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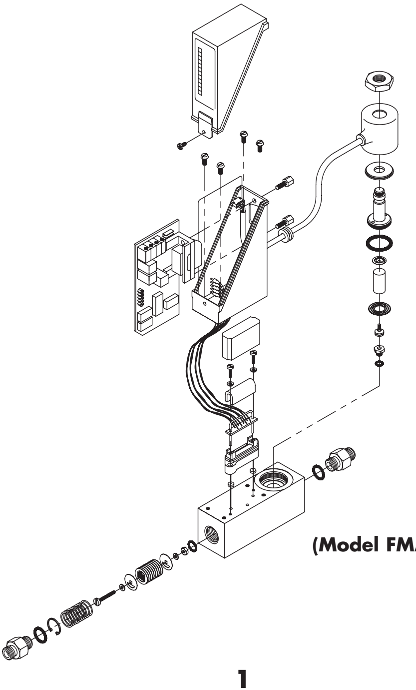
EXPLODED VIEW
SERIES FMA-700A MASS FLOW CONTROLLER



(Model FMA-761A-V Illustrated)

1.1 General Description

OMEGA's Mass Flow Products reflect over three decades of experience in the design and manufacture of precision instruments for the measurement and control of gas flow. OMEGA's Mass Flow products incorporate design principles that are simple and straightforward, yet flexible enough to operate under a wide variety of process parameters. The result is mass flowmeters (MFM's), mass flow controllers (MFC's) that are accurate, reliable and cost-effective solutions for many mass flow applications.

OMEGA's Series FMA-800A and Series FMA-700A accurately measure (Series FMA-700A/800A) and control (Series FMA-700A) flow rates of a wide variety of gases from 5 standard cubic centimeters per minute (SCCM) to 1000 standard liters per minute (SLM) full scale nitrogen flow for operating pressures up to 1500 PSIG. The MFM's and MFC's provide a linear flow signal output proportional to a calibrated flow rate. This output signal can be used to drive a digital display, such as the DPF60 Series, or other customer supplied data acquisition equipment.

The Series FMA-800A MFM's & FMA-700A MFC's incorporate an operating principle based on the thermodynamic properties of the process gas being monitored. Both the FMA-800A MFM'S & FMA-700A MFC's employ a sensor assembly that includes a heater and two precision resistance-type temperature sensors. The integral printed circuit board (PCB) assembly performs amplification and linearization of the sensor assembly output signal and provides the flow signal output. Patented, restrictive laminar flow elements condition the main channel of gas flow while thermal measurement occurs in the gas flowing through the bypass sensor assembly. The FMA-700A additionally incorporate an integral proportional control valve and closed loop control circuitry on the PCB assembly. Detailed explanation of operational theory is described in Section 4, Theory of Operation.

1.2 System Features

+ Single Power Supply Operation

Voltage output models operate from nominal power supply voltages of + 12 (±5%) or + 15 (±10%) Vdc. Current loop models operate from nominal power supply voltages of + 15 (±5%) or + 24 (±15%) Vdc. The voltage output models may be directly connected into existing installations having dual power supply voltages of ±15 Vdc with no change in performance and no modification to the installation to accept the new MFM/MFC.

+ 4-20 mAdc Operation

4-20 mAdc current loop model is sinking current loop current flow.

+ Fast Response

Control circuitry significantly reduces “dead time” when ramping from no (i.e. zero) flow conditions and improves MFC response time.

+ Absolute Zero (ABZ)

When the flow is detected to be less than 1.5% of of full scale, ABZ circuitry automatically clamps the flow signal output to zero, eliminating flow signal zero drift. Duringcalibration, the ABZ feature is disabled by means of a control input at the I/O connector (refer to Section 7, Input/Output [I/O} Designations [Electrical Connections] and I/O Electrical Specifications for details).

+ Internal Voltage Regulation and Temperature Compensation Circuits

Stabilizes flow signal output, flow signal accuracy and closed loop control during transitional conditions, regardless of power supply and temperature fluctuations.

+ Attitude Insensitivity

MFM's and MFC's may be mounted in any position and are able to maintain tight accuracy specifications with stable control.

+ Laminar Flow Element Package

Computer-determined for each specific application based on flow rate and the physical properties of the process gas.

+ Valve Override (SIM-VO)

The automatic closed loop control may be temporarily defeated to force the control valve fully open during system or process diagnostics.

2 SPECIFICATIONS

2.1 Specifications

Specifications for Series FMA-800A MFM's and Series FMA-700A MFC's

Response Time (per SEMI E17-91 Setting Time):	1 to 2 seconds
Accuracy and Linearity:	+/-1% full scale (≤500 SLM N_2). +/-1.5% full scale (>500 SLM N_2).
Repeatability:	Within ±0.2% full scale at any constant temperature within operating temperature range.

2.1 Specifications (Con't)

Specifications for Series FMA-800A MFM's and Series FMA-700A MFC's

Rangeability (Control Range):	50:1 (2% - 100% full scale) (accuracy and control)
Ambient and Operating Temperature Range:	-10 to 70°C (+ 14 to 158°F)
Temperature Coefficient (per SEMI E18-91 Zero Effect and Span Effect):	± 0.05% full scale/°C of zero ± 0.05% of reading/°C of span
Pressure Coefficient (per SEMI E28-92 Total Calibration Effect):	± 0.1% atmosphere typical using nitrogen (N_2)

Setpoint Input / Flow Signal Output:

Setpoint Input	Flow Signal Output
0-5 Vdc	0-5 Vdc (2K ohm minimum load resistance
1-5 Vdc	4-20 mAdc (refer to load resistance values **

Load resistance values for 4-20 mAdc flow signal output:

0-450 ohms for 6.5 -15 Vdc loop supply voltage

200 -750 ohms for 15-30 Vdc loop supply voltage

Power Supply Requirements
(Current consumption <45 mAdc for MFM's 250 mAdc for MFC's:

Voltage output models:
+12 (±5%)
+15 (±10%) Vdc

Current loop models
+ 15 (±5%) or +24 (±15%) Vdc

Mounting Orientation: Attitude insensitive

Warm-up Time: 10 minutes

External Electrical Connector:
Nine (9) - pin D-connector

3 INSTALLATION AND OPERATING PROCEDURES

3.1 General Information

OMEGA's Series FMA-800A MFM's and Series FMA-700A MFC's must be installed in a clean, dry area with adequate space surrounding the MFM/MFC for ease of maintenance. Ambient temperature should not exceed the specific operating range of -10 -70°C (14-158°F). The MFM's/MFC's are attitude insensitive, therefore, may be mounted in any position. Users may specify factory calibration in the exact attitude of the installation. Users must specify process gas, flow range, inlet pressure, outlet pressure (for FMA-700A), operating temperature and calibration standard at the time of ordering. When supplying a MFC, OMEGA Engineering will computer-calculate the appropriate value orifice for the application based on the user-specified operating parameters.

3.2 Gas Connections

Each MFM/MFC has two (2) threaded process connection ports, one (1) located at each end of the base block. One (1) serves as the gas inlet while the other is the gas outlet. For compression fittings, make certain the tubing which mates to the fitting is correctly sized, clean and is seated against the shoulder in the body of the compression fitting, prior to tightening the connection. Tighten the fittings hex nut sufficiently to prevent leakage. For face seal fittings, exercise caution so as not to damage the face seal sealing surfaces. Whether using compression or face seal fittings , refer to the applicable fitting manufacturer's data for specific recommendations regarding installation and tightening. Test joints for leaks. The inlet connection contains a 325 mesh (44 micron) filter screenwhich prevents foreign matter from entering the instrument. Refer to System Purging for additional recommendations.

3.3 System Purging

To eliminate contamination from foreign materials, start-up cleaning is highly recommended prior to MFM/MFC installation. Start-up cleaning must remove weld debris, tube scale and any loose particulate generated during system fabrication.

If corrosive gases or reactive gases are to be used. the complete gas handling system must be purged to remove all air before introducing process gas into the system. Purging can be accomplished with dry nitrogen or other suitable inert gases.

Also, if it becomes necessary to break any gas connection exposing the gas handling system to air, all traces of corrosive or reactive gas must be purged from the system before breaking the connection.

Never allowing a corrosive or reactive process to mix with air reduces the chance of particulate or precipitate formation in the gas handling system.

3.4 External Electrical Connector - 9-Pin D - Connector

Please note the two (2) "common" references noted in the text. SIGNAL COMMON (pin 4) is a zero current return reference for all functional circuit modules. POWER COMMON/0 VDC (pin 8) is the separate return for the proportional control valve operating current and all other circuit currents.

Figures 3-1 and 3-2 diagram the external electrical connections to be made to the FMA-800A MFM's and FMA-700A MFC's. A separate control valve common wire, connected to POWER COMMON/0 VDC (pin 8) is illustrated and required. This connection keeps the high current related to the control valve independent of the more sensitive, low level, processing circuitry, thus avoiding potential noise problems and/or ground loops.

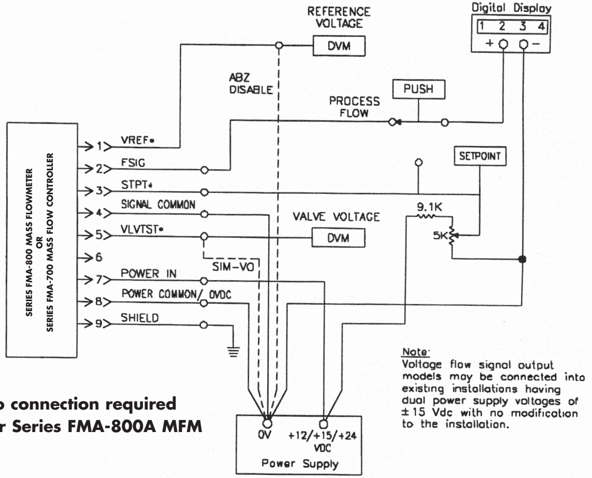
3.4 External Electrical Connector - 9-Pin D - Connector (Con't)

For Models having a 0-5 Vdc Flow Sgnal Output, Figure 3-1 also illustrates the circuit arrangement for a typical user-provided setpoint control. As an alternative OMEGA offers the FMA-78P Series Interface Modules.

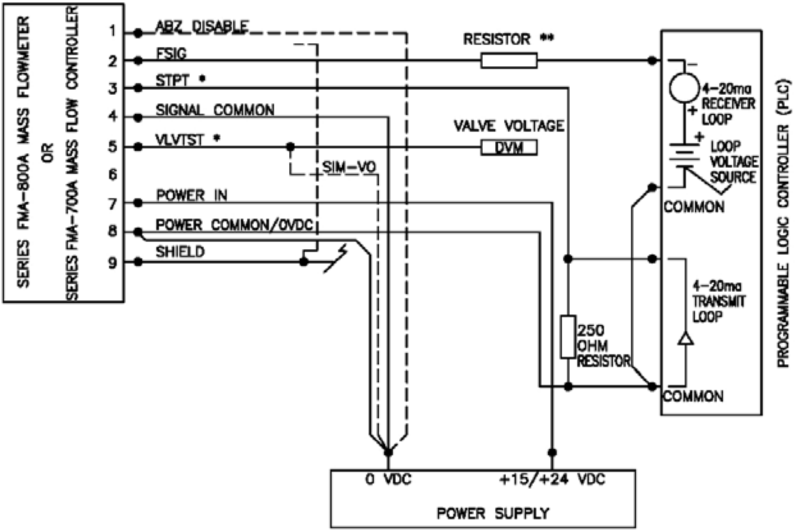
Refer to Section 7, Input/Output (I/O) Designations (Electrical Connections) & I/O Electrical Specifications, for more details of the individual pin functions for the 9-pin D-connector. See Section 8, Current Loop Specification, for details on current loop operation.

Figure 3-1 External Electrical Connections for Series FMA-800A MFM's and Series FMA-700A MFC's

For Models having a 0-5 Vdc Flow Sgnal Output



*** = No connection required for Series FMA-800A MFM**



* NO CONNECTION REQUIRED FOR SERIES FMA-800A MFM.

** FOR 24 VDC LOOP VOLTAGE SOURCE, TOTAL RESISTANCE (INCLUDING INTERNAL PLC RESISTANCE) SHOULD BE BETEEN 400-800 OHMS TO PREVENT DAMAGE TO CURRENT LOOP DRIVER.

3.5 Basic Operating Procedures to Establish a Controlled Flow Rate

To operate the FMA-700A MFC after electrically connecting the MFC to the interface module or other secondary electronics, introduce power to the system, allowing a ten (10) minute warm-up period prior to operation. Adjust SETPOINT to zero flow rate. Turn on te gas supply, being careful to avoid presure surges by bringing the MFC gradually up to the actual operating conditions. Adjust the SETPOINT to the desired flow rate.

3.6 Additional Features - Connections and Operations Valve Override (SIM-VO) for FMA-700A

Pin 5 of the 9-pin D-connector is designated VLVTST and has dual functions, both of them accessible by employing a diagnostic kit (breakout board) function. When connected to a digital voltmeter, pin 5 provides measurement of the valve voltage driving the opening and closing of the proportional control valve during closed loop control. When pin 5 is instead connected to the POWER COMMON/0 VDC, pin 8). the SIM-VO (simple valve override) function is activated and the proportional control valve is driven full open.

When using mechanical switches to provide the SIM-VO action, momentary push-button switches are preferable. If toggle switches are used, they should have a second set of contacts connected to a power source and a VALVE STATUS indicator. When operating, the VALVE STATUS indicator will remind the operator the valve override switch must be turned to automatic control operation. Mechanical switch contacts should be of a type appropriate for use in “dry” circuit applications. These contacts are usually gold or gold plated.

3.7 Reference Voltage (VREF) (Only on voltage output models)

Pin 1, VREF, has dual functions. When connected to a digital voltmeter. pin 1 provides a reference voltage measurement. The reference voltage may be adjusted to a +5 Vdc reading the digital voltmeter and adjusting the VREF trimpot located on the PC board (with 9-pin D-connector on right, far right trimpot in row of four trimpots at top of PC board assembly). The reference voltage may then be used in a simple system to provide a constant setpoint control. The reference voltage is stable under temperature changes and power supply fluctuations. A simple voltage divider (i.e. command potentiometer) with a minimum load resistance of 5K ohm could be used where the constant setpoint would be adjusted and fed into the setpoint input, pin 3 (STPT), of the 9-pin D-connector. Then, upon power up, the controller would go to the setpoint for a constant flow.

When pin 1 is instead connected to the power common (power supply 0 Vdc or POWER COMMON/0 VDC, pin 8), the ABZ function is disabled.

NOTE

The ABZ disabled is only used in calibration or troubleshooting procedures. Do not operate the MFC for normal process control with ABZ disabled.

3.8 Digital Interfacing

When digital logic IC's such as TTL or CMOS gates or drivers, etc., are used to interface and external computer/controller with the FMA-700A MFC, it is important to observe the logic level values required for proper and reliable operation. See details under Section 7, Simple Valve Override (SIM-VO).

4 THEORY OF OPERATION

4.1 Theory of Operation

OMEGA's Series FMA-800A Mass Flowmeters (MFM's) & Series FMA-700A Mass Flow Controllers (MFC's) incorporate an operating principle based on the thermodynamic properties of the process gas being monitored.

Mass flow measurement relates to the amount of heat absorbed by the process gas. The amount of heat the gas absorbs is determined by the gas' molecular structure. Specific heat, the amount of heat required to raise the temperature of one (1) gram of a particular gas one degree centigrade (1°C), quantitatively describes this "thermal absorbency".

Mass flow measurement consists of a bypass sensing tube with a heater wound around the center of the sensing tube and precision resistance-type temperature sensor located equidistant upstream and downstream of the heater. A laminar flow element package, located in the main flowstream, acts as an appropriate restriction creating a pressure drop forcing a fixed percentage of the total flow, approximately 10 SCCM, through the bypass sensing tube for temperature differential detection. For example, if a MFM is calibrated for a 1000 SCCM maximum flow, 10 SCCM would flow through the sensor assembly and 990 SCCM would flow through the laminar flow element assembly in the main flowstream.

Figure 4-1 illustrates the sensor assembly as a block diagram

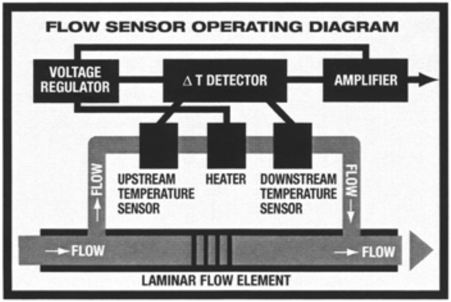


Figure 4-1 Block Diagram of Sensor Assembly

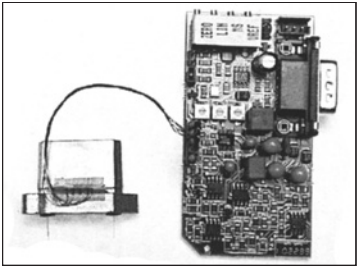
4.1 Theory of Operations (Con't)

Constant power heat input to the heater is supplied by a precision power supply on the PCB assembly. Heat from the heater spreads uniformly from the center of the sensor tube. At a no (i.e. zero) flow condition, the temperature at both the upstream and downstream temperature sensor is equal. As gas flows through the sensing tube, heat is displaced to the downstream temperature sensor creating a temperature differential between the upstream and downstream temperature sensors. The upstream and downstream temperatures sensors form two (2) legs of a bridge network at the sensors assembly inputs to the PCB assembly. The resulting temperature differential is amplified on the PCB assembly to a user-specified 0-5 Vdc or 4-20 mAdc output signal directly proportional to gas mass flow rate.

Three (3) important factors have been noted thus far: specific heat, heat input, and temperature differential. These three (3) factors help define a precise relationship to the mass flow. Therefore, if the specific heat & heat input are known and in an acceptable range, accurate temperature measurement will produce an accurate indication of flow rate for a particular gas. To ensure an accurate flow measurement, flow disturbances must be eliminated or greatly reduced. Accordingly, both the sensor tube and laminar flow. Actual gas or gas factors are used in calibration to account for the specific heat of the monitored gas.

The upstream temperature sensor, downstream temperature sensor and heater are connected to the PCB assembly via a miniature flexible interconnecting cable. These components are shown in Figure 4-2.

Figure 4-2
Sensor Assembly
and
Electronic Printed
Circuit Board



4.1 Theory of Operations (Con't)

As previously mentioned, the laminar flow element package, acting as a flow restriction creating the required pressure drop, is located in the main flowstream. The laminar flow element package, in addition to forcing a fixed percentage of the total flow through the bypass sensing tube, also determines the MFM's/MFC's maximum flow for which the unit may be calibrated. Disc-like, individual flow elements comprise the laminar flow element package. Each flow element has chemically-etched precision channels to restrict flow. The MFM's/MFC's maximum flow rate determines both the size and quantity of flow elements used. As few as one (1) and as many as three hundred (300) flow elements may be required.

Figure 4-3 illustrates three (3) of the five (5) available sizes of the laminar flow elements. The smallest flow element shown has only one (1) chemically-etched precision flow channel and would be used as part of a laminar flow element package in a low flow range MFM/MFC, for example Model FMA-800A MFM or Model FMA-700A MFC. In comparison, the largest flow element shown contains numerous flow channels. Varying the number of flow elements in the flow element package, using flow elements having more flow channels, combinations of similarly-sized flow elements or a physically larger flow element size would be used for the various available flow ranges. For example, a flow element package containing multiple flow elements provides a large number of parallel paths for gas flow, thereby obtaining a higher flow rate.

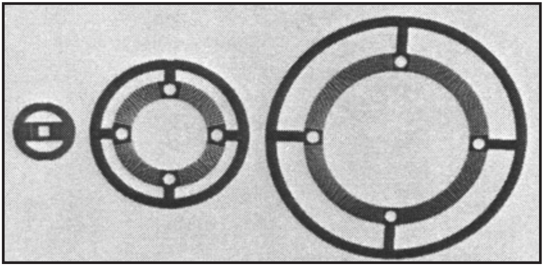


Figure 4-3 Laminar Flow Elements

4.2 Mass Flowmeter/Mass Flow Controller Electronics

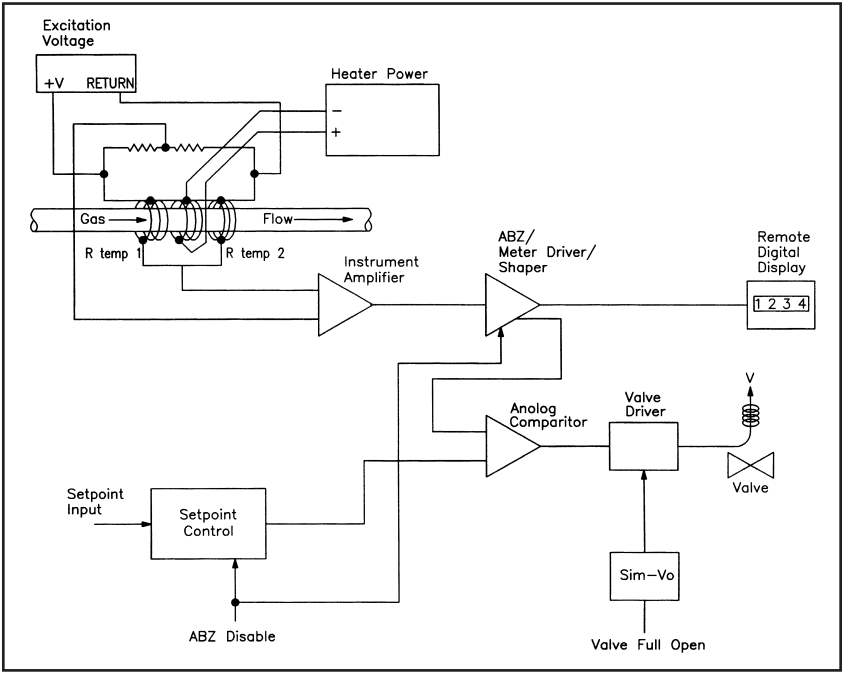
As briefly noted in Section 1, the PCB assembly performs three (3) general flowmeter functions: amplification, linearization, and flow signal output. If the instrument under discussion is an MFC, the required control circuitry to regulate a proportional control valve is included on the PCB. Refer to Figure 4-4 for the block diagram of the Series FMA-700A/800A MFM's/MFC's.

For a condition of no gas flow, both the upstream and downstream temperature sensors are heated equally, giving both sensors the same temperatures and resistance values. Therefore, the bridge network is balanced and the difference in voltage between each sensing leg of the bridge network is zero. With no flow, the instruments flow signal output is also zero. When gas flow does occur, the downstream temperature sensor increases its resistance, in response to a higher temperature, with respect to the upstream temperature sensor. A differential voltage is developed which is directly proportional to the mass flow rate of the gas. The differential voltage signal, typically about 30 millivolts (mV) maximum, is applied to the input of a precision instrument amplifier. The amplified signal is then fed to linearization circuitry which corrects the temperature sensor bridge network excitation voltage. The degree of correction is small, with subtle non-linearity effect accommodated as the flow approaches its full range value.

The output signal from the instrument amplifier also drives a special signal-conditioning amplifier, which is an output ABZ/meter driver/shaper stage. This multi-purpose stage is an active differentiator network having a tailored rapid response characteristic. The output flow signal must closely match the actual flow, even in transitional conditions of the flow controller response to a changed setpoint command. The stage is adjusted until the slower changing raw sensor flow signal is shaped to change in the same manner as the actual gas flow changes. Figure 4-5 shows how this circuit's signal closely duplicates a step change and correspondingly rapid actual gas flow rate change. The second purpose of this stage is to provide a user-specified 0-5 Vdc or 4-20 mAdc output signal for a 0 to 100 percent of full scale flow rate.

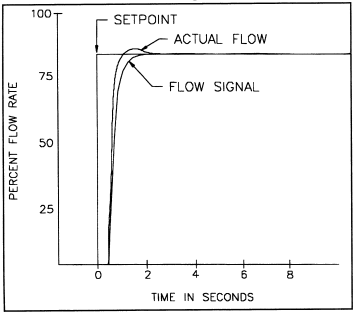
4.2 Mass Flowmeter/Mass Flow Controller Electronics (Con't)

Figure 4-4 Block Diagram of Series FMA-800A Mass Flowmeters and Series FMA-700A Mass Flow Controllers



4.2 Mass Flowmeter/Mass Flow Controller Electronics (Con't)

Figure 4-5 Response Curve:
Comparison between Flow Signal and Actual Gas Flow



4.3 Control of the Proportional Control Valve

Closed-loop control of the proportional control valve adds circuitry to the MFC schematic diagram not required for the MFM. The additional circuitry includes a setpoint input channel, an analog comparator and a valve (power) driver stage. Generally speaking, the closed-loop control system works as follows: the setpoint input signal is compared with the flow signal output in the analog comparator stage. If the setpoint input signal commands a flow change, comparison between the setpoint input signal and the flow signal output is such that the analog comparator applies a signal of a given magnitude and polarity to the valve driver stage causing the valve to respond to the flow change. As this occurs, the flow signal output approaches and theoretically equals the setpoint signal stabilizing the valve's power drive signal, holding the valve in a relatively stable position. Typical valve displacement (i.e. valve travel) for an MFC sized for 1 SLPM of nitrogen, an inlet pressure of 20 PSIG & an outlet pressure of 0 PSIG (14.7 PSIA), is approximately 0.0003 inch for 0 to 100 percent of full scale flow.

5 MAINTENANCE

5.1 GENERAL

Successful maintenance and troubleshooting depends upon the ability of the operator or technician to associate a given symptom with the source of the problem. The more familiar one is with the working of the MFM/MFC, the easier it is to make this association. Carefully reading Section 4, Theory of Operation, is recommended to gain this familiarity. Also, this knowledge will help in formulating troubleshooting procedures for less common problems. The potential problems described in this section are more general in nature. Should further assistance be required, contact the factory.

5.2 Preliminary Checks

When no specific cause of trouble is apparent , a good preliminary check is to make a visual inspection of the MFM / MFC in the following areas:

- Check interconnecting cable assemblies for loose or broken wires.
- Inspect interconnecting cable assemblies for loose fit.
- Test fuse in the power supply for continuity.
- Remove the housing enclosing the PC board assembly and inspect for discolored or charred components.

5.3 Control Valve Disassembly

Major maintenance procedures of cleaning and total MFC disassembly and recalibration are typically done at the factory. However for simple maintenance, the following steps explain how to disassemble the control valve for cleaning or service (refer to exploded view of Series FMA-700A MFC):

a). If the valve is integral with the controller, disconnect the electrical connector.

b). Remove the hex nut from the top of the valve assembly and carefully remove the cover/coil assembly.

c). Unscrew the valve stem and remove the valve stem and valve stem O-ring.

d). Remove the internal valve assembly. Do not change any shim positions.

e). Unscrew the orifice and remove the orifice and orifice O-ring.

f). Parts may be cleaned ultrasonically in a suitable solvent. The valve stem and orifice O-rings should be replaced prior to reassembly.

g). Reassemble parts in reverse order.

h). Test MFC performance for smooth opening flows and stable control at setpoint.

5.4 System Troubleshooting

The system troubleshooting table shown below in table 5-1 indicates the steps to follow after a physical check is completed. This table offers a cause and effect procedure aimed at localizing the trouble to a particular section or system component.

Table 5-1 System Troubleshooting Chart

Symptom	Possible Cause	Corrective Action
No output	No power input	Check power supply (with cable assembly connected) for required power supply voltage at pin 7 of the 9-pin D-connector. Check power supply line fuse.
Signal offset at zero flow	Digital display shifted upscale	Check by shorting input to digital display to pin 4 signal com (with pin 2 of the 9-pin D-connector open) or by depressing PROCESS/SETPOINT switch with SETPOINT control at zero.
Signal offset at zero flow (con't.)	MFM/MFC out of calibration	Refer to Section 6, Calibration.
Flow signal to setpoint is offset	Gas leak (MFM)	Check downstream gas connections. Check O-ring seals in MFM and valve.
Valve oscillates	Insufficient pressure drop	Increase supply pressure.
	Excessive pressure drop	Lower supply pressure.
	"Jumpy" supply pressure	Replace upstream pressure regulator.
Flow indication "pegged" (saturated) up or down scale	PCB assembly or sensor assembly failure (e.g. sensor open)	Return to factory for repair.
Flow indication appears to be erroneous	Digital display	Check digital display against digital voltmeter at pin 2 of the 9-pin D-connector to signal common (e.g. full scale display should equal 5.0 Vdc on voltmeter).
	Change in composition of metered gas	Check gas supply.
	Gas leaks (MFM)	Check downstream connections.
	Drift or shift in PCB assembly	Replace PCB assembly. Recalibration required.

5.5 Return Shipments

Contact OMEGA's Customer Service for a return number if an MFM/MFC is to be returned for any reason. The unit along with a Declaration of Contamination form and a Material Safety Data Sheet, must accompany all return shipments. If the MFM/MFC was used with corrosive or toxic gases, the customer is responsible for removing all traces of hazardous materials prior to shipment. Detail the condition of purging used. OMEGA is to be notified about application conditions before any MFM/MFC will be serviced. Items must be properly packed and shipped prepaid.

6 CALIBRATION

6.1 General

All OMEGA Series FMA-800A MFM's and FMA-700A MFC's are shipped calibrated to the customer's operating conditions within the tolerances given in the specifications specified in Section 2. If service is required, including replacement of the PCB assembly, recalibration may be required. The calibration section is general in nature and assumes the use of a qualified calibration facility,

6.2 Equipment Required

To verify or establish specified flow rates, an accurate volumetric calibration device is required. Do not use a rotameter or similar device, as its accuracy is not sufficient for calibration of the MFM or MFC. Typically, a digital voltmeter (0.1 percent accuracy or better) is also required. However, the digital display, used as a read-out device, may be substituted since it measures 0 to 5 Vdc at comparable accuracy.

6.3 Calibration Procedure

To calibrate Series FMA-800A MFM's and Series FMA-700A MFC's proceed as outlined in the following steps.

For Series FMA-800A MFM's:

1. Remove the cover to gain access to the PCB assembly.

2. **Check Reference Voltage:** Pin 1 has dual functions. When connected to a digital voltmeter, Pin 1 [V REF] and Pin 4 [SIGNAL COMMON], pin 1 provides a reference voltage measurment.

2.1 The reference voltage may be adjusted to +5 Vdc by reading the digital voltmeter and adjusting the VREF trimpot located on the PCB assembly (with 9-pin D-connector on right, far right trimpot in row of four trimpots at top of PCB assembly).

6.3 Calibration Procedure

2.2 Verify the reference voltage is appropriately set at +5 Vdc corresponding to desired setpoint and output ranges. If the reference voltage feature is not to be used, precise setting beyond being in the proper range is not required.

2.3 If the reference voltage feature is to be used, it must be precisely set first and not readjusted after further calibration adjustments of other trimpots

3. **Disable ABZ** by connecting pin 1 to the power supply 0 Vdc (power supply 0 Vdc or POWER COMMON/0 VDC, pin 8). This will allow proper calibration zero readings at zero flow.

Remember to restore the ABZ function after calibration by removing this connection.

4. Apply power and allow 10 minutes for system warm up and stabilization.

5. Connect the voltmeter or ammeter, whichever is applicable, to the output signal, FSIG pin 2 and pin 4 (signal common).

6. Measure and adjust

6.1 Use the three (3) trimpots located at the top of the PCB assembly, position 1 (ZERO), 2 (LIN) and 3 (MS), from left to right with the 9-pin D-connector on right (position 4 is VREF).

6.2 Note: If the MFM is significantly out of calibration, the LIN (linearity) trimpot may require an initialization adjustment prior to the calibration steps. Turn the LIN trimpot counter clockwise to the limit of its travel.

6.3

Step	Set Gas Flow (Vol. Cal. Device)	Adjust Trimpot (position/label)	Flow Signal Output (Vdc at pin 2)	Flow Signal Output (mAdc at pin 2)
1	10% of range	1/Z	0.000 (±5mV)	4.00 (±0.016mAdc)
2	50% of range	3/MS	2.500	12.00
3	100% of range	2/LIN	5.000	20.00

Z = Zero; LIN = Linearity; MS =Mid-Span

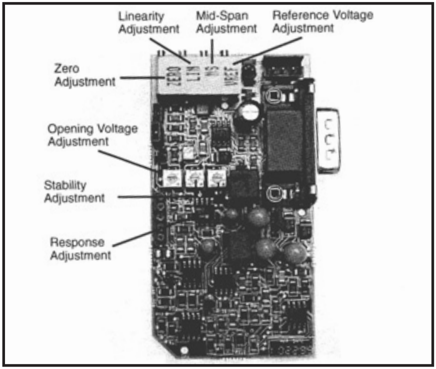
6.3 Calibration Procedure (Con't)

6.4 Repeat steps 1 through 3 above until the deviations between the desired values and the adjusted values are within acceptable limits.

6.5 Establish a dynamic flow measurment system having the capacity to change flow quickly, one flow to a second flow.

6.6 Locate the row of three (3) low-profile trimpots directly below (apprximately ½") the flow trimpots on the PCB assembly. The trimpot for response is position 3 from the left, with the 9-pin D-connector on right.

6.7 Adjust the response trimpot until the desired response to a setpoint change is established. Observe the actual flow response and the degree of match of the flow signal to the actual flow response.



For Series FMA-700A MFC's:

1. Remove the cover to gain access to the PCB assembly.
2. **Check Reference Voltage:** Pin 1 has dual functions. When connected to a digital voltmeter, Pin 1 [V REF] and Pin 4 [SIGNAL COMMON], pin 1 provides a reference voltage measurment.
   2.1 The reference voltage may be adjusted to +5 Vdc by reading the digital voltmeter and adjusting the VREF trimpot located on the PCB assembly (with 9-pin D-connector on right, far right trimpot in row of four trimpots at top of PCB assembly).

6.3 Calibration Procedure (Con't)

2.2 Verify the reference voltage is appropriately set at +5 Vdc, corresponding to desired setpoint and output ranges. If the reference voltage feature is not to be used, precise setting beyond being in the proper range is not required.

2.3 If the reference voltage feature is to be used, it must be precisely set first and not readjusted after further calibration adjustments of other trimpots

3. **Disable ABZ** by connecting pin 1 to the power supply 0 Vdc (power supply 0 Vdc or POWER COMMON/0 VDC, pin 8). This will allow proper calibration zero readings at zero flow. ***Remember to restore the ABZ function after calibration by removing this connection.***
4. Adjust SETPOINT input to (0%)
5. Apply power and allow 10 minutes for system warm up and stabilization.
6. Connect the voltmeter or ammeter, whichever is applicable, to the output signal, pin 2 (FSIG) on pin 4 (SIGNAL COMMON)
7. **Measure and adjust**

7.1 Adjust SETPOINT input to approximately (5%) and establish a controlled flow at that setpoint.

7.2 Locate the row of three (3) low-profile trimpots directly below (approximately ½") the flow trimpots on the PCB assembly. The trimpot for opening voltage setting is position 1 on the left, with the 9-pin D-connector on right.

8. **Set opening voltage o**f proportional control valve. (Reset when valve is reasembled)

8.1 Use the three (3) trimpots located at the top of the PCB assembly, position 1 (ZERO), 2 (LIN) and 3 (MS), from left to right with 9-pin D-connector on right (position 4 is VREF).

8.2 Note: If the MFC is significantly out of calibration, the LIN (linearity) trimpot may require an initialization adjustment prior to the calibration steps. Turn the LIN trimpot counterclockwise to the limit of its travel.

8.3

Step	Set Gas Flow (Vol. Cal. Device)	Adjust Trimpot (position/label)	Flow Signal Output (Vdc at pin 2)	Flow Signal Output (mAdc at pin 2)
1	0% of range	1/Z	0.000 (±5mV)	4.00 (±0.016mAdc)
2	50% of range	3/MS	2.500	12.00
3	100% of range	2/LIN	5.000	20.00

Z = Zero; LIN = Linearity; MS =Mid-Span

8.4 Repeat steps 1 through 3 above until the deviations between the desired values and the adjusted values are within acceptable limits.

6.3 Calibration Procedure (Con't)

8.3 Turn the opening voltage trimpot until the LED directly above the trimpot on the PCB assembly turns red. Turn the trimpot back again until the LED turns green. With this transition point established, leave the trimpot in the position with the LED green, and where a slight trimpot movement would turn the LED red. The opening voltage of the proportional control valve is now incorporated into the closed loop control threshold.

9. **Adjust Stability**

   9.1 Establish a dynamic flow measurement system with a linear flow restriction downstream of the MFC. The restrictive should create an approximate 35 mbar pressure drop at full flow of the MFC.

   9.2 Establish an MFC flow at a typical flow rate used in the process and observe the stability of flow using appropriate techniques of metrology (i.e. smoothness of volume tube piston travel, actual flow strip chart recording, oscilloscope measurement of output signals, etc).

   9.3 Locate the row of three (3) low-profile trimpots directly below (approximately ½") the flow trimpots on the PCB assembly. The trimpot for stability is position 2 from the left, with the 9-pin D-connector on right. Adjust the stability trimpot until the desired stability is established.

10. **Adjust Response**

   10.1 Establish a system of successive controller setpoints at flows of typical flow rates used in the process and observe the response time of actual flow using appropriate techniques of metrology.

   10.2 Locate the row of three (3) low-profile trimpots directly below (approximately ½") the flow trimpots on the PCB assembly. The trimpot for response is position 3 from the left, with the 9-pin D-connector on right.

   10.3 Adjust the response trimpot until the desired response to a setpoint change is established. Observe the actual flow response and the degree of match of the flow signal to the actual flow response.

11. **Stability and Response Interaction.**

   The stability trimpot may be adjusted again to further improve overall response and stability, as the two adjustments have a slight interaction.

INPUT/OUTPUT (I/0) DESIGNATIONS & ELECTRICAL SPECIFICATIONS

7

7.1 INPUT/OUTPUT (I/0) DESIGNATIONS (Electrical Connections)

SERIES FMA-800A MASS FLOWMETER

D-CONNECTOR PIN#	NAME/FUNCTION	INPUT/OUTPUT	COMMENTS
1	_	_	Connected only for ABZ disable
2	FSIG	Output	Flow Signal
3	_	_	No connection
4	SIGNAL COMMON	Input	Signal common; separate wire
5	_	_	No connection
6	_	_	No connection
7	POWER IN	Input	Power in
8	POWER COMMON/ 0 VDC	Input	Power common; separate wire
9	SHIELD	Input	Cable Shield

SERIES FMA-700A MASS FLOW/CONTROLLER

D-CONNECTOR PIN#	NAME/FUNCTION	INPUT/OUTPUT	COMMENTS
1	VREF	Output	Reference voltage or ABZ disable
2	FSIG	Output	Flow Signal
3	STPT	Input	Setpoint
4	SIGNAL COMMON	Input	Signal common; separate wire
5	VLVTST	Output/ Input	Valve voltage monitor or Simple Valve Override (SIM-VO)
6	_	_	No connection
7	POWER IN	Input	Power in
8	POWER COMMON/ 0 VDC	Input	Power common; separate wire
9	SHIELD	Input	Cable Shield

7.2 I/O Electrical Specifications

SERIES FMA-800A FLOWMETER (VOLTAGE OUTPUT)
(Note - Values typical unless otherwise noted)

+15 VDC		
	Voltage limits - maximum	+16.5 Vdc
	Voltage limits - minimum	+11.4 Vdc
	Current draw FMA-800A MFM's	<45 mAdc
	Current draw FMA-700A MFC's	<250 mAdc
Flow Signal		
	Output voltage (with ABZ enabled)	0-5 Vdc for 0-100% flow
	Output current limit	4 mAdc nominal
	External load resistance (reference to signal common).	2K min.
	Common reference	Power common

SERIES FMA-700A FLOW CONTROLLER (VOLTAGE OUTPUT)
(Note - Values typical unless otherwise noted)

+15 VDC		
	Voltage limits - maximum	+16.5 Vdc
	Voltage limits - minimum	+11.4 Vdc
	Current	<45 mAdc
Flow Signal		
	Output voltage (with ABZ enabled)	0-5 Vdc for 0-100% flow
	Output current limit	4 mAdc nominal
	External load resistance (reference to signal common)	2K min. for 0-5 Vdc flow signal
	Common reference	Signal common
Setpoint	Input voltage (for 0-100% flow control):	
	Normal	0 - 5 Vdc
	Limits	-2.5 to +11 Vdc
	Input current	< +50 microamp
	Input impedance	100k ohm in parallel with 0.1 mF
	Common reference	Power common

7-2 I/O Electrical Specification (Con't)

CURRENT LOOP

(Note - Values typical unless otherwise noted)

Power Supply	
Voltage limits	
Maximum	+27.6 Vdc
Minimum	14.25 Vdc
Current Configuration	
Series FMA-800A MFM's	<45 mAdc
Series FMA-700A MFC's	<250 mAdc
Flow Signal	
Output current (with ABZ enabled)	4-20 mAdc for 0 to 100%
Overrange capacity	10%
Output current limit	<30 mAdc
Output current maximum (for input signal fault)	26 mAdc
Output protection (continuous)	30 Vdc maximum
External load resistance (reference to power common)	0-supply voltage 200-750 ohm for 10-30 Vdc supply voltage
Loop driver voltage compliance	5.5-30 Vdc (with approdriate driver power dissipation limit
Common reference	Power common (sourcing current driver)
Setpoint (applicable to Series FMA-700A MFC's only)	
Input current (for 0-100% flow control)	
Normal	1-5 Vdc
Limits:	
Maximum	+11 Vdc
Minimum	-2.5 Vdc
Input offset (internal) value	<3.5 Vdc
Load resistance	Refer to figure 8.1
Output voltage maximum (for current loop input signal fault >20 mAdc but <40 mAdc)	<15 Vdc
Output protection (continuous)	30 Vdc maximum
Input current (V_{in} =+5 Vdc)	<+6 microamp
Input impedance	100k phm in parallel with .01
Common reference	Power common

7.3 Simple Valve Override (SIM-VO)

TO ACTUATE

Voltage (maximum) .... +0.40 Vdc
Voltage (minimum) .... -0.30 Vdc

Resistance (R_{SIM-VO}) to 0 Vdc (maximum) .... 275 ohms
Resistance (R_{SIM-VO}) to 0 Vdc (minimum) .... 0 ohms
Resistance to 0 Vdc (minimum) .... 0 ohms

Current from VLVTST (pin 5) to 0 Vdc with
R_{SIM-VO} = 0 ohms .... <1.6 mAdc

NON-ACTUATE (DEFEAT)

Voltage (minimum) .... +0.90 Vdc
Voltage (maximum) .... +17 Vdc
Resistance (R_{SIM-VO}) to 0 Vdc (minimum) .... >30K ohms
Current from VLVTST (pin 5) to 0 Vdc with
R_{SIM-VO} .... Refer to notes 2 &3

NOTE

1. R_{SIM-VO} represents a resistance connected between the VLVTST signal connection and 0 Vdc.
2. Current from VLVTST (pin 5) to 0 Vdc is variable and a function of R_{SIM-VO} and VLVTST voltage.
3. Ant resistance greater than 30K ohm connected between the VLVTST signal connection and 0 Vdc will not enable SIM_VO but remains a part of a resistive divider for Valve Test Voltage. The charge (error) introduced by the SIM_VO actuation resistance is defined as:

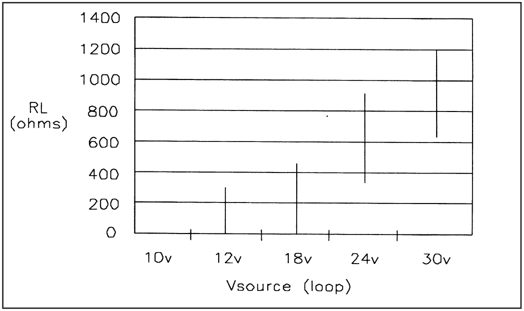
   $$\text{VLVTST (with } R_{SIM-VO}) = (R_{SIM-VO}/(R_{SIM-VO} + 10K)) \times \text{VLVTST (open circuit)}$$

4. Logic level devices may be used to actuate the SIM-VO function as long as the ACTUATE and NON-ACTUATE (DEFEAT) voltage and current conditions are satisfied. Note when SIM-VO is not actuated, voltage at VLVTST, under normal operation, can range from +1-13.5 Vdc connected to a low impedance source through a 10K ohm resistor. Logic level devices connected to VLVTST must be capable of withstanding this range of voltages.
5. VLVTST may be connected to any voltage between +0.90-17 Vdc without affecting proportional valve operation or invoking SIM-VO.

CURRENT LOOP SPECIFICATIONS 8

The Series FMA-800A MFM's and Series FMA-700A MFC's have available PCB assemblies which can be configured to provide flow signal output in a 4-20 mAdc current loop mode. The on-board current driver is not isolated and is electrically referenced to the power supply common of the MFM/MFC. Figure 8-1 indicates valid and safe flow signal output load resistance as related to various loop supply voltage sources. Additionally, the current driver is usable as a current sink and recommended connections are illustrated in Figure 8-2A. As a protection, in the event of a loop fault, the current driver limits output current.

Figure 8-1
Flow Signal Output Load Resistance



With the 9-pin D-connector on the right, locate the row of three (3) low-profile trimpots directly below (approximately ½") the flow trimpots on the PCB assembly. On the left and directly below the low-profile trimpots, locate (2) blue jumper blocks. To the left of the jumper blocks is a five (5)-pin connector, the sensor assembly's connection to the PCB assembly. Note the orientation of the sensor assembly's 5-pin connector (pin having red shrink sleeve on bottom). Disconnect the sensor assembly's 5-pin connector form the PCB assembly. To configure the PCB assembly as a sinking current driver, position the jumper blocks to connect pins 2 & 3 and 5 & 6.

After configuring the PCB assembly appropriately, reconnect the sensor assembly's 5-pin connector to the PCB assembly.

When used as a current sink, there may be a separate power supply for the instrument (V) and for the loop (Vs). With the loop configured to use the current drivers as a current source, the display load should be referenced to the instrument power supply common.

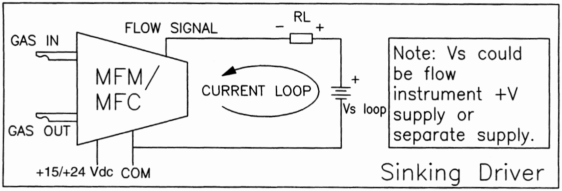


Figure 8-2A
Recommended Electrical Connections for Sinking Current Driver

GAS CONVERSION FACTORS

Flowmeters and flow controllers are shipped from the factory calibrated for use with a specific gas. The original calibration conditions are stated on the serial tag attached to the top of the p.c. board cover.

It is desired to use a flowmeter or contoller with a gas other than the original calibration gas, the following calibration is necessary.

Select the conversion factor for each gas from the chart. Multiply the output reading by the ratio of the conversion factor for the desired gas to the conversion factor for the calibration gas.

Example: Meter calibration on N_2 (200 cc/min.), Gas flow passing the meter is CO_2, Output signal is 80.0% (4V), Actual CO_2 flow = $80.0 \times \frac{0.745}{1.000} = 59.6\%$ or $\frac{59.6}{100} \times 200 = 119.2$ cc/min.

Gas	Symbol	Conversion factor	Specific heat C_p at 25° and 1 atm. kcal/kgK	Density at 0° and 1 atm. kg/m^3
Acetylene	C_2H_2	0.602	0.391	1.162
Air	–	1.000	0.240	1.293
Allene (Propadiene)	C_3H_4	0.43	0.352	1.787
Ammonia	NH_3	0.73	0.492	0.760
Argon	Ar	1.443	0.1244	1.782
Arsine	AsH_3	0.662	0.1167	3.478
Boron Trichloride	BCl_3	0.41	0.1279	5.227
Boron Trifluoride	BF_3	0.51	0.1778	3.025
Bromine	Br_2	0.81	0.0539	7.130
Bromine Pentafluoride	BrF_5	0.26	0.1369	7.803
Bromine Trifluoride	BrF_3	0.38	0.1161	6.108
Bromo Trifluoromethane (Freon-13 B1)	$CBrF_3$	0.37	0.1113	6.644

Gas	Symbol	Conversion factor	Specific heat C_p at 25° and 1 atm. kcal/kgK	Density at 0° and 1 atm. kg/m^3
Butadiene	C_4H_6	0.32	0.3514	2.413
Butane	C_4H_{10}	0.26	0.4007	2.593
1-Butene	C_4H_8	0.295	0.3648	2.503
2-Butene (Cis)	C_4H_8	0.324	0.336	2.503
2-Butene (Trans)	C_4H_8	0.291	0.374	2.503
Carbon Dioxide	CO_2	0.745	0.2016	1.964
Carbon Disulfide	CS_2	0.60	0.1428	3.397
Carbon Monoxide	CO	1.001	0.2483	1.250
Carbon Tetrachloride	CCl_4	0.309	0.1655	6.860
Carbonyl Fluoride	COF_2	0.420	0.1710	2.045
Carbonyl Sulfide	COS	0.544	0.1651	2.680
Carbon Tetrafluoride	CF_4	0.640	0.1654	3.926
Chlorine	Cl_2	0.852	0.1144	3.163
Chlorine Trifluoride	ClF_3	0.403	0.1650	4.125
Chloro Difluoromethane (Freon-22)	$CHClF_2$	0.456	0.1544	3.858
Chloroform	$CHCl_3$	0.388		
Chloro Pentafluoro-ethane (Freon-115)	C_2ClF_5	0.24	0.164	6.892
Chloro Trifluoro-methane (Freon-13)	$CClF_3$	0.38	0.153	4.660
Cyanogen	C_2N_2	0.44	0.2613	2.322
Cyanogen Chloride	ClCN	0.61	0.1739	2.742
Cyclopropane	C_3H	0.460	0.3177	1.877
Deuterium	D_2	1.003	1.722	0.1799
Diborane	B_2H_6	0.434	0.508	1.235
Dibromo Difluoro-methane	CBr_2F_2	0.19	0.15	9.362
Dichloro Difluoro-methane (Freon-12)	CCl_2F_2	0.354	0.1432	5.395
Dichloro Fluoromethane (Freon-21)	$CHCl_2F$	0.417	0.140	4.592

Gas	Symbol	Conversion factor	Specific heat C_p at 25° and 1 atm. kcal/kgK	Density at 0° and 1 atm. kg/m^3
Dichloro Methyl Silane	$(CH_3)_2SiCl_2$	0.25	0.1882	5.758
Dichloro Silane	SiH_2Cl_2	0.40	0.150	4.506
1,2-Dichloro Tetrafluoro-ethane (Freon-114)	5 $C_2Cl_2F_4$	0.22	0.160	7.626
1,1-Difluoro Ethylene (Freon-1132A)	$C_2H_2F_2$	0.43	0.224	2.857
Dimethylamine	$(CH_3)_2NH$	0.370	0.366	2.011
Dimethylether	$(CH_3)_2O$	0.390	0.3414	2.055
2,2-Dimethylpropane	C_5H_{12}	0.22	0.3914	3.219
Ethane	C_2H_6	0.497	0.4097	1.342
Ethyl Acetylene	C_4H_6	0.32	0.3513	2.413
Ethylchloride	C_2H_5Cl	0.40	0.244	2.879
Ethylene	C_2H_4	0.622	0.351	1.252
Ethylene Oxide	C_2H_4O	0.52	0.268	1.965
Fluorine	F_2	0.978	0.1873	1.695
Fluoroform (Freon-23)	CHF_3	0.506	0.176	3.127
Freon-11	CCl_3F	0.34	0.1357	6.129
Freon-12	CCl_2F_2	0.34	0.1432	5.395
Freon-13	$CClF_3$	0.383	0.153	4.661
Freon-13 B1	$CBrF_3$	0.36	0.1113	6.644
Freon-14	CF_4	0.41	0.1654	3.926
Freon-21	$CHCl_2F$	0.42	0.140	4.592
Freon-22	$CHClF_2$	0.438	0.1579	3.939
Freon-23	CHF_3	0.50	0.176	3.127
Freon-113	CCl_2FCClF_2	0.20	0.161	8.360
Freon-114	$C_2Cl_2F_4$	0.22	0.160	7.626
Freon-115	C_2ClF_5	0.24	0.164	6.892
Freon-116	F_3CCF_3	0.24	0.1843	6.157
Freon-C318	C_4F_8	0.17	0.185	8.397
Freon-1132A	$C_2H_2F_2$	0.43	0.224	2.857
Genetran-21	$CHCl_2F_4$	0.41		
Genetran-115	C_2ClF_5	0.24		
Germane	GeH_4	0.596	0.1404	3.418
Germanium Tetra-chloride	$GeCl_4$	0.27	0.1071	9.565

Gas	Symbol	Conversion factor	Specific heat C_p at 25° and 1 atm. kcal/kgK	Density at 0° and 1 atm. kg/m^3
Helium	He	1.444	1.241	0.1786
3-Helium	$_3He$	1.45		
Hexafluoro-ethane	C_2F_6	0.24	0.1843	6.157
Hydrogen	H_2	1.021	3.3852	0.0899
Hydrogen Bromide	HBr	0.985	0.0874	3.610
Hydrogen Chloride	HCl	0.998	0.1912	1.627
Hydrogen Cyanide	HCN	0.76	0.3171	1.206
Hydrogen Fluoride	HF	0.997	0.3479	0.893
Hydrogen Iodide	HI	0.999	0.5449	5.707
Hydrogen Selenide	H_2Se	0.78	0.1025	3.613
Hydrogen Sulfide	H_2S	0.799	0.2397	1.520
Iodine Pentafluoride	IF_5	0.25	0.1108	9.90
Isobutane	C_4H_{10}	0.26	0.3872	3.593
Isobutylene	C_4H_8	0.29	0.3701	2.503
Krypton	Kr	1.45	0.0593	3.739
Methane	CH_4	0.731	0.5223	0.716
Methyl Acetylene	C_3H_4	0.43	0.3547	1.787
Methylamine	CH_4N	0.491		
Methyl Bromide	CH_3Br	0.56	0.1106	4.236
Methyl Chloride	CH_3Cl	0.63	0.1926	2.253
Methyl Fluoride	CH_3F	0.559	0.3221	1.517
Methyl Mercaptan	CH_4S	0.52	0.2459	2.146
Methyl Trichlorosilane	CH_3SiCl_3	0.250	0.164	6.669
Molybdenum Hexa-fluoride	MoF_6	0.21	0.1373	9.366
Monoethylamine	$C_2H_5NH_2$	0.35	0.387	2.011
Monomethylamine	CH_3NH_2	0.45	0.4343	1.386
Neon	Ne	1.445	0.246	0.900
Nitric Oxide	NO	0.997	0.2328	1.339
Nitrogen	N_2	1.000	0.2485	1.250
Nitrogen Dioxide	NO_2	0.74	0.1933	2.052
Nitrogen Fluoride	NF_3	0.48	0.1797	3.168
Nitrosyl Chloride	NOCl	0.61	0.1632	2.920
Nitrous Oxide	N_2O	0.713	0.2088	1.964
Octafluorocyclobutane (Freon-C318)	C_4F_6	0.17	0.185	8.937

Gas	Symbol	Conversion factor	Specific heat C_p at 25° and 1 atm. kcal/kgK	Density at 0° and 1 atm. kg/m^3
Oxygen	O	0.994	0.2190	1.428
Oxygen Difluoride	OF_2	0.63	0.1917	2.409
Pentaborane	B_5H_9	0.26	0.38	2.816
Perchloryl Fluoride	ClO_3F	0.39	0.1514	4.571
Tetrafluoroethvlene	C_2F_4	0.33		
Perfluoropropane	C_3F_8	0.17	0.194	8.388
Phosgene	$COCl_2$	0.44	0.1394	4.418
Phosphine	PH_3	0.76	0.2374	1.517
Phosphorus Penta-fluoride	PF_5	0.30	0.1610	5.620
Propane	C_3H_8	0.372	0.3735	1.967
Propylene	C_3H_6	0.405	0.3541	1.877
Silane	SiH_4	0.596	0.3189	1.433
Silicon Tetrachloride	$SiCl_4$	0.288	0.1270	7.580
Silicon Tetrafluoride	SiF_4	0.35	0.1691	4.643
Sulfur Dioxide	SO_2	0.687	0.1488	2.858
Sulfur Hexafluoride	SF_6	0.27	0.1592	6.516
Sulfuryl Fluoride	SO_2F_2	0.39	0.1543	4.562
Tetrafluorhydrazine	N_2F_4	0.32	0.183	4.640
Performa-ethylene	C_2F_4	0.33		
Trichlorofluoromethane (Freon-11)	CCl_3F	0.33	0.1357	6.129
1,1,2-Trichloro-1,2,2-				
Tri-isobutyl Aluminium	$(C_4H_9)_3Al$	0.061	0.508	8.848
Trimethylamine	$(CH_3)_3N$	0.27	0.3710	2.639
Tungsten Hexafluoride	WF_6	0.25	0.0810	13.28
Uranium Hexafluoride	UF_6	0.20	0.0888	15.70
Vinyl Bromide	C_2H_3Br	0.46	0.1241	14.772
Vinyl Chloride	C_2H_3Cl	0.48	0.2054	2.788
Vinyl Fluoride	C_2H_3F	0.551		
Xenon	Xe	1.41	0.0378	5.858

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's 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 malfunctions, 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 having been 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 in which wear is not warranted, include but are not limited to contact points, fuses, and triacs.

OMEGA is pleased to offer suggestions on the use of its various products. However, OMEGA neither assumes responsibility for any omissions or errors nor assumes liability for any damages that result from the use of its products in accordance with information provided by OMEGA, either verbal or written. OMEGA warrants only that the parts manufactured by the company 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 purchaser 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.

CONDITIONS: Equipment sold by OMEGA is not intended to be used, nor shall it be used: (1) as a "Basic Component" under 10 CFR 21 (NRC), used in or with any nuclear installation or activity; or (2) in medical applications or used on humans. Should any Product(s) be used in or with any nuclear installation or activity, medical application, used on humans, or misused in any way, OMEGA assumes no responsibility as set forth in our basic WARRANTY/ DISCLAIMER language, and, additionally, purchaser will indemnify OMEGA and hold OMEGA harmless from any liability or damage whatsoever arising out of the use of the Product(s) in such a manner.

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

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