OMEGA
ENGINEERING, INC.
An OMEGA Technologies Company

FMA-5000 SERIES Electronic Mass Flowmeters

Operator's Manual

WARRANTY

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

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Direct all warranty and repair requests/inquiries to OMEGA Customer Service Department, telephone number (203) 359-1660. BEFORE RETURNING ANY INSTRUMENT, PLEASE CONTACT THE OMEGA CUSTOMER SERVICE DEPARTMENT TO OBTAIN AN AUTHORIZED RETURN (AR) NUMBER. The designated AR number should then be marked on the outside of the return package.

To avoid processing delays, also please be sure to include:

1. **Returnee's name, address, and phone number.**
2. **Model and Serial numbers.**
3. **Repair Instructions.**

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

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M698/068

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FMA-5000 Series

QUICK OPERATING INSTRUCTIONS

(See Section 3 for Detailed Operating Instructions)

1. Install the FMA-5000 Series into the gas flow line. Note the flow direction arrow on the flowmeter. If you are using ¼ inch pipe, use a good quality paste pipe thread sealant for sealing and tighten one-and-one-half turns only. Do not overtighten.

CAUTION

Overtightening may crack the fittings or shift calibration.

The line pressure and temperature should not exceed 150 psig or 150°F (50°C).

2. Apply power to the flowmeter. If you are using the FMA-PST Power Supply, just plug the power supply into line power and the connector into the input power jack on the side of the flowmeter. If you are providing your own power, use 12 to 15 VDC at 100 mA maximum. 24 VDC operation is made possible by removing the 0 ohm resistor in the R-10 location and replacing it with a 160 ohm ½ watt resistor. The resistor will not fit between the D connector and DC power jack, so stand it off from the PCB. This is acceptable since it gets hot in normal operation. Do not supply +DC power at the D connector while using an FMA-PST power supply at the DC power jack. The D connector pinout is shown in Section 2.4.
3. Allow at least 15 minutes for warm-up.
4. After the warm-up period, the flowmeter is monitoring the gas mass flow rate.
5. Output Signals: The output signal of the flowmeter is either 0-5 VDC (standard) or 4-20 mA (optional). The output is linearly proportional to the gas mass flow rate. The full scale range and gas are shown on the front label. Section 2.4 describes the electrical output signal hookup. For example, if you have a 0-5 VDC output signal, 5.00 VDC is the output signal for the full scale listed on the label; 2.50 VDC is for one-half of full scale, and 0.00 VDC is for zero flow. On the other hand, if you have 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. FMA-5000 Series with Integral or Remote Display: The 3½ digit LCD reads directly in engineering units or percent of full scale. The full scale range and gas are shown on the front label. The decimal point for the flow rate is set at the factory and will show automatically (e.g., 5.54 SLM or 76.4%).

SECTION 1 INTRODUCTION

1.1 GENERAL DESCRIPTION

The OMEGA® FMA-5000 Series Electronic Mass Flowmeters measure the mass flow rate of gases in 13 ranges from 0-10 SCCM (standard cubic centimeters per minute), to 0-40 SLM (standard liters per minute). Their analog output, integral/remote digital display, insensitivity to temperature and pressure variations, and low cost make them ideal substitutes for rotameters, and they can also be used to calibrate rotameters. Other applications include chemical and food processing, gas chromatography, and leak and filter testing to name a few.

The FMA-5000 Series are available with or without a digital display. The display is tiltable over 180° for easy viewing and can be ordered with 25 feet of cable for remote surface mounting. The flowmeters require a 14 to 24 VDC external power source that can be provided by the optional Model FMA-PST Power Supply. A 0-5 VDC (standard) or 4-20 mA (optional) output signal linearly proportional to gas mass flow rate is provided for recording, datalogging, or control. A 9-pin "D" subconnector for the output signal, input power, and remote display drive is supplied with its mating connector for all FMA-5000 Series units.

All wetted surfaces are constructed of corrosion-resistant glass-filled nylon plastic, 316SS, and Viton O-rings. This rugged construction accommodates almost any gas including air, oxygen, process gases, and even corrosives.

SECTION 2 INSTALLATION

2.1 UNPACKING

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

Upon receipt of the shipment, inspect the container and equipment for any signs of damage. Take particular note of any evidence of rough handling in transit. Immediately report any damage to the shipping agent.

NOTE

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

2.2 MECHANICAL INSTALLATION

CAUTION

The maximum pressure and temperature in the flow line in which the flowmeter is to be installed should not exceed 150 psig (10 kg/cm² gage) or 150°F (50°C).

In order to ensure a successful installation, inlet and outlet tubing or piping should be in a clean state prior to installing the flowmeter into the system. The FMA-5000 Series 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 flowmeter.

Do not locate the flowmeter 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. If the unit is to be mounted in other than a horizontal position, the zero will need adjustment. Refer to Section 5.2.

The flowmeter may be mounted to a chassis with two 6-32 self-tapping screws. Refer to Figure 2-1.

2.3 TRANSDUCER CONNECTIONS

The transducers are supplied with either ¼ inch female NPT (standard) or ¼ inch inlet and outlet fittings. These fittings should not be removed unless the flowmeter is being cleaned or calibrated for a new flow range. VCO or VCR fittings are available on special order. ¼ inch pipe requires a good quality paste pipe thread sealant and should be installed in the inlet and outlet fittings 1½ turns beyond hand-tight.

CAUTION

Overtightening may crack the fittings or shift calibration.

For the first installation of ¼ inch (outside diameter) fittings, 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 6 o'clock position. While holding the fitting body steady with a back-up wrench, tighten the nut 1¼ turns, watching the scribe mark make one complete revolution and continue to the 9 o'clock position. After this, the fitting can be reconnected by snugging with a wrench. Do not fail to use a back-up wrench or the inlet fitting may be damaged. Do not mix or interchange parts of tube fittings made by different manufacturers.

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

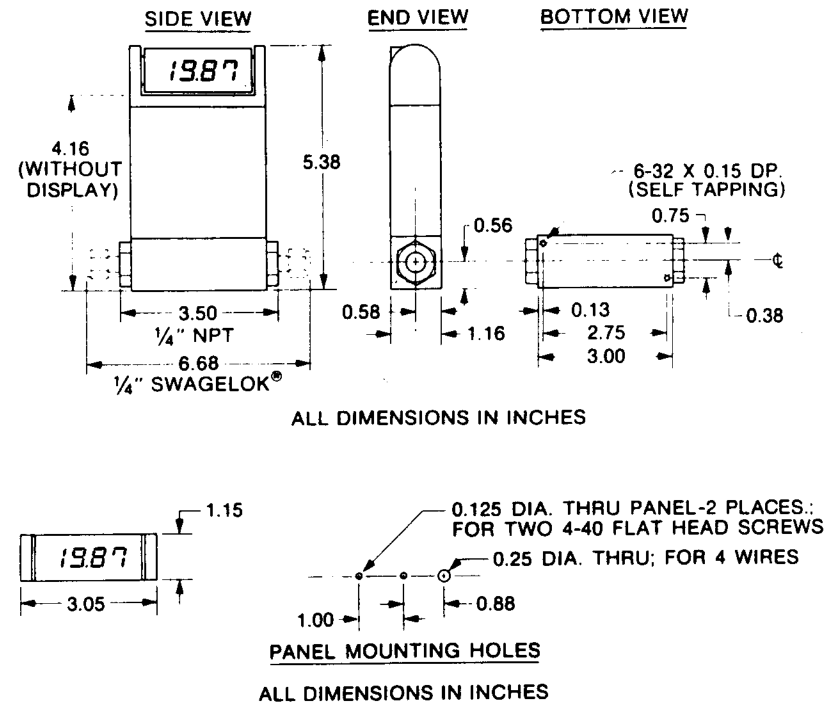


Figure 2-1. Dimensions

2.4 ELECTRICAL CONNECTIONS

2.4.1 9-Pin D Connector Pin Assignments

The flowmeter requires a single +12 to +15 VDC power supply capable of providing a minimum current of 100 mA, and can also be configured for +24 VDC power at 100 mA. Operating power input is via either the DC power jack or the 9-pin D connector on the side of the enclosure. The pin numbers for this D connector are shown in Figure 2-2 and the pin assignments are given in Table 2-1. The output signal is obtained from the 9-pin D connector. A 0-5 VDC output signal linearly proportional to gas mass flow rate is standard. A 4-20 mA current loop signal is optionally available.

When the flowmeter is configured for a remote display, connections are made via the D connector. Power connections for the display and transducer are shared in this mode unless the optional power supply is used.

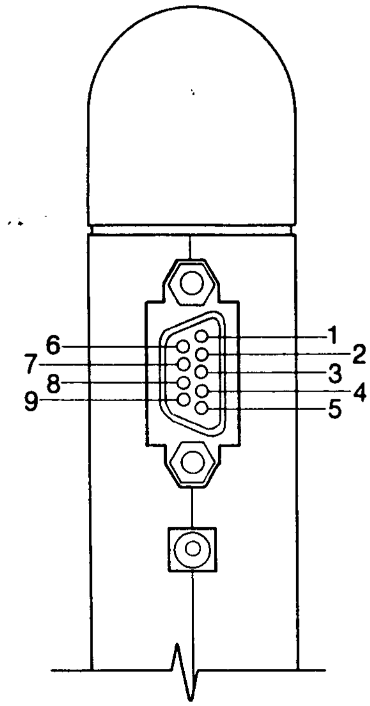


Figure 2-2. D Connector and DC Power Jack

The following connection points can be made through the D connector or, in OEM applications, made through the circuit board solder pad connections. The display pad connections are shown for applications requiring remote mounting of the digital display. The letters appear on the display circuit board and are shown in Figure 2-3.

PIN NO.	FUNCTION	DISPLAY PAD
1	No Connection	N/A
2	Signal Common	N/A
3	0 to +5 VDC Flow Signal	N/A
4	+Power Supply (12 or 24 VDC)	(A)
5	Remote Display Flow Signal	(D)
6	Remote Display Reference	(C)
7	Power Common	(B)
8	4 to 20 mA Return (Common)	N/A
9	4 to 20 mA Output	N/A

Note that the numbers on the connector plug may not agree with the numbering system as it appears in Figure 2-2. It is important to make sure that the proper wires are in the proper location.

NOTES

1. Remote display connects through the 9-pin D connector only. The pads A-D in the top right of the main circuit board are for integral display mounting only.
2. Power supply voltage must be specified at time of order. Operating a 12 VDC meter at 24 VDC will cause damage. Running a 24 VDC meter at 12 VDC will result in faulty operation.
3. Do not supply +DC power at the D connector while using an FMA-PST power supply at the DC power jack. Both supplies may be damaged.

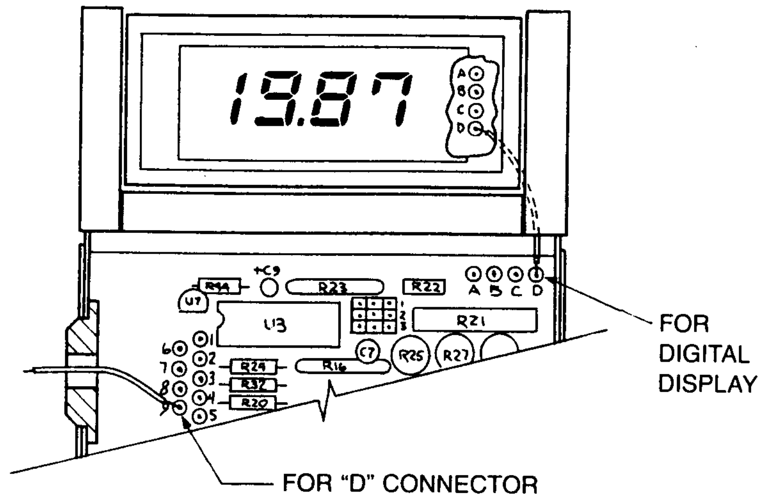


Figure 2-3. PCB Input/Output Solder Pad Assignments

2.4.2 OEM Electrical Connections

One special design OEM version transducer has an electrical port (hole) on its side for electrical input/outputs. This port is just above the input power jack (see the exploded view, item 27, in Appendix 1). Wires entering via this port are soldered to the printed circuit board as shown in Figure 2-3. The solder pad assignments are given in Table 2-1.

To gain access to the PCB to make the solder connections for special design applications, refer to the exploded view in Appendix 1 and follow these steps.

1. If the flowmeter has the digital display:
   (a) First, remove the display from the transducer by carefully rotating the display until it hits the top plate and slowly continue to rotate until this lever-arm action snaps out the two yokes holding the display (No. 30). Use extra caution during this operation as excessive force will break the delicate wire connections. Carefully move the display assembly to expose the two screws securing the display base (No. 35). Do not exert excessive force on the display while rotating, as doing so could crack the LCD display.
   (b) Next, remove the two screws (No. 21) in the display base (No. 35) and the two screws (also No. 21) in the back of the enclosure (No. 10).
   (c) The top, front and back sides of the enclosure can now be removed (the front slides out towards you and perpendicular to the flow path), exposing the PCB.

2. If the flowmeter does not have the digital display:
   (a) Remove the label (No. 29) from the plain top cover (No. 28) to expose the two screws.
   (b) Then follow steps 1b and 1c above.

To reassemble, reverse this process.

For applications requiring flow totalization or alarms, it is possible to connect the FMA-5000 Series to the OMEGA FMA-DV Series electronics. Contact OMEGA Sales Department for special applications.

SECTION 3 OPERATION

3.1 QUICK OPERATING INSTRUCTIONS

Quick operating instructions are given on the first page of this manual.

3.2 OPERATING NOTES

1. Referencing the Flow Rate to Other Temperature and Pressure Conditions

The gas flow rate output of the flowmeter is referenced to standard conditions of 21°C (70°F) and 760 mm of mercury (1 atmosphere), unless you have specified otherwise in your order. Be sure you know the reference conditions of your unit, because it may make a difference if you are comparing the output with another type of flowmeter. For example, the output reading of the FMA-5000 Series will be approximately 7% lower if it is referenced to 0°C rather than 21°C. Appendix 3 shows how to convert the flow rate output of your instrument to other standard conditions and how to find the flow rate referenced to the actual temperature and pressure conditions in the pipe.

2. Accuracy

The standard accuracy is ±2% of full scale. A ±1% accuracy is available with special calibration or upon recalibration (See Section 5.2). The ±2% of full scale accuracy means the 0-5 VDC output signal is accurate to within ±0.1 VDC, and the 4-20 mA output is accurate to within ±0.4 mA. This means, for example, that the output signal for zero flow can be as much as ±0.1 VDC or ±0.4mA. Please note if you get an output signal at zero flow (as long as it is within either of these two ranges), it does not mean the flowmeter is malfunctioning. For models with the digital readout, the accuracy is simply 2% times the full scale flow rate listed on the front label. For example, if your full scale is 10 SLM, the digital readout will be accurate to ±0.2 SLM, and the reading at zero flow may be as much as ±0.2 SLM and still be within the stated accuracy specification.

3. Overranging

If the flow rate exceeds the full scale range listed on the front label, the output signal and digital display (if you have it) will read a higher value.

The FMA-5000 Series has not been calibrated for overranged flows and probably will be both non-linear and inaccurate. If the supply voltage is only 12 VDC, the overranged reading may only exceed the full scale reading by 10% maximum. If the supply voltage is higher, such as with the 24 VDC option, then the output can exceed full scale by as much as 50%, or more. If you have 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.

Due to the operating principle of the sensor, if the flow overranges, the output will become nonlinear and at some point will go "over the hump". After this point, the output signal will decrease even though the flow is increasing. This will not cause any damage and will correct itself, usually within 30 seconds after the flow is shut off or returns to within the calibrated range of the meter. In systems where it is possible for overrange conditions to occur, it is recommended that a valve or critical orifice be inserted in the line to limit the flow to approximately 25% above the full scale range.

4. Optional 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 (50 to 500 ohms) to ground. Figures 3-1 and 3-2 illustrate single and multiple installations with current loop outputs.

5. Zero and Span Adjustments

The zero and span potentiometers are accessed through marked ports on the right side. If your zero output is more than ±2% of full scale, you may adjust the zero potentiometer when you are absolutely certain that you have zero flow.

Since the output does not indicate negative numbers, it is necessary to adjust down from a slightly positive reading. Slowly rotate the zero pot clockwise until a positive reading is indicated. Then turn the pot counterclockwise slowly just until zero is reached. This completes the zero adjustment.

Normally, span adjustments are not made unless you are calibrating the flowmeter, as described in Section 5. The span adjustment should not be used unless you have a known precise non-zero flow rate that you wish to match.

6. Attitude

Unless specified otherwise, the instrument has been calibrated for installation with the flow direction in the horizontal plane (±15°) with the enclosure facing upward. If your actual installation orientation is different, you will have to make a small zero adjustment.

3.3 PRINCIPLE OF OPERATION

Gas enters the flow body and divides into two flow paths. Most of the flow goes through the laminar flow bypass. This creates a pressure drop that forces a small fraction of the flow through the sensor tube.

The straight sensor tube is mounted on the top of the bypass flow path. Since both paths are perfectly laminar, the ratio of the total flow (m) to the sensed flow (m1) is exactly constant. This contributes to the flowmeter's exceptional accuracy. Two resistance detector (RTD) coils around the sensor tube direct a constant amount of heat into the gas stream.

In actual operation, the gas mass flow carries heat from the upstream coil to the downstream coil. The resulting temperature difference T2-T1 is detected by the RTD coils and gives the output signal. Since the molecules of gas carry away the heat, the output signal is directly and linearly proportional to gas mass flow.

The laminar flow bypass makes changing of flow ranges easy with the proper calibration facilities. Each of the two bypasses in the optional Laminar Flow Bypass Set has a combination of rectangular slots along its circumference as shown in Figure 3-5 below.

To change the flow rate of the flowmeter, follow the instructions provided with the Laminar Flow Bypass Set and cut away the gates leading to the right combination of laminar flow paths in one of the two bypasses. This procedure requires calibration facilities and minimal skills in electronics.

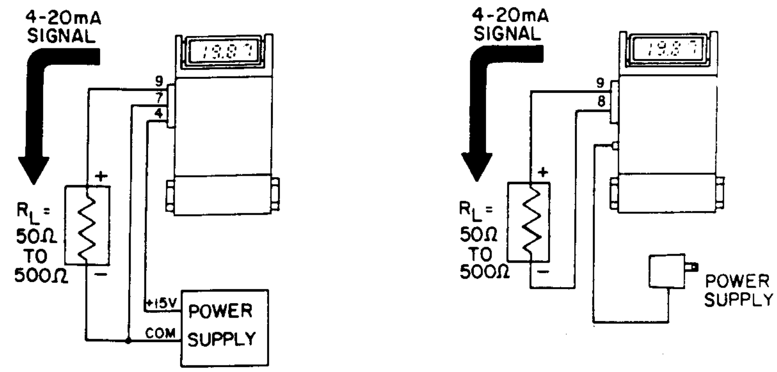


Figure 3-1. Single Unit 4-20 Hookup

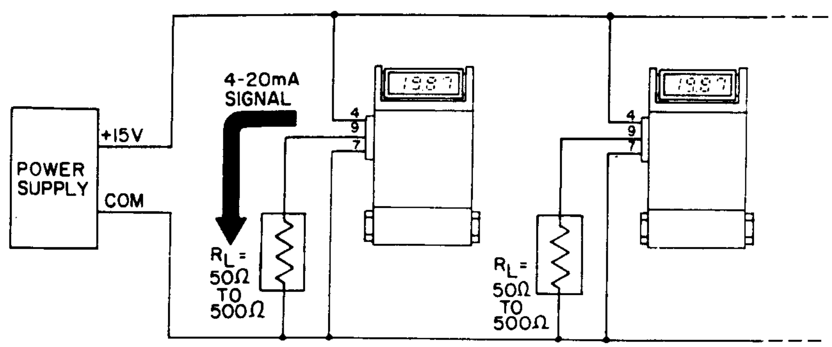


Figure 3-2. Multiple Installation 4-20 Hookup

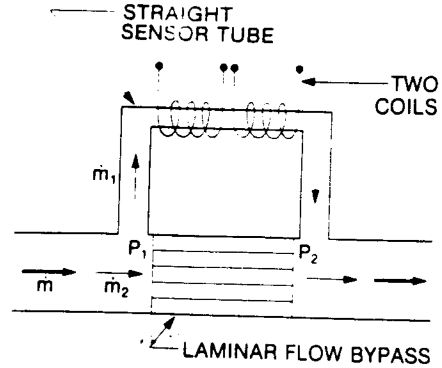


Figure 3-3. Two Flow Paths

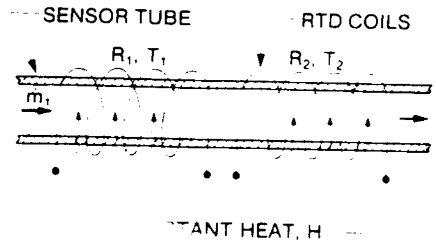


Figure 3-4. Meas...

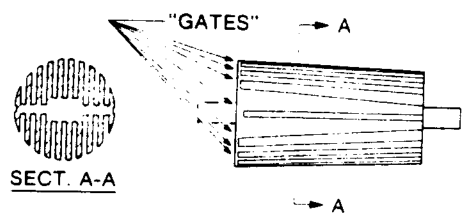


Figure 3-5. Laminar Flow Bypass Set

SECTION 4 MAINTENANCE

The FMA-5000 Series essentially requires no maintenance and has no regular maintenance schedule, other than periodic flow path cleaning if the gas is dirty. Calibrations may be scheduled once or twice yearly, depending on the accuracy to be maintained, or as needed.

4.1 Flow Path Cleaning

The flow path (wetted parts) are 5% glass-filled Nylon 6/6; 316 SS (sensor tube) and Viton O-rings (standard).

CAUTION

If you wish to clean the flowmeter, purge it thoroughly before disconnecting from the gas line when toxic or corrosive gases are used. Never return the instrument to OMEGA for repair or calibration without fully neutralizing any toxic gases trapped inside.

Refer to the exploded drawing of the transducer in Appendix 1 when performing the following procedures. All cleaning of the flow path can be accomplished with Freon, alcohol or any cleaner safe for the listed materials.

4.1.1 Inlet and Outlet Screen

Remove inlet and outlet fittings (No. 13), pull out the LFE hold-downs (No. 12) and either replace or clean the inlet and outlet screens (No. 14).

4.1.2 Laminar Flow Element (LFE)

Remove the inlet and outlet fitting as in Section 4.1.1. The LFE has a slightly tapered shape with the larger diameter upstream (on the inlet side). To remove the LFE for cleaning, push it out the inlet side from the outlet side using a blunt object which does not mar the flow channels. A ⅜" nut driver is perfect for this job. When cleaning, be sure to carefully clean all active flow channels in the LFE. When reinstalling the LFE, it is of utmost importance to press it in the correct distance. Refer to Figure 4-1.

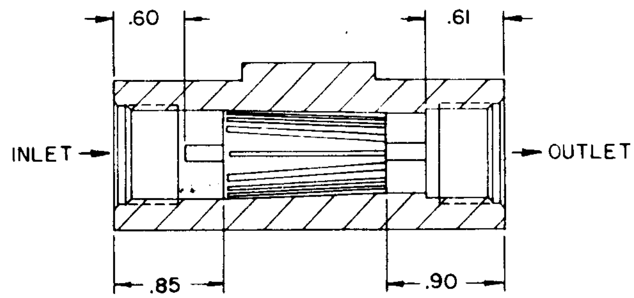


Figure 4-1. LFE Location Within the Flow Body

4.1.3 Sensor Tube

CAUTION

Opening the sensor cavity will shift calibration.

Do not remove the PCB bracket (No. 7) unless it is absolutely necessary to gain access to the sensor cavity. Doing so will shift the calibration more than 2%. The remaining parts of the flow path are disassembled as shown in the exploded view in Appendix 1. Note the position of the insulation blanket before removal and reinstall in the same manner. After removal, the sensor tube (No. 5) can be cleaned by purging, washing with a solvent, or by rodding out the 0.031 inch I.D. tube with a 0.029-0.030 inch O.D. rod or wire. To maximize the time response, the sensor tube has thin walls. Therefore, when cleaning, be extremely careful not to bend the sensor tube or to mar its inlet or outlet edges. It is important when reinstalling the sensor to make sure that no torque is imparted on the sensor tube. Torque can be eliminated by using a good quality oxygen compatible grease on the sensor sealing O-rings. The sensor assembly should slide freely into the cavity flanges without having to twist it. Twisting will impart undesirable torque on the sensor and could lead to long term shifting of the zero value. Also, take care to not disturb or unravel the sensor windings.

SECTION 5 CALIBRATION

5.1 GENERAL FLOW CALIBRATION PROCEDURE

Flow calibration requires a calibration standard of at least double accuracy and preferably an order of magnitude better. Most calibrations can be done using dry nitrogen and the "K" factors and gas tables given in Appendix 4.

5.2 RECALIBRATION OVER THE SAME FLOW RANGE

Flow recalibration is performed by using the following procedure. Refer to the electrical schematics in Appendix 2. Calibration checks and minor adjustments to the zero and full scale may be made via the access ports in the side of the enclosure. If the linearity needs adjustment (as may be required when installing a different laminar flow element bypass to change the range), go to Step 4.

Step 1 Warm-Up: Plug in the flowmeter to be calibrated and allow at least 15 minutes warm-up time before attempting any adjustments.

Step 2 Zero Adjust: Slide open the zero and span access ports on the side. Using a voltmeter connected to the meter output pins, adjust the zero potentiometer (R5) for zero flow (4 mA for 4-20 mA outputs).

Step 3 Check Full Scale: Generate the full scale flow using a metering valve in line with the instrument under test. Compare the indicated flow rate with the flow standard reading. If they agree to within ±10%, adjust the span potentiometer (R21) for exact agreement. If the readings do not agree within ±10%, attempt to determine the cause of disagreement. Possibilities are:

a) Partially clogged or dirty sensor tube
b) Wrong or improper use of K factor
c) Wrong or improper correction for temperature and pressure
d) Leaks in the system or in the flowmeter
e) Replacement of parts in the flow path do not exactly match the original parts.

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

Step 4 Adjusting Linearity: First gain access to the printed circuit board inside the enclosure by using the procedure described in Section 2.4.3. Orient the meter so that the component side of the circuit board is facing you. Plug in the meter and allow it to warm up for at least 15 minutes.

Step 5 Zero Adjust: Connect a voltmeter to the meter output pins and adjust the zero potentiometer (R5) for zero volts at zero flow (4 mA for 4-20 mA outputs).

Step 6 Calibrate 25%: Use the calibration standard to set a flow rate of 25% of full scale. Adjust the span potentiometer (R21) for 1.25 volts (8 mA for 4-20 mA outputs) at the output of the meter.

	INC.	DEC.			INC.	DEC.	
J1	0	0	0	J1	[XXXXX]	0	Adjust R25 (50%)
J2	0	0	0	J2	0	[XXXXX]	Adjust R27 (75%
J3	0	0	0	J3	[XXXXX]	0	Adjust R29 (100%

Linearizer Jumper Array   Jumpers Installed

Figure 5-1. Linearizer Jumper Array

Step 7 Calibrate 50%: Increase the flow rate to 50% of full scale. If the output is within ±100mV, no adjustment is necessary. If the output is beyond these limits, install a jumper block at J1 in the appropriate position (increment or decrement—See Figure 5-1) and adjust R25 for the proper reading.

Step 8 Calibrate 75% and 100%: Set the flow to 75% of full scale. If the output is outside the limits set in Step 7, install a jumper block in J2 in the proper location and adjust R27 for the correct reading. Repeat this procedure for 100% flow, using J3 and R29 if necessary.

If the curve being linearized is not monotonic (e.g. jumpers are in both increment and decrement positions), repeat Steps 6 through 8 at least one more time.

5.3 FLOW CALIBRATION OVER A DIFFERENT FLOW RANGE AND/OR GAS

The procedure for calibrating over a different flow range and/or gas is identical to that described in Section 5.2, except that the range of the laminar flow element (LFE) may need changing.

The first step is to determine the equivalent nitrogen flow rate. To do so, you must first determine your "standard" gas conditions. 21°C (or 70°F) and 760 mm of mercury (1 atmosphere) is standard. Appendix 3 is helpful in this regard. You must then use the K factor tables in Appendix 4.

The next step uses the Laminar Flow Bypass Set to open "gates" to the individual laminar flow channels. The instruction manual for the set describes this procedure in detail.

Note: Potentiometer R-15 shown in Appendix 2 is for speed of response and does not require any adjustment.

SECTION 6 TROUBLESHOOTING

6.1 GENERAL TROUBLESHOOTING

When it is suspected that the flowmeter is not operating correctly, a few simple checks can be made before dismantling for repair.

1. Make sure there are no leaks in the line.
2. Check that all cables are plugged in and are in good condition.
3. Check that the power supply is in the correct range.
4. Double-check connector pinouts.

6.2 TROUBLESHOOTING GUIDE

This guide is provided to help locate the section at fault. In the case of most repairs, the unit should be returned to OMEGA for service.

SYMPTOM	POSSIBLE CAUSE	CORRECTIVE ACTION
No output	No power	Plug in power supply
	Clogged sensor	Clean or replace sensor
	PCB defective	Repair or replace PCB
	Inlet filter screen clogged	Clean or replace
Will not zero	Gas leak	Find and correct leaks
	Application requires high pressure and non-horizontal mounting	Re-zero meter
	PCB defective	Repair or replace
Reads full scale with zero flow	Defective sensor	Return to factory for replacement
	Gas leak	Find and correct leaks
Out of calibration	Dirty or clogged sensor	Clean or replace sensor
	Change in composition of gas	See K factor tables in Appendix 4
	Gas leak	Find and correct leaks
	PCB defective	Repair or replace
	LFE dirty	Clean
	Inlet filter screen clogged	Clean or replace

SECTION 7 SPECIFICATIONS

ACCURACY:	±2% of full scale including linearity over 15 to 25°C and 5 to 60 psia (0.35 to 4.2 kg/cm); with special calibration ±1% of full scale accuracy at a specific temperature and pressure is available.
REPEATABILITY:	±0.5% of full scale
RESPONSE TIME:	800 ms time constant; 2 seconds (typical) to within ±2% of final value over 25 to 100% of full scale; 1 second to within ±2% of final value is available on special order.
GAS PRESSURE:	150 psi gage max; 20 psi gage optimum
GAS AND AMBIENT TEMPERATURE:	0 to 50°C
OUTPUT SIGNAL:	Linear 0-5 VDC standard, 1000 ohms min. load impedance; 4-20 mA optional, 50 to 500 ohms loop resistance.
POWER REQUIREMENTS:	12 to 15 VDC nominal; 100 mA max. (24 VDC optional)
WETTED MATERIALS:	5% glass-filled Nylon 6/6; 316 stainless steel; Viton O-rings
DISPLAY:	3½ digit LCD (0.5 in. H)
WEIGHT:	2 lb

PRESSURE DROP

Flow Rate (SLM)	Max. Press. Drop (cm of Water)
Up to 10	2.5
20	10
30	16
40	24

MODEL	DESCRIPTION
FMA-56 [*]	Flowmeter with Display
FMA-57 [*]	Flowmeter without Display

RANGE CODE TABLE

(Insert code into above model number)

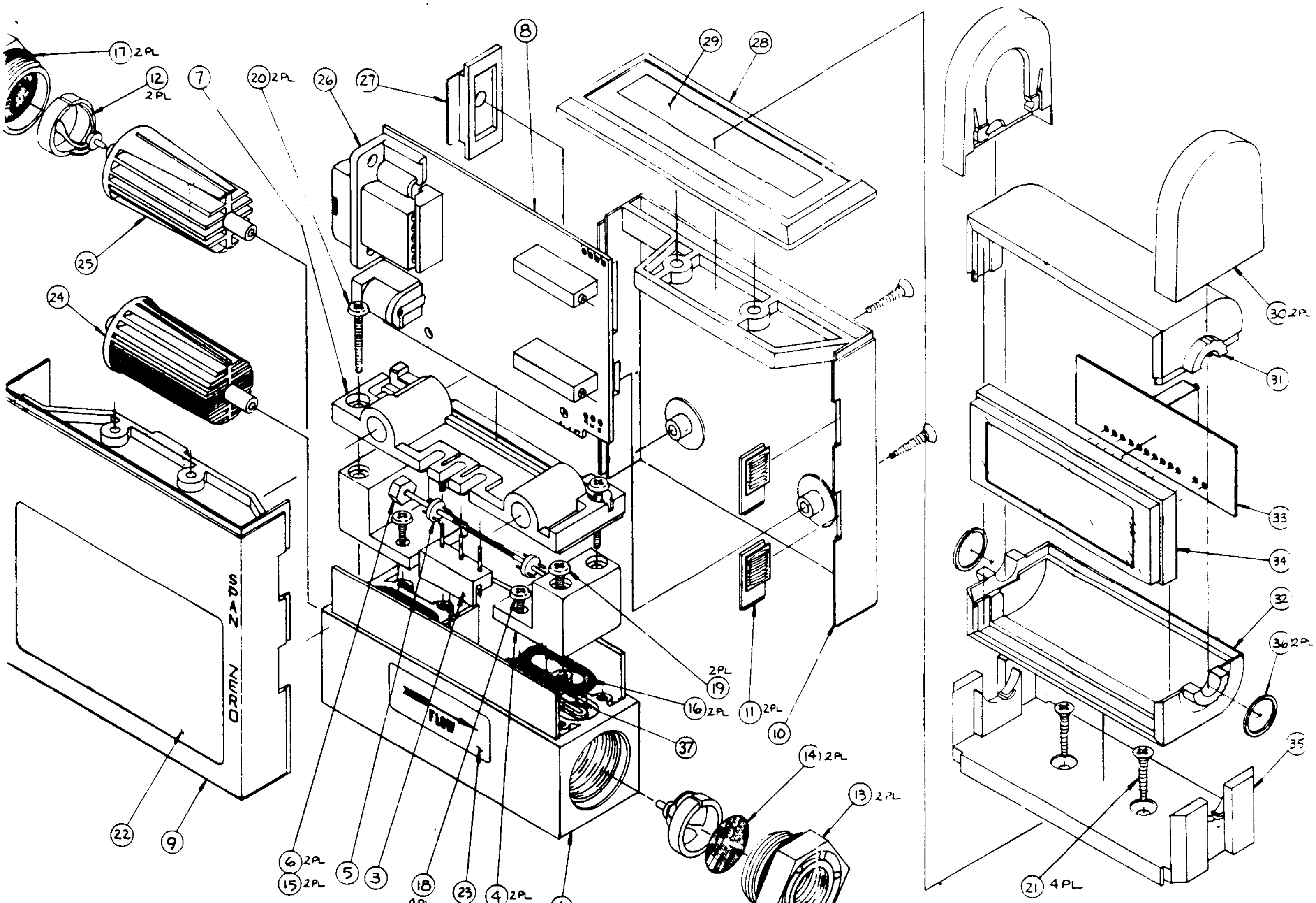
Code	SCCM	Code	SLM
01	0-10	07	0-1
02	0-20	08	0-2
03	0-50	09	0-5
04	0-100	10	0-10
05	0-200	11	0-20
06	0-500	12	0-30
		13	0-40

ACCESSORIES

FMA-LFB	Spare Laminar Flow Bypass Set for use in changing Flow Ranges
FMA-PST	Power Supply for FMA-5600

Appendix 1. Exploded View of Transducer and Parts List

ITEM NO.	PART NO.	DESCRIPTION
1	820-020-001	Flow Body
3	820-020-003	Sensor Feedthrough
4	820-020-004	Sensor Mounting
5	830-030-007	Sensor
6	820-020-005	Sensor Nut
7	820-020-006	PCB Bracket
8	820-030-009	PCB
9	820-020-008	Front Enclosure
10	820-020-007	Back Enclosure
11	820-020-009	Zero/Span Slide
12	820-020-012	LFE Hold Down
13	820-020-011	Adapter ¾-16 to ¼ FNPT
14	820-020-019	Screen
15	S440001-001	"O"-Rings—Sensor
16	S440002-014	"O"-Rings—Flow Body
17	S440003-908	"O"-Rings—Fitting
18	S030001-002	Pan Head Screw (Phil., 4-40)
19	S030001-004	Pan Head Screw (Phil., 4-40)
20	S030006-005	Flat Head Screw (Phil., 4-40)
21	S030006-002	Flat Head Screw (Phil., 4-40)
22	820-020-026	Label—Front
23	820-022-027	Label—Flow Arrow
24	820-020-032	Laminar Flow—Low Flow
25	820-020-035	Laminar Flow—High Flow
26	S540001-001	DB9 Connector—9-Pin
27	820-020-010	Connector Block
28	820-020-014	Plain Top Cover
29	820-020-025	Label
30	820-020-016	Display Cover
31	820-020-017	Display Enclosure—Top
32	820-020-018	Display Enclosure—Bottom
33	820-030-005	Display Board
34	S590001-001	Display
35	820-020-015	Display Base
36	S170001-001	Snap Rings
37	820-020-002	Flow Booster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SPAN
ZERO
FLOW
2PL
19
16 2PL
11 2PL
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37
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6 2PL
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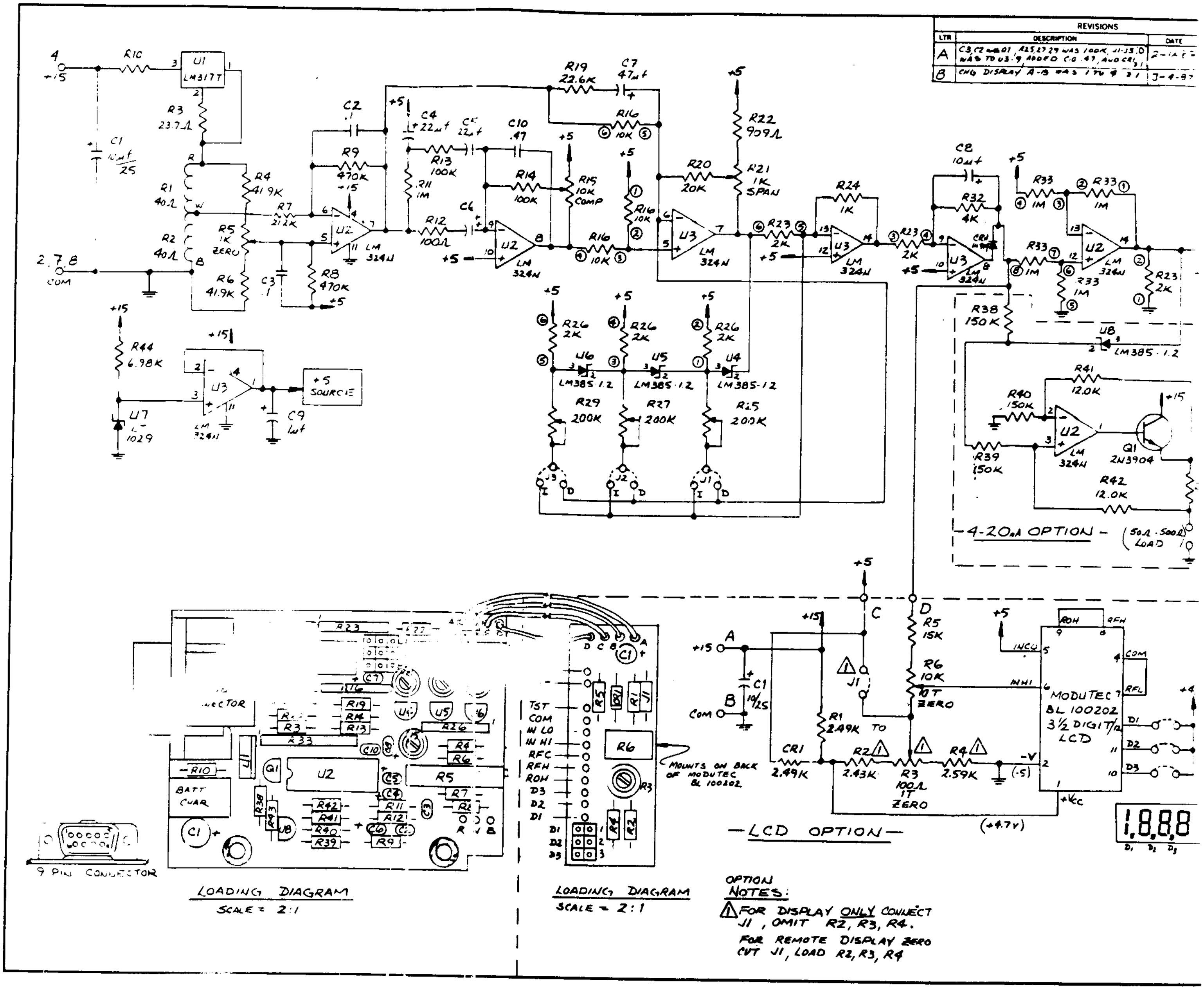
21 4PL

Appendix 2. Electrical Schematics



Appendix 3. Conversion of Flow Rate to Other T and P Conditions

The flow rate of your FMA-5000 is referenced to certain "standard" conditions of temperature and pressure. Unless otherwise specified in your order, these standard conditions are 21°C (70°F) and 760 mm of mercury (1 atmosphere). If you wish to convert to other "standard" conditions or to find the "actual" conditions in the pipe where your flowmeter is installed, use the following relationship:

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

$(\ )_1$ = Refers to the standard conditions with which your flowmeter was calibrated,

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

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

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

P = Absolute pressure (kg/cm^2 or psia), and

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

EXAMPLE 1 Changing "Standard" Conditions

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

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

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

EXAMPLE 2 Finding the "Actual" Flow Rate

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

$$Q_2 = \frac{14.7}{14.7+30} \quad \frac{460+100}{460+70} \quad (10.00) = 3.47 \text{ ALM}$$

Appendix 4. K Factors and Gas Tables

A4.1. For a Single Gas

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:

a. 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.).

b. Interpreting the reading of a flowmeter or flow controller which has been calibrated with a gas other than the actual gas.

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

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

Where:

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

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

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

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

The K-factor is derived from the first law of thermodynamics applied to the sensor tube, as described in Figure 1-2, p.2:

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

Where:

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

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

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

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

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

NUMBER OF ATOMS IN THE GAS MOLECULE	N
Monatomic	1.040
Diatomic	1.000
Triatomic	0.941
Polyatomic	0.880

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

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

Where:

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

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

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

Where:

a = A constant.

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

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

Where:

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

For our purposes, we want the ratio of the flow rate, Q_1, for an actual gas to the flow rate of a reference gas, Q_2, which will produce the same output voltage in a particular mass flow meter or controller. We get this by combining Equations (1) and (5):

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

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

In the third column of the tables, the relative K-factor is $K_{actual}/K_{reference}$, where the reference gas is a gas very close molecularly to the actual gas. In the fourth column, the relative K-factor is K_{actual}/KN_2, where the reference gas is the commonly used gas, nitrogen (N_2). The remaining columns give C_p and ρ, enabling you to calculate K_1/K_2 directly using Equation (6). In some instances, K_1/K_2 from the Table 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-5000 Series mass flow meter with primary standards using the actual gas or a molecularly equivalent reference gas. The calibration certificate accompanying your flow meter will cite the reference gas used. When a reference gas is used, the actual flow rate will be within 2-4% of the calculated flow rate.

EXAMPLE 1
A flowmeter is calibrated for nitrogen (N_2), and the flow rate is 1000 SCCM for a 5.00 VDC output signal. The flow rate for carbon dioxide at 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 flowmeter is calibrated for hydrogen (H_2), and the flow rate is 100 SCCM for a 5.00 VDC output signal. The flow rate for nitrous oxide (N_2O) 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 flowmeter 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?

$$Q_{SiH_2CL_2}/Q_{CF_4} = K_{SiH_2CL_2}/K_{CF_4}$$
$$100/Q_{CF_4} = 0.869$$
$$Q_{CF_4} = 100/0.869 = 115 \text{ SCCM}$$

A4.2 For Dual-Gas Mixtures

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

The equivalent gas density is:

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

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	Reference Gas	K Factor Rel. to Ref. Gas	K Factor Relative N_2	C_p (Cal/g)	Density (g/1) @ 0°C	Molecul Weight
Acetylene C_2H_2	C_2H_4	.973	.58	.4036	1.162	
Air	N_2	1.00	1.00	.240	1.293	
Allene (Propadiene) C_3H_4	CF_4	.934	.43	.352	1.787	
Ammonia NH_3	N_2O	1.028	.73	.492	.760	
Argon Ar	Ar	1.000	1.45	.1244	1.782	
Arsine AsH_3	N_2O	.943	.67	.1167	3.478	
Boron Trichloride BCl_3	CF_4	.891	.41	.1279	5.227	
Boron Trifluoride BF_3	CF_4	1.108	.51	.1778	3.025	
Bromine Br_2	N_2O	1.140	.81	.0539	7.130	
Boron Tribromide Br_3	CF_4	.826	.38	.0647	11.18	
Bromine Pentafluoride BrF_5	CF_4	.565	.26	.1369	7.803	
Bromine Trifluoride BrF_3	CF_4	.826	.38	.1161	6.108	
Bromotrifluoromethane (Freon-13 B1) $CBrF_3$	CF_4	.804	.37	.1113	6.644	
1,3-Butadiene C_4H_6	CF_4	.695	.32	.3514	2.413	
Butane C_4H_{10}	CF_4	.565	.26	.4007	2.593	
1-Butane C_4H_8	CF_4	.652	.30	.3648	2.503	
2-Butane C_4H_8 CIS	CF_4	.704	.324	.336	2.503	
2-Butane C_4H_8 TRANS	CF_4	.632	.291	.374	2.503	
Carbon Dioxide CO_2	N_2O	1.042	.74	.2016	1.964	
Carbon Disulfide CS_2	C_2H_4	1.007	.60	.1428	3.397	
Carbon Monoxide CO	N_2	1.000	1.00	.2488	1.250	
Carbon Tetrachloride CCl_4	CF_4	.673	.31	.1655	6.860	
Carbon Tetrafluoride (Freon-14) CF_4	CF_4	.913	.42	.11654	3.926	
Carbonyl Fluoride COF_2	C_2H_4	.907	.54	.1710	2.945	
Carbonyl Sulfide COS	N_2O	.929	.66	.1651	2.680	

Actual Gas	Reference Gas	K Factor Rel. to Ref. Gas	K Factor Relative N_2	C_p (Cal/g)	Density (g/1) @ 0°C	Molecular Weight
Chlorine Cl_2	N_2	.860	.86	.114	3.163	
Chlorine Trifluoride ClF_3	CF_4	.869	.40	.1650	4.125	
Chlorodifluoromethane (Freon-22) $CHClF_2$	CF_4	1.000	.46	.1544	3.858	
Chloroform $CHCl_3$	CF_4	.847	.39	.1309	5.326	
Chloropentafluoroethane (Freon-115) C_2ClF_5	CF_4	.521	.24	.164	6.892	
Chlorotriflurομethane (Freon-13) $CClF_3$	CF_4	.826	.38	.153	4.660	
Cyanogen C_2N_2	C_2H_4	.7526	.61	.2613	2.322	
Cyanogen Chloride ClCN	C_2H_2	1.024	.61	.1739	2.742	
Cychlopropane C_3H_5	CF_4	1.00	.46	.3177	1.877	
Deuterium D_2	N_2	1.00	1.00	1.722	1.799	
Diborane B_2H_6	CF_4	.956	.44	.508	1.235	
Dibromodifluoromethane	CF_4	.413	.19	.15	9.362	
CBr_2F_2	CF_4	1.021	.47	.075	7.76	
Dichlorodifluoromethane (Freon-12) CCl_2F_2	CF_4	.760	.35	.1432	5.395	
Dichlorofluoromethane (Freon-21) $CHCl_2F$	CF_4	.913	.42	.140	4.592	
Dichloromethylsilane $(CH_3)_2SiCl_2$	CF_4	.543	.25	.1882	5.758	
Dichlorosilane SiH_2Cl_2	CF_4	.869	.40	.150	4.506	
Dichlorotetrafluoroethane (Freon-114) $C_2Cl_2F_4$	CF_4	.478	.22	.1604	7.626	
1,1-Difluoroethylene (Freon-1132A) $C_2H_2F_2$	CF_4	.934	.43	.224	2.857	
Dimethylamine $(CH_3)_2NH$	CF_4	.804	.37	.366	2.011	
Dimethyl Ether $(CH_3)_2O$	CF_4	.847	.39	.3414	2.055	
2,2-Dimethylpropane C_5H_{12}	CF_4	.423	.22	.3914	3.219	
Ethane C_2H_6	CF_4					
Ethanol C_2H_6O	CF_4	.856	.39	.3395	2.055	

Actual Gas	Reference Gas	K Factor Rel. to Ref. Gas	K Factor Relative N_2	C_p (Cal/g)	Density (g/l) @ 0°C	Molecu Weight
Ethyl Acetylene C_4H_6	CF_4	.703	.32	.3513	2.413	
Ethyl Chloride C_2H_5Cl	CF_4	.84	.39	.244	2.879	
Ethylene C_2H_4	C_2H_4	1.000	.60	.1365	1.251	
Ethylene Oxide C_2H_4O	CF_4	1.130	.52	.268	1.965	
Fluorine F_2	N_2	.980	.98	.1873	1.695	
Fluoroform (Freon-23) CHF_3	CF_4	1.086	.50	.176	3.127	
Freon-11 CCl_3F	CF_4	.717	.33	.1357	6.129	
Freon-12 CCl_2F_2	CF_4	.760	.35	.1432	5.395	
Freon-13 $CClF_3$	CF_4	.826	.38	.153	4.660	
Freon-13 B1 $CBrF_3$	CF_4	.804	.37	.1113	6.644	
Freon-14 CF_4	CF_4	1.000	.42	.1654	3.926	
Freon-21 $CHCl_2F$	CF_4	.913	.42	.140	4.592	
Freon-22 $CHClF_2$	CF_4	1.095	.46	.1544	3.858	
Freon-113 CCl_2FCClF_2	CF_4	.434	.20	.161	8.360	
Freon-114 $C_2Cl_2F_4$	CF_4	.478	.22	.160	7.626	
Freon-115 C_2ClF_5	CF_4	.521	.24	.164	6.892	
Freon-C318 C_4F_8	CF_4	.369	.17	.185	8.397	
Germane GeH_4	C_2H_4	.950	.57	.1404	3.418	
Germanium Tetrachloride $GeCl_4$	CF_4	.586	.27	.1071	9.565	
Helium He	He	1.000	1.454	1.241	.11786	
Hexafluoroethane C_2F_6 (Freon-116)	CF_4	.521	.24	.1834	6.157	
Hexane C_6H_{14}	CF_4	.391	.18	.3968	3.845	
Hydrogen H_2	H_2	1.000	1.01	3.419	.0899	
Hydrogen Bromide HBr	N_2	1.000	1.00	.0861	3.610	
Hydrogen Chloride HCl	N_2	1.000	1.00	.1912	1.627	

Actual Gas	Reference Gas	K Factor Rel. to Ref. Gas	K Factor Relative N_2	C_p (Cal/g)	Density (g/1) @ 0°C	Molecular Weight
Hydrogen Cyanide HCN	N_2	1.070	.76	.3171	1.206	
Hydrogen Fluoride HF	N_2	1.000	1.00	.3479	.893	
Hydrogen Iodide HI	N_2	1.000	1.00	.0545	5.707	
Hydrogen Selenide H_2Se	N_2O	1.112	.79	.1025	3.613	
Hydrogen Sulfide H_2S	N_2O	1.126	.80	.2397	1.520	
Iodine Pentafluoride IF_5	CF_4	.543	.25	.1108	9.90	
Isobutane $CH(CH_3)_3$	CF_4	.586	.27	.3872	3.593	
Isobutylene C_4H_6	CF_4	.630	.29	.3701	2.503	
Krypton Kr	Ar	1.002	1.453	.0593	3.739	
Methane CH_4	N_2O	1.014	.72	.5328	.715	
Methanlo CH_3	C_2H_4	.966	.58	.3274	1.429	
Methyl Acetylene C_3H_4	CF_4	.934	.43	.3547	1.787	
Methyl Bromide CH_2Br	C_2H_4	.966	.58	.1106	4.236	
Methyl Chloride CH_3Cl	C_2H_4	1.050	.63	.1926	2.253	
Methyl Fluoride CH_3F	C_2H_4	.957	.68	.3221	1.518	
Methyl Mercaptan CH_3SH	CF_4	1.130	.52	.2459	2.146	
Methyl Trichlorosilane $(CH_3)SiCL_3$	CF_4	.543	.25	.164	6.669	
Molybdenum Hexafluoride MoF_6	CF_4	.456	.21	.1373	9.366	
Monoethylamine $C_2H_5NH_2$	CF_4	.760	.35	.387	2.011	
Monomethylamine CH_3NH_2	CF_4	.850	.51	.4343	1.386	
Neon NE	Ar	1.006	1.46	.246	.900	
Nitric Oxide NO	N_2	.990	.99	.2328	1.339	
Nitrogen N_2	N_2	1.000	1.00	.2485	1.25	
Nitrogen Dioxide NO_2	N_2O	1.042	.74	.1933	2.052	
Nitrogen Trifluoride NF_3	CF_4	1.043	.48	.1797	3.168	

Actual Gas	Reference Gas	K Factor Rel. to Ref. Gas	K Factor Relative N_2	C_p (Cal/g)	Density (g/1) @ 0°C	Molecu Weight
Nitrosyl Chloride NOCl	C_2H_4	1.016	.61	.1632	2.920	
Nitrous Oxide N_2O	N_2O	1.000	.71	.2088	1.964	
Octafluorocyclobutane (Freon-C318) C_4F_8	CF_4	.369	.17	.185	8.397	
Oxygen O_2	N_2	1.000	1.00	.2193	1.427	
Oxygen Difluoride OF_2	C_2H_4	1.050	.63	.1917	2.406	
Pentaborane B_5H_9	CF_4	.565	.26	.38	2.816	
Pentane C_5H_{12}	CF_4	.456	.21	.398	3.219	
Perchloryl Fluoride ClO_3F	CF_4	.847	.39	.1514	4.571	
Perfluoropropane C_3F_8	CF_4	.369	.174	.197	8.388	
Phosgene $COCl_2$	CF_4	.956	.44	.1394	4.418	
Phosphine PH_3	N_2O	1.070	.76	.2374	1.517	
Phosphorous Oxychloride $POCl_3$	CF_4	.782	.36	.1324	6.843	
Phosphorous Pentafluoride PH_5	CF_4	.652	.30	.1610	5.620	
Phosphorous Trichloride PCl_3	CF_4	.652	.30	.1250	6.127	
Propane C_3H_8						
Propylene C_3H_6	CF_4	.891	.41	.3541	1.877	
Silane SiH_4	C_2H_4	1.000	.60	.3189	1.433	
Silicon Tetrachloride $SiCl_4$	CF_4	.608	.28	.1270	7.580	
Silicon Tetrafluoride SiF_4	CF_4	.760	.35	.1691	4.643	
Sulfur Dioxide SO_2						
Sulfur Hexafluoride SF_6	CF_4	.565	.26	.1592	6.516	
Sulfuryl Fluoride SO_2F_2	CF_4	.847	.39	.1543	4.562	
Tetrafluorahydrazine N_2F_4	CF_4	.695	.32	.182	4.64	
Trichlorofluoromethane (Freon-11) CCl_3F	CF_4	.717	.33	.1357	6.129	
Trichlorosilane $SiHCl_3$	CF_4	.717	.33	.1380	6.043	

Actual Gas	Reference Gas	K Factor Rel. to Ref. Gas	K Factor Relative N_2	C_p (Cal/g)	Density (g/1) @ 0°C	Molecular Weight
1,1,2-Trichloro-1,2,2 Trifluoroethane (Freon-113) CCl_2FCClF_2	CF_4	.434	.20	.161	8.360	
Trisobutyl Aluminum $(C_4H_9)Al$	CF_4	.132	.061	.508	8.848	
Titanium Tetrachloride $TiCl_4$	CF_4	.586	.27	.120	8.465	
Trichloro Ethylene C_2HCl_3	CF_4	.695	.32	.163	5.95	
Trimethylamine $(CH_3)_3N$	CF_4	.608	.28	.3710	2.639	
Tungsten Hexafluoride WF_6	CF_4	.552	.25	.0810	13.28	
Uranium Hexafluoride UF_6	CF_4	.434	.20	.0888	15.70	
Vinyl Bromide CH_2CHBr	CF_4	1.000	.46	.1241	4.772	
Vinyl Chloride CH_2CHCl	CF_4	1.043	.48	.12054	2.788	
Xenon Xe	Ar	.993	1.44	.0378	5.858	