	41-0012-02	0.020
41-0023-111	1043	41-0012-02	0.020
41-0023-121	1383	41-0012-02	0.020
41-0023-131	1538	41-0012-02	0.020
41-0023-141	2187	41-0012-02	0.020
41-0023-151	3830	41-0012-03	0.040
41-0023-161	5852	41-0012-03	0.040
41-0023-171	8482	41-0012-03	0.040
41-0023-181	11,241	41-0012-03	0.040
41-0023-191	11,583	41-0012-04	0.055

E Mounting Dimensions, Mass Flow Meters and Controllers

Low Flow Body



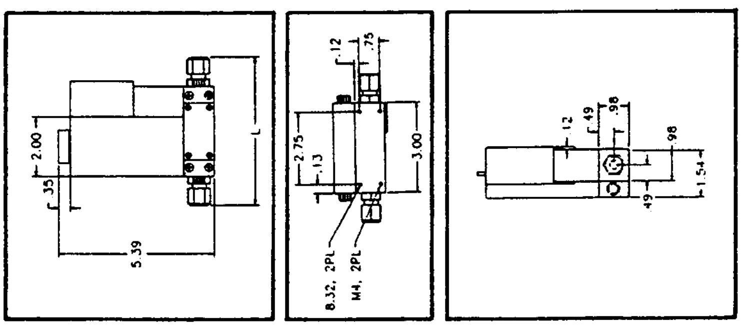
Side View **Bottom** **Outlet End View**

1/4"O.D. Tube Fitting Type (9/16"-18 Thd.)	Swagelok
Dim. "L"	5.02

Table

Mounting Dimensions, FMA-200 Mass Flow Meters

Low Flow Body



Side View **Bottom** **Outlet End View**

1/4"O.D. Tube Fitting Type (9/16"-18 Thd.)	Swagelok
Dim. "L"	5.02

Table

Mounting Dimensions, FMA-100 Mass Flow Controllers

F Recommended Wire Gauges for Flow Meters and Controllers

Using the correct wire gauge for cabling runs to FMA-100 controllers insures proper operation in most installations. For very long cable runs (<150'), consider a local power supply. Also, the low flow range controllers can be run more economically over long cables than the high flow models. FMA-200 flow meter cable requirements are independent of range.

TABLE I FMA-100/200 (All Ranges)

Distance in Feet	Recommended Min. Wire Gauge
25	34
50	32
100	28
200	26
300	24
500	22

Table II FMA-100/200 Low Flow

Distance in Feet	Recommended Min. Wire Gauge	
	Pins 2 & F	All Others
25	30	34
50	28	32
75	26	28
100	26	28
125	24	26
150	24	26

G Conversion of Flow Rate to Other T and P Conditions

The flow rate of your instrument is referenced to certain "standard" conditions of temperature and pressure. Unless otherwise specified in your order, these standard conditions are 21°C (70°F) and 760 mm of mercury (1 atmosphere). If you wish to convert to other "standard" conditions or to find the "actual" conditions in the pipe where your instrument is installed, use the following relationship:

$$Q_2 = \frac{P_1}{P_2}\frac{T_2}{T_1}Q_1 \qquad (1)$$

$(\ )_1$ = The standard conditions under which your instrument was calibrated,

$(\ )_2$ = The new standard conditions or the actual temperature and pressure conditions in the pipe,

Q_1 = The gas mass flow rate referenced to the calibrated standard conditions (SCCM or SLM),

Q_2 = The gas mass flow rate referenced to the new standard or actual conditions (SCCM or SLM—"S" means "standard"; ACCM or ALM—"A" means "actual",

P = Absolute pressure (kg/cm_2 or psia), and

T = Absolute temperature (°K or °R) (°K = °C + 273, °R = °F + 460)

Example 1: Changing "Standard" Conditions

If your instrument has a flow rate reading of 10.00 SLM and was calibrated at standard conditions of 70°F (21°C) and 1 atmosphere (14.7 psia), and if you wish to convert this reading to standard conditions of 32°F (0°C) and 1 atmosphere, then you would use Equation (1) as follows:

$$Q_2 = \frac{14.7}{14.7}\frac{460 + 32}{460 + 70}(10.0) = 9.28\text{SLM}$$

So, you can see that the flow rate referenced to 0°C will be approximately 7% lower than when referenced to room conditions of 21°C.

Example 2: Finding the "Actual" Flow Rate

If the flow rate and calibrated standard conditions are as given in Example 1 and you wish to find the actual flow rate at 100°F and 30 psig, then you would use Equation (1) as follows:

$$Q_2 = \frac{14.7}{14.7 + 30} \cdot \frac{460 + 100}{460 + 70}(10.00) = 3.47\,\text{SLM}$$

MADE IN USA

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. 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.

© Copyright 1994 OMEGA ENGINEERING, INC. All rights reserved. This documentation may not be copied, photocopied, reproduced, translated, or reduced to any electronic medium or machine-readable form, in whole or in part, without prior written consent of OMEGA ENGINEERING, INC.

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

M1842/0594