User's Guide

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FMA-1900
Mass Flow Meter

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CAUTION Over-tightening the pipe connection may crack the fittings or shift the calibration of the FMA-1900 controller.

CAUTION The maximum pressure and temperature in the flow line in which your FMA-1900 is to be installed should not exceed 150 psig (10 kg/cm^2 gauge) or 122°F (50°C), respectively.

CAUTION The FMA-1900 is not a loop powered device! Do NOT apply power to the 4-20 mA output or input section.

CAUTION The FMA-1900 controller requires a 24 VDC regulated power supply (50 mV RMS ripple) with the ability to provide at least 6 watts (250mA) @ 24 VDC ±10%. If you are providing your own power source, refer to Section 2.3, paragraph 8, for specific power supply requirements and jumper settings.

CAUTION Do not use liquid leak detectors to search for leaks inside or outside the FMA-1900. Instead, monitor pressure decay.

Operator's Manual
M2483/0898

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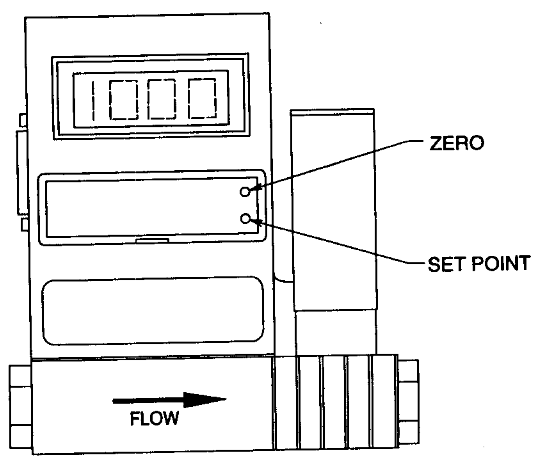
INTRODUCTION

1.1 Description

Omega's FMA-1900 Series products can be calibrated to measure and control the mass flow rate of gases in several ranges from 0-10 standard cubic centimeters per minute (SCCM) to 0-50 standard liters per minute (SLM). Accuracy is ±1.5% of full scale over a wide temperature and pressure range, and time response is 5 seconds to within 2% of set point.

The FMA-1900 is ideal for a complete range of gas flow applications including general process control, laboratories, instrument OEM's, gas panels, and flow calibration.

Figure 1-1 The FMA-1900 Flow Controller



The versatile FMA-1900 product digitally displays the mass flow rate directly in engineering units or percent of full scale.

The FMA-1900 is a transducer requiring a regulated 24 VDC external power source. The 0-5 VDC and 4-20 mA output signals, which are linearly proportional to gas mass flow rate, are provided for recording, data-logging, or control. A 15-pin "D" connector is provided for power input, output signal and set point control. FMA-1900 is available in several basic configurations with either NPT (female) or compression inlet/outlet fittings, and with or without the optional power supply.

1.2 Specifications

FLOW RATES: 0-10 SCCM to 0-50 SLM; flow ranges specified are for an equivalent flow of nitrogen at 760 mm Hg and 21.1°C (70°F). Other ranges in other units are available (e.g., SCFH or nm^3/h).

FMA-1900 SERIES MINIMUM DP REQUIREMENTS: 5-50 PSI (0.35-3.5 kg/cm^2) differential standard; 30 PSI (2 kg/cm^2) optimum.

GASES: Most gases (e.g., air, nitrogen, methane, carbon dioxide, argon, helium, hydrogen); check compatibility with wetted materials; specify when ordering.

OUTPUT SIGNALS: Linear 0-5 VDC into 2000 Ohm minimum load resistance standard or linear 4-20 mA into 1000 ohm maximum load resistance for 24 VDC supply (500 ohm/15 VDC supply).

CONTROL RANGE: Calibrated for 10 to 100% of full scale.

INPUT POWER: 0 to 15 SLM/15 VDC ±10%; 0 to 50 SLM/24 VDC ±10%

ACCURACY: ±1.5% of full scale from 10-100% of full scale.

REPEATABILITY: ±0.25% of full scale.

TEMPERATURE COEFFICIENT: 0.08% of full scale per °C, or better.

PRESSURE COEFFICIENT: 0.02% of full scale per PSI (0.07 kg/cm^2), or better:

RESPONSE TIME: One second to 63% of final value.

GAS PRESSURE: 150 PSI (10 kg/cm^2) gauge maximum; 20 PSI (1.4 kg/cm^2) gauge optimum.

LEAK INTEGRITY: 1 x 10^{-4}ATM cc/sec of helium maximum to outside environment. (Not recommended for use as a positive shut-off valve.)

GAS AND AMBIENT TEMPERATURE: 32° to 122°F (0 to 50°C)

WETTED MATERIALS: 10% glass-filled Nylon 6/6; 316 stainless steel, 430F stainless steel; nickel plating; Viton "O"-rings.

SETPOINT COMMAND SIGNALS: 0-5 VDC (0-10 VDC optional) into ≥2000 Ohms. 0-20 mA and 4-20 mA into 250 Ohms input impedance.

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INSTALLATION

2.1 Receipt of Your FMA-1900

After receiving your FMA-1900, carefully check the outside of the packing carton for damage incurred in shipment. If the packing carton is damaged, notify the carrier at once regarding their liability. A report with the serial number and part number should be submitted to Customer Service. Call 800-622-2378 for detailed instructions.

Remove the packing slip from its envelope and check that the carton contains all parts listed. Make sure spare parts or accessories are not discarded with the packing material. In case of shortages, contact 800-872-9436 (800-USA-WHEN). Have your purchase order and model number available.

2.2 Return Shipment

Do not return any equipment without a Return Authorization, obtainable from the Customer Service Department at the number shown above.

Information describing the problem, the corrective action or work to be accomplished at the factory, the purchase order number under which the work is to be done, and the name of person to contact must be included with the returned equipment.

NOTE: Equipment returned for repair that is found to be completely operational will be subject to the current "no problem found" billing rate. In a case such as this, Omega will attempt to identify possible problems with the installation or application.

2.3 Before Beginning the Installation

Read the following notes in their entirety before beginning actual installation of your FMA-1900 flow controller.

1. Using the flow direction arrow on the FMA-1900 to properly orient the controller, install the FMA-1900 into the gas flow line. If you are utilizing 1/4-inch pipe, use a good quality paste pipe thread sealant. First tighten the fittings by hand, then tighten no more than one and a half turns to avoid cracked fittings or creating a calibration shift.

   The line pressure and temperature should not exceed 150 psig (10 kg/cm^2 gauge) or 150°F (66°C). Maximum operating pressure differential is 50 psig.

2. Apply power to your FMA-1900. If you are using the Omega power supply, connect it to the 15-pin "D" connector on the side of your FMA-1900, then plug the power supply into line power. If you are providing your own power source, refer to Section 2.3, paragraph 8, for specific power supply requirements and jumper settings.

3. Upon application of power, the output signal will be at a high level for the first 10 to 20 seconds, after which (assuming zero flow) it will drop to 0 VDC (or 4mA, depending on output configuration). Allow at least 15 minutes for complete warm-up.

   CAUTION: The FMA-1900 is not a loop powered device! Do NOT apply power to the 4-20 mA output or input section.

4. After the warm-up period, your FMA-1900 will begin monitoring the gas mass flow rate.

5. Output Signals: The FMA-1900 has either 0-5 VDC (0-10 VDC optional) or 4-20 mA output signals. The effective control range of the unit is 10% to 100% of the calibrated flow range. The output is linearly proportional to the gas mass flow rate. The full scale range and the gas for which the unit was calibrated are shown on the FMA-1900 data tag. Section 2.6, ELECTRICAL CONNECTIONS, describes the electrical output signal hookup. For example, if you are monitoring the 0-5 VDC output signal, 5.00 VDC is the output signal for the full scale listed on the FMA-1900 data tag; 2.50 VDC is for one-half of full scale; and 0.00 VDC is for zero flow. If you are monitoring the 4-20 mA output signal, 20.00 mA is the output signal for the full scale; 12.00 mA is for one-half of full scale; and 4.00 mA is for zero flow.

6. Integral Display: The 3 1/2 digit LCD display reads directly in engineering units or optional percent of full scale. The full scale range and gas are shown on the instrument data tag. The decimal point for the flow rate is set at the factory and will show automatically (e.g., "5.54" SLM or "76.4" %).

7. Overrange conditions are indicated by the display and/or output going to a high level, above the full scale range. After the over-range condition has been removed, it may take several minutes for the FMA-1900 to recover and resume normal operation.

8. The FMA-1900 has more stringent power supply requirements due to the presence of the valve. Because the valve is operated in a control loop, power supply variations cannot be tolerated. This means the power supply must be a regulated 24 VDC with ripple not to exceed 50mV peak to peak, and capable of producing at least 250mA (6 watts).

   The standard power supply for both the FMA-1900 is 24 VDC. It is possible to operate the FMA-1900 on 15 VDC at reduced performance levels. There is a direct relationship between the amount of power the valve requires and the flow rate. Due to this relationship, 15 VDC powered controllers are limited to a flow rate of 15 SLM. To achieve flow rates above 15 SLM, use a 24 VDC power supply.

   The minimum power requirements for all FMA-1900 controllers are as follows:

   - 15 VDC @ 160mA, Jumper J3 closed (shorting block installed) [If less than 15 SLM].
   - 24 VDC @ 250mA, Jumper J3 open (shorting block removed) [15 to 250 SLM].
   - A regulated power supply is required. Ripple content should not exceed 50mV peak to peak.
   - Refer to the component location diagram (Figure 3-2) for the location of Jumper J3.

2.4 Mechanical Installation

CAUTION: The maximum pressure and temperature in the flow line in which your FMA-1900 is to be installed should not exceed 150 psig (10 kg/cm^2 gauge) or 122°F (50°C), respectively.

In order to ensure a successful installation, inlet and outlet tubing or piping should be in a clean state prior to plumbing your FMA-1900 to the system. FMA-1900 is applicable to clean gas only because particulates and other foreign matter may clog the sensor tube and laminar flow element over a period of time. If the gas contains particulate matter install a high-efficiency, 50 to 100 micron, in-line filter upstream of the FMA-1900.

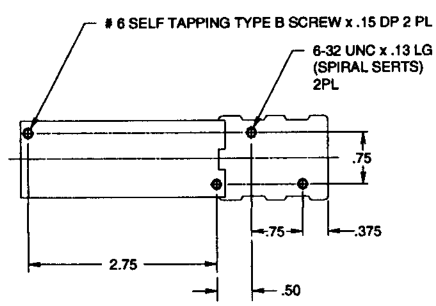
Do not locate the FMA-1900 in areas subject to sudden temperature changes, moisture, or near equipment radiating significant amounts of heat. Allow adequate space for cable connectors and wiring. Be sure the arrow on the side of the transducer points in the direction of flow. You can obtain best results if you operate the FMA-1900 in the plane in which it was calibrated. If you mount the unit in a position other than its calibrated position, you may have mild to severe performance problems. (See Section 3.6.)

CAUTION: Do not use liquid leak detectors to search for leaks inside or outside the FMA-1900. Instead, monitor pressure decay.

Mount the FMA-1900 to a chassis with two #6, type "B" self-tapping screws.

CAUTION: These screws should extend into the flow body no further than .15" (4mm). If screws extend further than .15" (4mm), the flow body may be damaged. See Figure 2-1.

Figure 2-1 Mounting the FMA-1900 Series



2.5 Plumbing Connections

Your FMA-1900 transducer is supplied with either female NPT (standard) or compression inlet and outlet fittings. These fittings should not be removed unless your FMA-1900 is being cleaned or calibrated for a new flow range. 1/4-inch pipe requires a good quality, paste, pipe thread sealant which should be used in the inlet and outlet fittings. Tighten fitting only one and a half turns past hand tight.

CAUTION: Over-tightening the pipe connection may crack the fittings or shift calibration.

For installation of 1/4-inch (outside diameter) compression fittings, simply 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. Scribe the nut at the six o'clock position. While holding the fitting body steady with a back-up wrench, tighten the nut one and a quarter turns, watching the scribe mark make one complete revolution and continue to the nine o'clock position. After this, the fitting can be reconnected by snugging with a wrench. *Use a back-up wrench to avoid damaging the inlet fitting.*

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

CAUTION: All instruments are leak-tested prior to shipping. To check your installation, test the fittings only. Do not use liquid leak detectors to search for leaks inside or outside the FMA-1900. Instead, monitor pressure decay.

IMPORTANT

Install a section of straight pipe at least five pipe diameters in length upstream of the transducer. DO NOT use reducers. If the gas contains any particulate matter, an in-line filter is recommended. There can be no restrictions (such as valves, tubing or piping internal diameters, reducers, etc.) upstream or downstream of the MFC less than the valve orifice diameter. Failure to comply with this requirement will result in severely impaired performance and possible oscillations in flow controllers. Refer to Table 2-1 for minimum restriction diameters upstream or downstream of the flow controller.

TABLE 2-1 TYPICAL MINIMUM RESTRICTION DIAMETERS
(Under Standard ΔP Conditions of 30 PSIG Inlet and Ambient Outlet)

Flow Ranges Relative to N2	Valve Orifice Diameter (Typical-in inches)
0-10 to 0-500 SCCM	0.02
0-500 to 0-1000 SCCM	0.03
0-2 to 0-5 SLM	0.05
0-10 SLM	0.05
0-15 SLM	0.065
0-30 to 0-50 SLM	0.083

2.6 Electrical Connections

CAUTION: The FMA-1900 is not a loop powered device! Do NOT apply power to the 4-20 mA output or input section.

FMA-1900 is provided with a 15-pin "D" connector located on the side of theFMA-1900 enclosure. The pin numbers of this "D" connector are shown in Figure 2-2, and the pin assignments are given in Table 2-2. Operating power input and output signals are supplied via the "D" connector.

Figure 2-2 "D" Connector Location and Pin Number Assignments

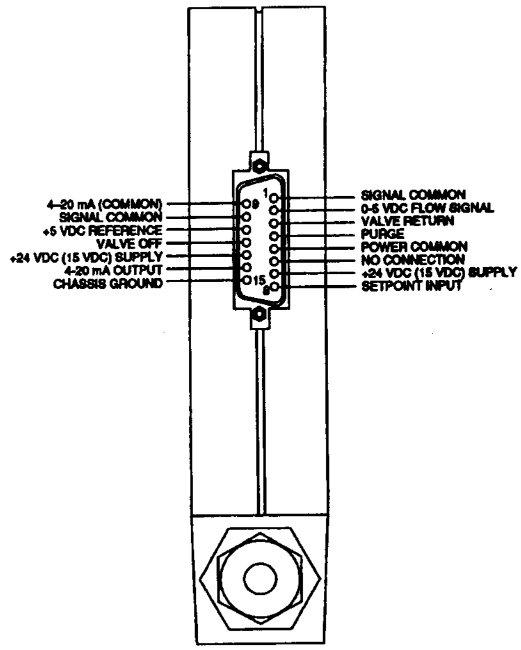


TABLE 2-2 "D" CONNECTOR PIN ASSIGNMENTS

PIN #	FUNCTION	PIN #	FUNCTION
1	Signal Common	9	4-20 mA (Common)
2	0-5 VDC Flow Signal*	10	Signal Common
3	Valve Return	11	+5 VDC Reference
4	Purge	12	Valve Off
5	Power Common	13	+24 VDC (15 VDC) Supply
6	No Connection	14	4-20 mA Output
7	+24 VDC (15 VDC) Supply	15	Chassis Ground
8	Setpoint Input		

NOTE: +15 VDC operation uses same supply pins.
See page 6, #8.

*0-10 VDC optional

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OPERATION

3.1 Referencing the Flow Rate to Other Temperature and Pressure Conditions

The gas flow rate output of your FMA-1900 is referenced to "standard" conditions of 21.1°C (70°F) and 760 mm of mercury (one atmosphere), unless you have specified otherwise in your order. Be sure you know the reference conditions of your FMA-1900, because it may make a difference if you are comparing the output of FMA-1900 with another type of flow meter. For example, the output reading of FMA-1900 will be approximately 7% lower if you compare it to a device that uses a "standard" temperature of 0°C rather than 21.1°C.

3.2 Accuracy

The accuracy of FMA-1900 is ±1.5% of full scale, and the effective control range of the device is 10% to 100%. The ±1.5% of full scale accuracy means the 0-5 VDC output signal is accurate to within ±0.075 VDC (0-10 VDC accuracy ± 0.150 VDC) and the 4-20 mA output is accurate to within ±0.24mA. This means, for example, that the output signal for zero flow can be as high as ±0.075 VDC or ±0.24mA. Please note if you get an output signal at zero flow that is within either of these two ranges, your FMA-1900 is functioning properly. With respect to the FMA-1900 digital readout, the accuracy is simply 1.5% times the full scale flow rate listed on the instrument data tag. For example, if full scale is 10 SLM, the digital readout will be accurate to ±0.15 SLM, and the reading at zero flow may be as high as ±0.15 SLM and still be within the stated accuracy specification.

3.3 Overranging

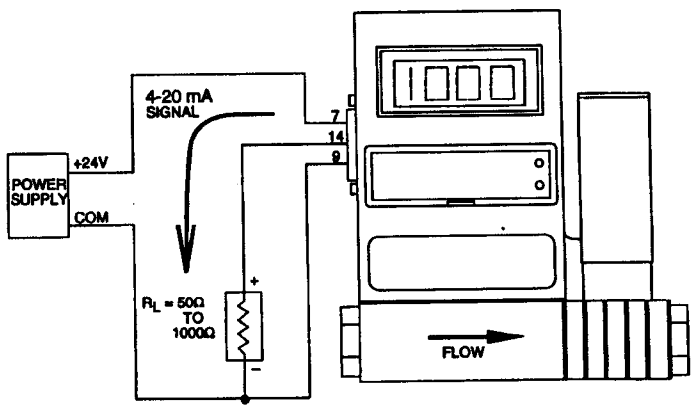
If the flow rate exceeds the full scale range listed on the FMA-1900 data tag, the output signal and digital display will read a higher value. The FMA-1900 has not been calibrated for overranged flows and will be both non-linear and inaccurate if an overrange condition exists. The 0-5 VDC (0-10 optional) and 4-20 mA outputs can exceed full scale by as much as 50% or more. On the digital display, the display cannot exceed the four digits 1999. If the flow rate exceeds 1999, the right-most digits will blank and only the left-hand "1" will appear on the display.

Overrange conditions are indicated by the display and/or output going to a high level, above the full scale range. After the overrange condition has been removed, it may take several minutes for the FMA-1900 to recover and resume normal operation. An overrange condition will not harm the instrument.

3.4 The 4-20 mA Output Signal

The 4-20 mA output signal current flows from the 4-20 mA output pin on the "D" connector through the load (1000 Ohms maximum) to ground (see Section 2.6, Electrical Connections). Figure 3-1 illustrates an installation with a current loop output.

Figure 3-1 Hookup Wiring for a Single 4-20 mA Unit



3.5 Zero and Local Setpoint Adjustments

The zero and local setpoint potentiometers are accessed through ports marked on the front of your FMA-1900. If the zero output is more than ±1.5% of scale, you may adjust the zero potentiometer when you are absolutely certain that the system has reached its normal operating temperature and there is zero flow at the desired pressure and orientation.

The local setpoint potentiometer is used when you are not using an external setpoint. Turning the potentiometer clockwise increases the setpoint.

3.6 Mounting Position

Unless specified otherwise, your FMA-1900 has been calibrated for installation with the flow section in a horizontal plane (±15°) with the enclosure standing up. If your actual installation position is different, you will have to make a zero adjustment.

NOTE: The zero value may shift and be more pronounced when under pressure and when mounted in different positions.

3.7 Output Options, Meters and Controllers

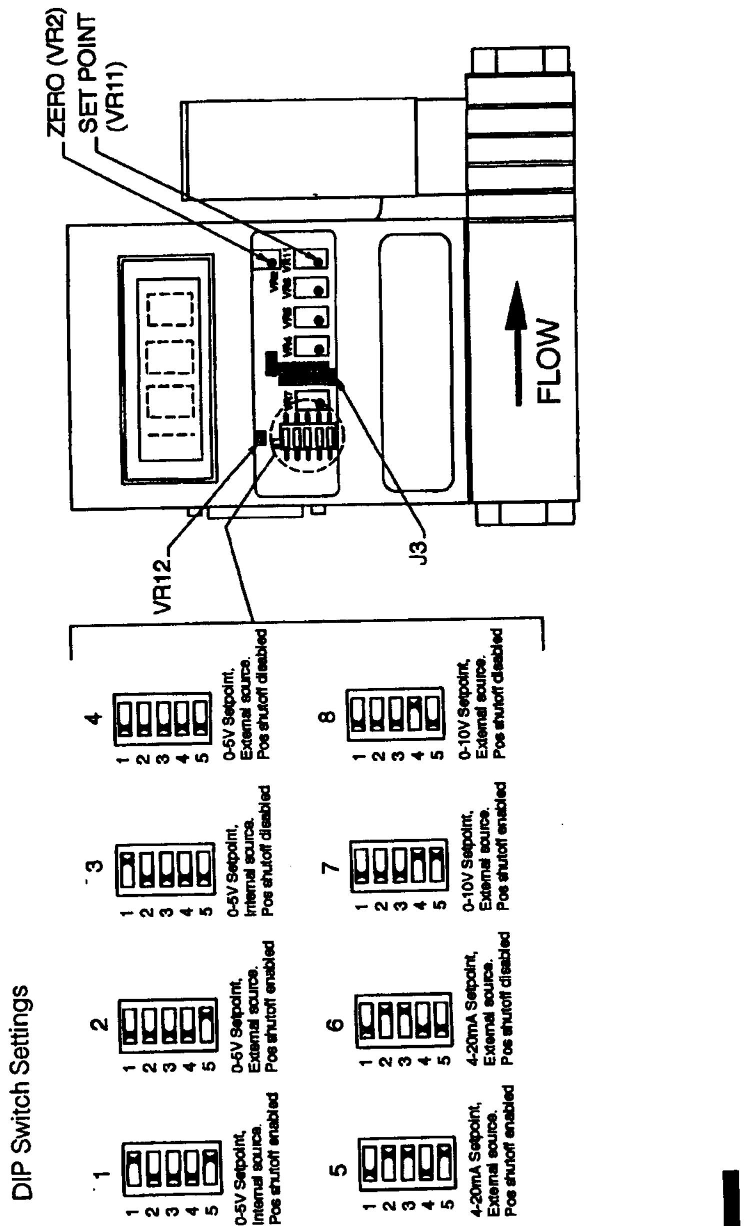
The standard output for all FMA-1900 controllers is either a 0-5 VDC (0-10 VDC optional) or 4-20 mA signal that corresponds linearly to the 0-100% mass flow full scale range. The 0-5 VDC (and 0-10 VDC optional) output requires a minimum load resistance of 2000 Ohms, while the 4-20 mA output accommodates a load resistance of up to 1000 Ohms at 24 VDC and 500 Ohms at 15 VDC.

3.8 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 causes a condition of 0% flow to occur and a 5.00 VDC setpoint causes 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 within one second to 63% of final value, and within five seconds to ±2% of full scale. Either 0-5 VDC (0-10 VDC optional) or 4-20 mA setpoint commands are available.

Figure 3-2 Component Location and DIP Switch Set Up



3.9 Setpoint Configuration

The DIP switches on the FMA-1900 flow controller are used to configure setpoint operation and the Positive Shut-Off feature.

The default configuration is for an internal 0-5 VDC setpoint using the on-board setpoint command potentiometer (accessible through a hole in the case) and the positive shut-off option enabled.

Other options include internally or externally sourced 0-5 VDC setpoint with positive shut-off enabled or disabled and externally sourced 4-20 mA setpoint with positive shut-off enabled or disabled. A factory installed option of 0-10 VDC in and out is also available.*

Move DIP switch 1 to the right (ON) to select the internal on-board setpoint potentiometer. Move this switch to the left (OFF) to select an external setpoint, which you must supply. This is also the position required if you choose to use a local setpoint potentiometer.

Move DIP switches 2 and 3 to the right to select 4-20 mA setpoint input. Move these switches to the left to select 0-5 VDC setpoint. If your FMA-1900 was originally set up for 0-5 VDC setpoint and you decide to switch to a 4-20 mA setpoint signal you may need to adjust VR12 to ensure that the setpoint and output match at full scale.

Move DIP switch 5 to the right to have the controller valve forced shut (auto shut-off) whenever the setpoint is less than 2% of full scale. Move this switch to the left to disable auto shut-off.

A 5.1 VDC reference is provided for internal and external setpoint command pots. The reference provides approximately 0.125 volts headroom to allow for external cabling and ensures the ability to always reach full scale when using these inputs. The 0-10V setpoint input is intended to be provided externally by the user. If the internal setpoint is to be used with a 0-10V output, DIP switch 1 is moved to the right-hand position and DIP switch 4 must be in the left-hand (open) position. This allows the controller to operate from the internal (or external local) 0-5V setpoint command pot even though the output is 0-10V.

NOTE: If the setpoint input is not connected to some type of command control device, the valve-off function must be activated or DIP switch #1 must be in the "internal source" 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.

*The internal setpoint, when used with the 0-10 V in/out setup, requires DIP switch S1-4 opened. External set must be disconnected.

3.10 Cold Sensor Lockout Circuit

FMA-1900 controllers incorporate a safety circuit that closes the valve when a fault condition is detected that could result in uncontrolled flow (valve wide open). The circuit operates by monitoring the temperature of the sensor elements and forcing the output high if the temperature falls below a preset limit. There are several conditions under which this could occur:

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

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

c) Sensor failure.

The operation of this circuit may be checked by observing the output upon power-up. (The output signal should be high for the first 10 to 20 seconds. After that, assuming zero flow, the output will drop to 0 VDC or 4mA, depending on which output you are observing.)

3.11 Auto Shut-Off

All FMA-1900 controllers are provided with an Auto Shut-Off feature that, when enabled, closes the valve at a command signal level of 2% or less of full scale.

To enable this feature on your FMA-1900, move DIP switch 5 to the right. The valve will then be forced shut whenever the setpoint is less than 2% of full scale. To disable the feature, move DIP switch 5 to the left. The valve will then remain open even when the setpoint falls below 2% of full scale. The default is enabled.

3.12 On/Off Control

For all FMA-1900 controllers, on/off control is provided via a mechanical or open collector switch. You can implement this option manually by connecting an on/off switch between pins 3 and 12 of the 15-pin "D" connector (See Appendix B). Normal operation resumes when pin 12 is left floating.

3.13 Purging of FMA-1900 Products

The purge function opens the controller valve completely for the purpose of purging the meter and for quickly flushing unwanted gas from the flow path. When the valve is opened for purging, it allows flows far in excess of the rated full scale of the controller. Because of the uncontrolled nature of the purge function, two conditions must be met before a controller can be purged.

1) The Valve OFF switch, if it is used, must be in the ON or open state.

2) The Auto-Shutoff function cannot be active (the setpoint command signal must be above 2% of full scale or DIP switch 5 must be in the OFF position).

The activation of either the Valve OFF switch or the Auto-Shutoff function will override the purge command.

To activate purge, connect pin 4 of the 15-pin "D" connector to common through either a mechanical switch or an open-collector transistor or logic output capable of sinking at least 4mA (See Appendix B). The maximum voltage appearing on this pin is 5.0 VDC.

3.13.1 Purging Non-reactive Gases

Purge non-reactive gases from the FMA-1900 with clean, dry nitrogen or argon for a minimum of two hours.

3.13.2 Purging Reactive Gases

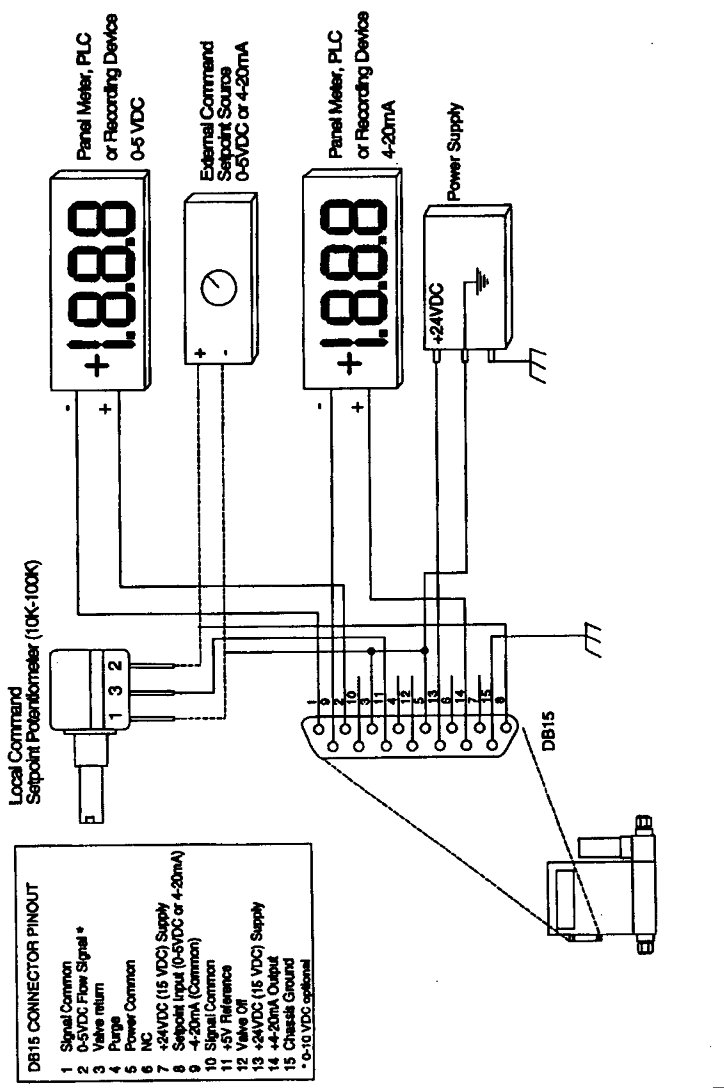
Purge reactive gases from the FMA-1900 using one of the following methods:

1) Cycle purge. This is done by alternately evacuating and purging the device for two to four hours with clean, dry nitrogen or argon.

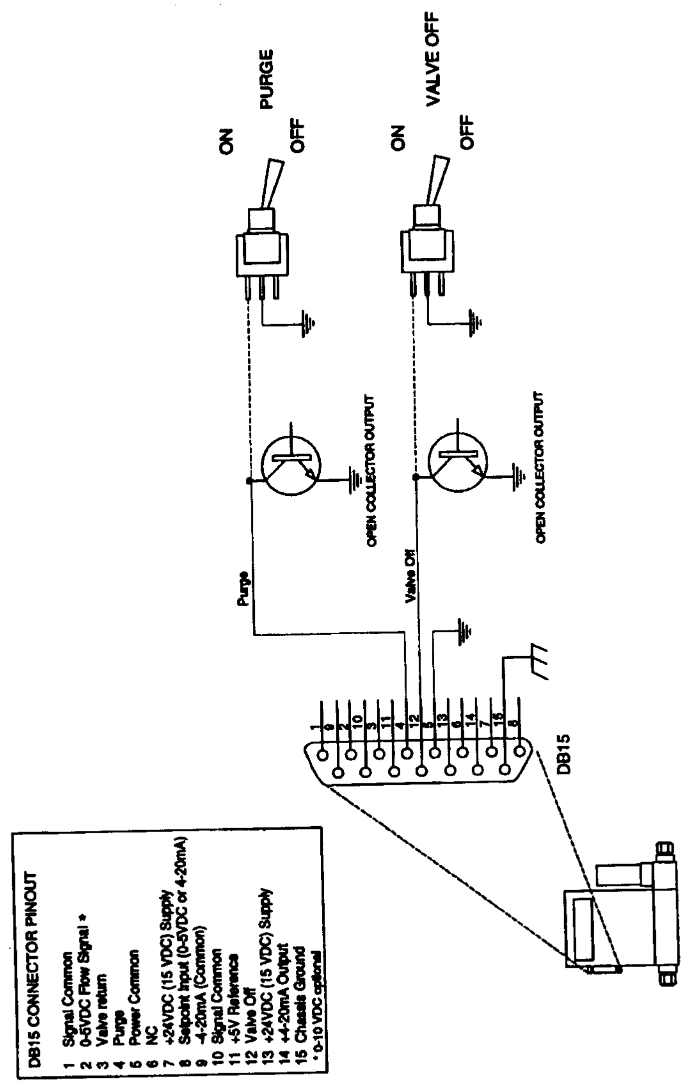
2) Purge the device with clean, dry nitrogen or argon for eight to twenty-four hours.

3) Evacuate the device for eight to twenty-four hours.

Appendix A. Pin Connections



Appendix B. Purge and Valve Off Connections



Appendix C. 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:

1. 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 a so-called "nasty" gas (i.e., toxic, flammable, corrosive, etc.).
2. Interpreting the reading of a flow controller which has been calibrated with a gas other than the actual gas.

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

$$Q_1 / Q_2 = K_1 / K_2 \qquad (1)$$

where:

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

K = The "K" factor defined in equation (6), $(\ )_1$ = 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.

$$H = \frac{\dot{m}\, C_P \Delta T}{N} \qquad (2)$$

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 Tables (at 0°C).

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

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

Number of Atoms in the Gas Molecule	N
Monatomic	1.040
Diatomic	1.000
Triatomic	0.941
Polyatomic	0.880

The mass flow rate, m, can also be written as:

$$\dot{m} = \rho Q \quad (3)$$

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

$$\Delta T = aE \quad (4)$$

where: a = A contstant

If we combine Equations (3) and (4), insert them into Equation (2), and solve for Q, we get:

$$Q = (bN/ \rho C_P) \quad (5)$$

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, to produce the same output voltage in a particular mass flow controller. We get this by comgining Equations (1) and (5):

$$Q_1 / Q_2 = K_1 / K_2 = (N_1 / \rho_2 \ C_{P2}) \quad (6)$$

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 molecularly equivalent 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.

Omega calibrates every FMA-1900 Series mass flow controller with primary standards using the actual gas or a molecularly equivalent reference gas. The calibration certificate accompanying your flow controller will cite the reference gas used. When a reference gas is used, the actual flow rate will be within 2 to 4% of the calculated flow rate.

EXAMPLE 1: A flow controller 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:

$$Q_{CO_2} / Q_{N_2} = K_{CO_2} / K_{N_2}, \text{ or}$$

$$Q_{CO_2} = (0.74 / 1.000)\ 1000 = 740 \text{ SCCM}$$

EXAMPLE 2: A flow controller 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_20) is found as follows:

$$Q_{N_2O} / Q_{H_2} = K_{N_2O} / K_{H_2}, \text{ or}$$

$$Q_{N_2O} = (0.71 / 1.01)\ 100 = 70.3 \text{ SCCM}$$

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

EXAMPLE 3: We want a flow controller 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?

$$Q_{SiH_2CL_2} / Q_{CF_4} = K_{SiH_2CL_2} / K_{CF_4}$$

$$100 / Q_{CF_4} = 0.869$$

$$Q_{CF_4} = 100 / 0.869 = 115 \text{ SCCM}$$

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: $\rho = (\dot{m}_1 / \dot{m}_T)\ \rho_1 + (\dot{m}_2 / \dot{m}_T)\ \rho_2$ (7)

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: $C_P = F_1\ C_{P1} + F_2\ C_{P2}$

where: $F_1 = (\dot{m}_1\ \rho_1) / (\dot{m}_T\ \rho)$ 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.

Actual Gas	Chemical Symbol	Ref. Gas	K-fac. Rel. to Ref. Gas	K-fac. Rel. to N_2	Cp (Cal/g)	Density (g/l) @0°C	Elastomer O-ring*	Valve Seat
Acetylene	C_2H_2	N_2	.58		.4036	1.162		
Air		N_2	1.00		.240	1.293		
Allene (Propadiene)	C_3H_4	N_2	.43		.352	1.787		KR
Ammonia	NH_3	N_2	.73		.492	.760	NEO	NEO
Argon	Ar	Ar	1.000	1.45	.1244	1.782		
Arsine	AsH_3	N_2	.67		.1167	3.478		KR
Boron Trichloride	BCl_3	N_2	.41		.1279	5.227	KR	KR
Boron Trifluoride	BF_3	N_2	.51		.1778	3.025		KR
Bromine	Br_2	N_2	.81		.0539	7.130		
Boron Tribromide	Br_3	N_2	.38		.0647	11.18		KR
Bromine Pentafluoride	BrF_5	N_2	.26		.1369	7.803		KR
Bromine Trifluoride	BrF_3	N_2	.38		.1161	6.108		KR
Bromotrifloromethane (Freon-13 B1)	$CBrF_3$	N_2	.37		.1113	6.644		
1,3-Butadiene	C_4H_6	N_2	.32		.3514	2.413		
Butane	C_4H_{10}	N_2	.26		.4007	2.593	NEO	KR
1-Butane	C_4H_8	N_2	.30		.3648	2.503	NEO	KR
2-Butane	C_4H_8 CIS	N	.324		.336	2.503	NEO	KR
2-Butane	C_4H_8 TRANS	N_2	.291		.374	2.503		
Carbon Dioxide	CO_2	N_2	.74		.2016	1.964		
Carbon Disulfide	CS_2	N_2	.60		.1428	3.397		
Carbon Monoxide	CO	N_2	1.00		.2488	1.250		
Carbon Tetrachloride	CCl_4	N_2	.31		.1655	6.860		KR
Carbon Tetrafluoride (Freon-14)	CF_4	N_2	.42		.1654	3.926		KR
Carbonyl Fluoride	COF_2	N_2	.54		.1710	2.945		
Carbonyl Sulfide	COS	N_2	.66		.1651	2.680		
Chlorine	CL_2	N_2	.86		.114	3.163		KR
Chlorine Trifluoride	ClF_3	N_2	.40		.1650	4.125		KR
Chlorodifluoromethane (Freon-22)	$CHClF_2$	N_2	.46		.1544	3.858		KR
Chloroform	$CHCl_3$	N_2	.39		.1309	5.326		KR
Chloropentafluoroethane (Freon-115)	C_2ClF_5	N_2	.24		.164	6.892		KR
Chlorotrifluromethane (Freon-13)	$CClF_3$	N_2	.38		.153	4.660		KR
Cyanogen	C_2N_2	N_2	.61		.2613	2.322		
Cyanogen Chloride	ClCN	N_2	.61		.1739	2.742		KR
Cychlopropane	C_3H_6	N_2	.46		.3177	1.877		KR

Actual Gas	Chemical Symbol	Ref. Gas	K-fac. Rel. to Ref. Gas	K-fac. Rel. to N_2	Cp (Cal/g)	Density (g/l) @0°C	Elastomer O-ring*	Elastomer Valve Seat
Deuterium	D_2	N_2	1.00		.1722	1.799		
Diborane	B_2H_6	N_2	.44		.508	1.235		KR
Dibromodifluoromethane	CBr_2F_2	N_2	.19		.15	9.362		KR
Dibromethane		N_2	.47		.075	7.76		KR
Dichlorodifluoromethane (Freon-12)	CCl_2F_2	N_2	.35		.1432	5.395		KR
Dichlorofluoromethane (Freon-21)	$CHCl_2F$	N_2	.42		.140	4.952		KR
Dichloromethylsilane	$(CH_3)_2SiCl_2$	N_2	.25		.1882	5.758		KR
Dichlorosilane	SiH_2Cl_2	N_2	.40		.150	4.506		KR
Dichlorotetrafluoroethane (Freon-114)	$C_2Cl_2F_4$	N_2	.22		.1604	7.626		KR
1,1-Difluoroethylene (Freon-1132A)	$C_2H_2F_2$	N_2	.43		.224	2.857		KR
Dimethylamine	$(CH_3)_2NH$	N_2	.37		.366	2.011		KR
Dimeyl Ether	$(CH_3)_2O$	N_2	.39		.3414	2.055		KR
2,2-Dimethylpropane	C_5H_{12}	N_2	.22		.3914	3.219		KR
Ethane	C_2H_6	N_2	.50		.4097	1.342		
Ethanol	C_2H_6O	N_2	.39		.3395	2.055		KR
EthylAcetylene	C_4H_6	N_2	.32		.3513	2.413		KR
Ethyl Chloride	C_2H_5Cl	N_2	.39		.244	2.879		KR
Ethylene	C_2H_4	N_2	.60		.1365	1.251		
Ethylene Oxide	$C_2H_4O)$	N_2	.52		.268	1.965		KR
Fluorine	F_2	N_2	.980		.1873	1.695		KR
Fluoroform (Freon-23)	CHF_3	N_2	.50		.176	3.127		KR
Freon-11	CCl_3F	N_2	.33		.1357	6.129		KR
Freon-12	CCl_2F_2	N_2	.35		.1432	5.395		KR
Freon-13	$CClF_3$	N_2	.38		.153	4.660		KR
Freon-13	B1 $CFrF_3$	N_2	.37		.1113	6.644		KR
Freon-14	CF_4	N_2	.42		.1654	3.926		
Freon-21	$CHCl_2F$	N_2	.42		.140	4.952		KR
Freon-22	$CHClF_2$	N_2	.46		.1544	3.858		KR
Freon-113	CCl_2FCClF_2	N_2	.20		.161	8.360		KR
Freon-114	$C_2Cl_2F_4$	N_2	.22		.160	7.626		KR
Freon-115	C_2ClF_5	N_2	.24		.164	6.892		KR
Freon-C318	C_4F_8	N_2	.17		.185	8.397		KR
Germane	GeH_4	N_2	.57		.1404	3.418		
Germanium Tetrachloride	$GeCL_4$	N_2	.27		.1071	9.565		KR

Actual Gas	Chemical Symbol	Ref. Gas	K-fac. Rel. to Ref. Gas	K-fac. Rel. to N_2	Cp (Cal/g)	Density (g/l) @0°C	Elastomer O-ring*	Elastomer Valve Seat
Helium	He	He	1.000	1.454	1.241	.1786		
Hexafluoroethane (Freon-116)	C_2F_6	N_2	.24		.1834	6.157		KR
Hexane	C_6H_{14}	N_2	.18		.3968	3.845		KR
Hydrogen	H_2	H_2	1.000	1.01	3.419	.0899		
Hydrogen Bromide	HBr	N_2	1.000		.0861	3.610		KR
Hydrogen Chloride	HCl	N_2	1.000		.1912	1.627	KR	KR
Hydrogen Cyanide	HCN	N_2	1.070		.3171	1.206		KR
Hydrogen Fluoride	HF	N_2	1.000		.3479	.893	KR	KR
Hydrogen Iodide	HI	N_2	1.000		.0545	5.707		KR
Hydrogen Selenide	H_2Se	N_2	.79		.1025	3.613		KR
Hydrogen Sulfide	H_2S	N_2	.80		.2397	1.520		KR
Iodine Pentafluoride	IF_5	N_2	.25		.1108	9.90		KR
Isobutane	$CH(CH_3)_3$	N_2	.27		.3872	3.593		KR
Isobutylene	C_4H_8	N_2	.29		.3701	2.503		KR
Krypton	Kr	Ar	1.002	1.453	.0593	3.739		
Methane	CH_4	N_2	.72		.5328	.715		
Methanol	CH_3OH	N_2	.58		.3274	1.429		
Methyl Acetylene	C_3H_4	N_2	.43		.3547	1.787		KR
Methyl Bromide	CH_3Br	N_2	.58		.1106	4.236		
Methyl Chloride	CH_3Cl	N_2	.63		.1926	2.253		KR
Methyl Fluoride	CH_3F	N_2	.68		.3221	1.518		KR
Methyl Mercaptan	CH_3SH	N_2	.52		.2459	2.146		KR
Methyl Trichlorosilane	$(CH_3)\ SiCl_3$	N_2	.25		.164	6.669		KR
Molybdenum Hexafluoride	MoF_6	N_2	.21		.1373	9.366		KR
Monoethylamine	$C_2H_5NH_2$	N_2	.35		.387	2.011		KR
Monomethylamine	CH_3NH_2	N_2	.51		.4343	1.386		KR
Neon	NE	Ar	1.006	1.46	.245	.900		
Nitric Oxide	NO	N_2	.990		.2328	1.339		
Nitrogen	N_2	N_2	1.000		.2485	1.25		
Nitrogen Dioxide	NO_2	N_2	.74		.1933	2.052		
Nitrogen Trifluoride	NF_3	N_2	.48		.1797	3.168		KR
Nitrosyl Chloride	NOCl	N_2	.61		.1632	2.920		KR
Nitrous Oxide	N_2O	N_2	.71		.2088	1.964		

Actual Gas	Chemical Symbol	Ref. Gas	K-fac. Rel. to Ref. Gas	K-fac. Rel. to N_2	Cp (Cal/g)	Density (g/l) @0°C	Elastomer O-ring*	Elastomer Valve Seat
Octafluorocyclobutane (Freon-C318)	C_4F_8	N_2	.17		.185	8.397		KR
Oxygen Difluoride	OF_2	N_2	.63		.1917	2.406		
Oxygen	O_2	N_2	1.000		.2193	1.427		
Ozone	O_3	N_2	.446		.3	2.144		
Pentaborane	B_5H_9	N_2	.26		.38	2.816		KR
Pentane	C_5HI_2	N_2	.21		.398	3.219		KR
Perchloryl Fluoride	ClO_3F	N_2	.39		.1514	4.571		KR
Perfluoropropane	C_3F_8	N_2	.174		.197	8.388		KR
Phosgene	$COCl_2$	N_2	.44		.1394	4.418		KR
Phosphine	PH_3	N_2	1.070		.2374	1.517		KR
Phosphorous Oxychloride	$POCl_3$	N_2	.36		.1324	6.843		KR
Phosphorous Pentafluoride	PH_5	N_2	.30		.1610	5.620		KR
Phosphorous Trichloride	PCl_5	N_2	.30		.1250	6.127		KR
Propane	C_3H_8	N_2	.36		.3885	1.967		KR
Propylene	C_3H_6	N_2	.41		.3541	1.877		KR
Silane	SiH_4	N_2	.60		.3189	1.433		KR
Silicon Tetrachloride	$SiCl_4$	N_2	.28		.1270	7.580		KR
Silicon Tetrafluoride	SiF_4	N_2	.35		.1691	4.643		KR
Sulfur Dioxide	So_2	N_2	.69		.1488	2.858		KR
Sulfur Hexafluoride	SF_6	N_2	.26		.1592	6.516		KR
Sulfuryl Fluoride	SO_2F_2	N_2	.39		.1543	4.562		KR
Teos		N_2	.090				KR	KR
Tetrafluorahydrazine	N_2F_4	N_2	.32		.182	4.64		KR
Trichlorofluormethane (Freon-11)	CCl_3F	N_2	.33		.1357	6.129		KR
Trichlorisilane	$SiHCl_3$	N_2	.33		.1380	6.043		KR
1,1,2-Trichloro-1,2,2 Trifluorethane (Freon-113)	CCl_2FCClF_2	N_2	.20		.161	8.360		KR
Trisobutyl Aluminum	$(C_4H_9)Al$	N_2	.061		.508	8.848		KR
Titanium Tetrachloride	$TiCl_4$	N_2	.27		.120	8.465		KR
Trichloro Ethylene	C_2HCl_3	N_2	.32		.163	5.95		KR
Trimethylamine	$(CH_3)_3N$	N_2	.28		.3710	2.639		KR
Tungsten Hexasfuoride	WF_6	N_2	.25		.0810	13.28	KR	Teflon
Uranium Hexafluoride	UF_6	N_2	.20		.0888	15.70		KR
Vinyl Bromide	CH_2CHBr	N_2	.46		.1241	4.772		KR
Vinyl Chloride	CH_2CHCl	N_2	.48		.12054	2.788		KR
Xenon	Xe	Ar	.993	1.44	.0378	5.858		

WARRANTY/DISCLAIMER

OMEGA ENGINEERING, INC. warrants this unit to be free of defects in materials and workmanship for a period of **13 months** from date of purchase. OMEGA Warranty adds an additional one (1) month grace period to the normal **one (1) year product warranty** to cover handling and shipping time. This ensures that OMEGA's customers receive maximum coverage on each product.

If the unit should malfunction, it must be returned to the factory for evaluation. OMEGA's Customer Service Department will issue an Authorized Return (AR) number immediately upon phone or written request. Upon examination by OMEGA, if the unit is found to be defective it will be repaired or replaced at no charge. OMEGA's WARRANTY does not apply to defects resulting from any action of the purchaser, including but not limited to mishandling, improper interfacing, operation outside of design limits, improper repair, or unauthorized modification. This WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion; or current, heat, moisture or vibration; improper specification; misapplication; misuse or other operating conditions outside of OMEGA's control. Components which wear are not warranted, including but not limited to contact points, fuses, and triacs.

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 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 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. P.O. number under which the product was PURCHASED,
2. Model and serial number of the product under warranty, and
3. Repair instructions and/or specific problems relative to the product.

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

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

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