

KOBOLD MAS Series

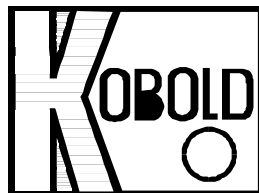
Thermal Mass
Flowmeters

March 1997

r2_12-13

Part Number:

IM-82



KOBOLD Instruments Inc
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(412) 788-2830 • (800) 998-1020 • Fax (412) 788-4890

The purpose of this instruction manual is to cover the following Kobold Instruments Inc products:

Model MAS-1000 Flowmeter with Polyamide body and display.

Model MAS-2000 Flowmeter with Polyamide body and no display.

Model MAS-3000 Flowmeter with stainless steel flow body and display.

Model MAS-4000 Flowmeter with stainless steel flow body and no display.

Model MAS-1100 Flowmeter with aluminum body and display.

Model MAS-2100 Flowmeter with aluminum body and no display.

Kobold Instruments' MAS Series Flowmeters measure the mass flow rate of gases in ranges from 0-10 standard cubic centimeters per minute (SCCM) to 0-500 standard liters per minute (SLM). For most models, accuracy is 1.5% of full scale over a wide temperature and pressure range, and time response is 2 seconds to within 2% of final flow. Certain models are rated at 1% or 5% of full scale.

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

1 INTRODUCTION

1.1 Purpose

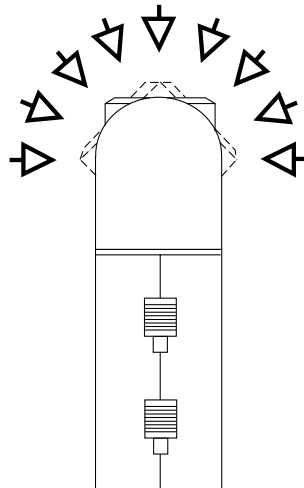


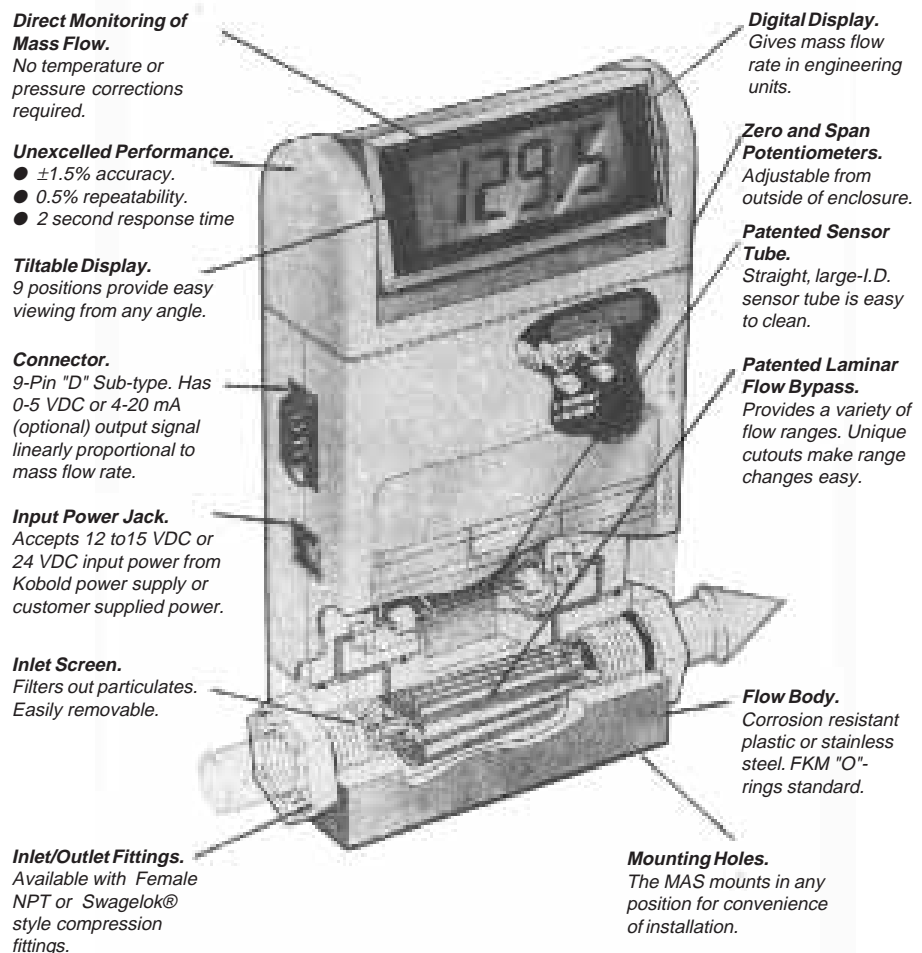
Figure 1-1
Tiltable Display is Viewed
from any Angle

CAUTION! Any application whatsoever related to human respiration must have the written consent of Kobold Instruments Inc.

The versatile MAS Flowmeter digitally displays the mass flow rate directly in engineering units or percent of full scale. The display is tiltable over 180° for easy viewing and can be removed for remote mounting on a front panel.

The Kobold MAS directly monitors the mass flow rate of the gas. This means it measures molecular flow – the measurement quality of direct concern in most applications, such as human respiration, chemical processes, combustion, and heating or cooling. No temperature or pressure corrections are required, as in the case of most other flow monitoring devices like rotameters, turbine meters, and orifice plates.

Figure 1-2
MAS Operation
and Features



The MAS Flowmeter is a transducer requiring a 12-15 VDC (24 VDC optional) external power source. A 0-5 VDC or optional 4-20 mA output signal linearly proportional to gas mass flow rate is provided for recording, data-logging, or control. A 9-Pin "D" sub-connector is provided for power input and signal output. The MAS is available in several basic configurations with either 1/4 inch NPT (female) or 1/4 to 1/2 inch O.D. tube compression inlet/outlet fittings, with or without the digital display, or the optional power supply.

Gas enters the MAS 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.

**1.2
Principle of
Operation**

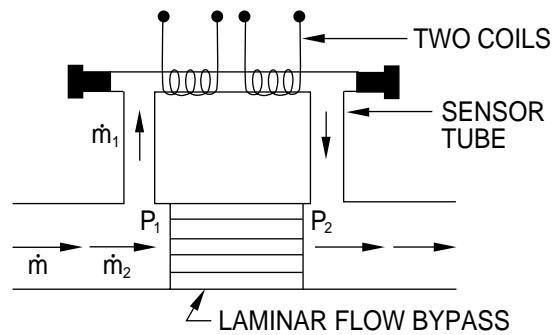
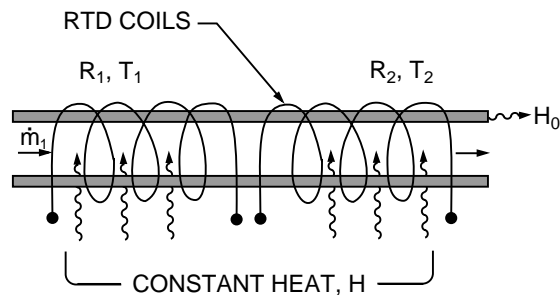


Figure 1-3
Two Flow Paths

The patented* straight sensor tube is mounted parallel to the bypass flow path. Since both paths are perfectly laminar, the ratio of the total flow (\dot{m}) to the sensed flow (\dot{m}_1) is constant. Two resistance temperature detector (RTD) coils around the sensor tube direct a constant amount of heat into the gas stream.



FIRST LAW OF THERMODYNAMICS
(HEAT IN = HEAT OUT)
 $H = \dot{m}_1 C_p (T_2 - T_1) + H_0$

$$\dot{m} = \frac{H - H_0}{C_p \Delta T}$$

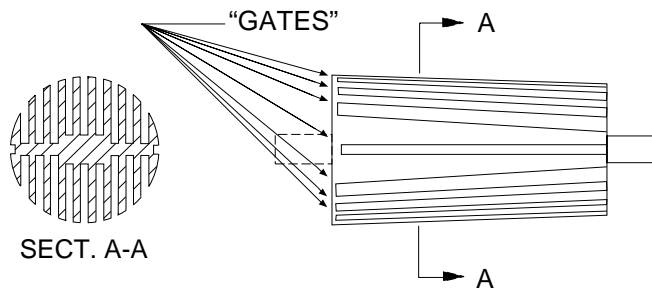
Figure 1-4
Measuring Sensor Flow

*U.S. Patent No. 4,487,062.

In actual operation, the gas mass flow carries heat from the upstream coil to the downstream coil. The resulting temperature difference $T_2 - T_1$ is detected by the RTD coils and gives the output signal. Since the molecules of the gas carry away the heat, the output signal is directly and linearly proportional to gas mass flow.

MAS's patented 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 1-5 below.

Figure 1-5
Changing Flow Ranges
is Easy with MAS's
Patented Bypass



To change the flow range of your MAS, follow the instructions provided with the Kobold Model EL Laminar Flow Bypass Set and cut away the "gate(s)" leading to the right combination of laminar flow paths in one of the two bypasses. This procedure requires proper calibration facilities and minimal skill in electronics.

1.3
Specifications

FLOW RANGES

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

Flow ranges specified are for an equivalent flow of nitrogen at 760 mm Hg and 21 °C (70 °F). Other ranges are available.

GASES

Most gases; check compatibility with wetted materials; specify when ordering.

DISPLAY

3 1/2 digit LCD (0.5 inch tall); removable for remote mounting.

OUTPUT SIGNAL

Linear 0-5 VDC standard, 1000 ohms min. load impedance; 4-20 mA optional, 50 to 500 ohms loop resistance.

POWER REQUIREMENTS

12-15 VDC nominal; 100 mA max (24 VDC optional, specify when ordering).

ACCURACY

$\pm 1.5\%$ of full scale including linearity over 15 to 25 °C and 5 to 60 psia (0.35 to 4.2 kg/cm²); with special calibration $\pm 1\%$ of full scale accuracy at a specific temperature and pressure is available.

REPEATABILITY

$\pm 0.5\%$ of full scale.

TEMPERATURE COEFFICIENT

0.15% of full scale per °C, or better.

PRESSURE COEFFICIENT

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

RESPONSE TIME

800 ms time constant; 2 seconds (typical) to within $\pm 2\%$ of final value over 25 to 100% of full scale.

PRESSURE DROP

Typical Flow Rates	Maximum Pressure Drop (cm of Water)
100 SCCM	.025
1 SLM	.454
10 SLM	6.00
20 SLM	23.83
30 SLM	45.60
40 SLM	83.36

GAS PRESSURE

150 psi (10 kg/cm²) gauge max; 20 psi (1.4 kg/cm²) gauge optimum.

LEAK INTEGRITY

1×10^{-4} SCCS of helium max to outside environment.

GAS AND AMBIENT TEMPERATURE

0 to 50 °C.

MAS Instruction Manual

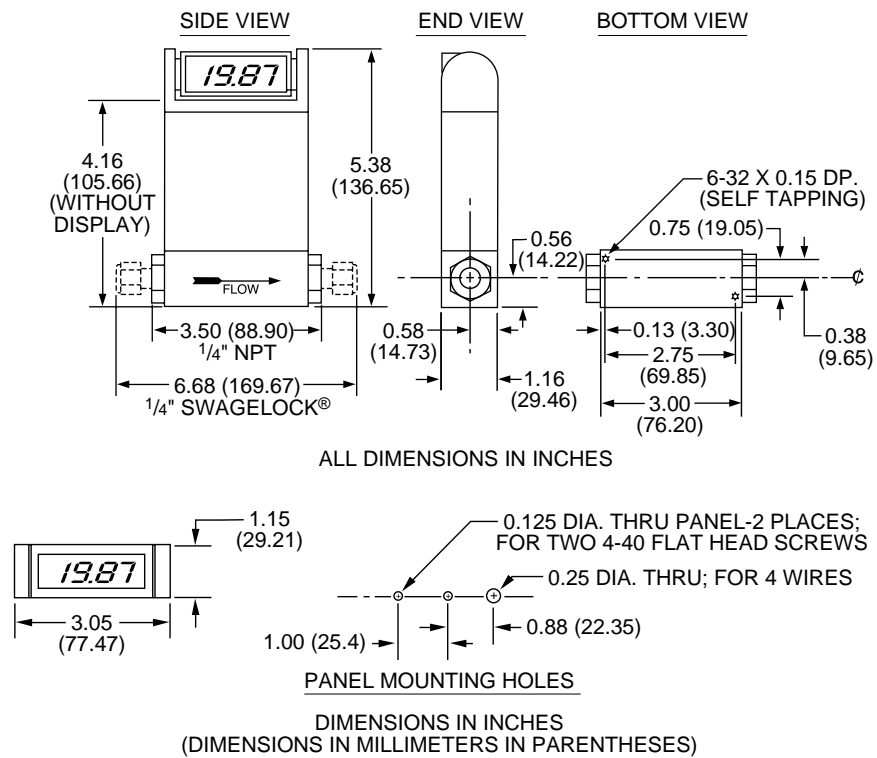
WETTED MATERIALS

5% glass-filled Polyamide 6/6; 316 stainless steel; FKM "O"-rings standard, FFKM and silicone O-rings optional.

WEIGHT

2 lb. (0.9 kg) net; 3 lb. (1.4 kg) shipping.

Dimensions



Many options are available for your Kobold MAS. Please consult Kobold's current Price List for the respective prices.

**1.4
Options**

- V4 (Optional) 4-20 mA output signal
- C() Cable assembly, specify cable type (round or ribbon) and length
- T2 1-5 Channel Power Supply, in NEMA Box, 115 VAC
- T4 1-5 Channel Power Supply, in NEMA Box, 230 VAC
- T5 Power Supply, for one channel, 110 VAC
- T6 Power Supply, for one channel, 230 VAC
- UV Upstream valve
- DV Downstream valve
- MS Replacement mass flow sensor, includes "O"-rings and mounting flanges
- OV Complete set of FKM "O"-rings
- TP Tip plate for electrical enclosure
- RD-() Remote display

* U.S. and foreign patents pending.

® Registered trademarks: Swagelok, VCO, VCR—Crawford Fitting Co.

2 INSTALLATION

When the equipment is received, carefully check the outside packing carton for damage incurred in shipment. If the packing carton is damaged, the local carrier should be notified at once regarding their liability. Kobold's Customer Service Department should also be notified immediately.

2.1 Receipt of Your MAS

Customer Service Phone Number:

USA(412) 788-2830, or Fax(412) 788-4890

For our customers other than the USA, Canada and Mexico please call the distributor from whom you purchased your MAS or call our head office in Germany for the Kobold location nearest you:

Germany 49(0)61-92-29-90 or Fax 49(0)61-92-23-398

Remove the packing slip from its envelope and verify that the carton contains all parts listed. Inspect the carton and packing material thoroughly to ensure that no spare parts or accessories are mistakenly discarded. In case of shortages, please contact Customer Service at the above phone number, or they may be contacted in writing at the address listed in the next section.

2.2 Return Shipment

Please do not return any equipment without a Return Material Authorization, which is obtained from the Customer Service Department. Information describing the problem, corrective action or work to be performed at the factory, the purchase order number that the equipment was purchased under, and the name of the person to contact must be included with the returned equipment. The use of a Return Material Authorization is for your benefit. It makes the proper service and return of your equipment much easier to accomplish.

Return shipping address:

USA KOBOLD INSTRUMENTS INC.
1801 Parkway View Drive
Pittsburgh, PA 15205

Non-North American customers may contact the KOBOLD Messring GmbH Customer Service Department Technical Assistance at:

Europe KOBOLD MESSRING GmbH
Nordring 22-24
65719 Hofheim/Ts.
Germany

NOTE: Equipment returned for repair that is found to be completely operational will be subject to the current "no problem found" billing rate.

CAUTION! The maximum pressure and temperature in the flow line in which your MAS is to be installed must not exceed 150 psig (10 kg/cm² gauge) or 150°F (65°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 MAS to the system. MAS 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 MAS.

Do not locate the MAS Flowmeter in areas subject to sudden temperature changes, moisture, drafts, or near equipment radiating significant amounts of heat. Allow adequate space for cable connectors and wiring. If your MAS is to be mounted in other than a horizontal position, the zero will need adjustment. See Section 5.2, RECALIBRATION OVER THE SAME FLOW RANGE.

CAUTION! Be sure the arrow on the side of the transducer points in the direction of flow.

The MAS may be mounted to a chassis with two 6-32 self-tapping screws. See Section 1.3, SPECIFICATIONS, for hole dimensions.

Your MAS is supplied with either $\frac{1}{4}$ inch female NPT (standard) or $\frac{1}{4}$, $\frac{3}{8}$ or $\frac{1}{2}$ inch compression inlet and outlet fittings. These fittings should not be removed unless your MAS is being cleaned or calibrated for a new flow range. VCO[®] or VCR[®] fittings are available on special order. $\frac{1}{4}$ -inch pipe requires a good quality paste pipe thread sealant and should be installed in the inlet and outlet fittings $1\frac{1}{2}$ turns beyond hand-tight.

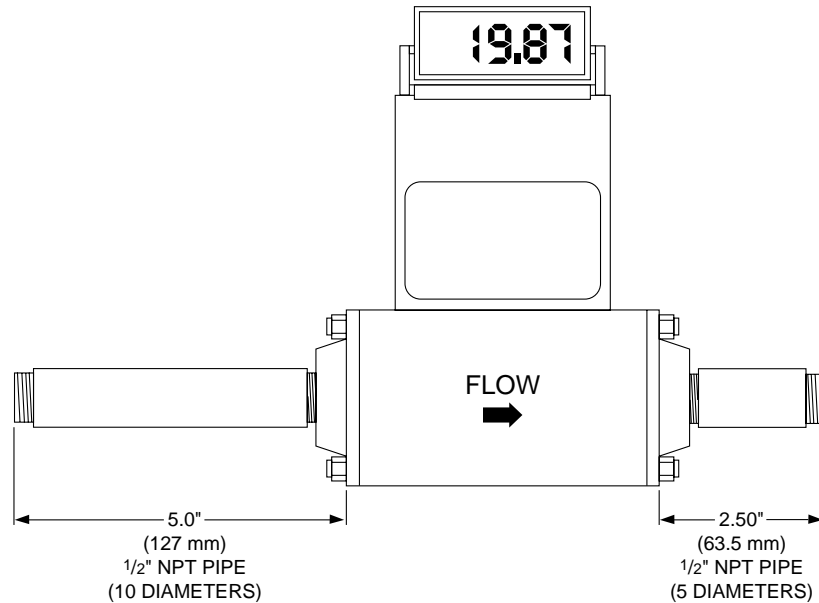
CAUTION! Over-tightening will crack the fittings and shift calibration.

For the first installation of 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 hand-tight. Scribe the nut at the six o'clock position. While holding the fitting body steady with a back-up wrench, tighten the nut $1\frac{1}{4}$ 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. Do not fail to use a back-up wrench or the inlet fitting may be damaged.

2.3 Mechanical Installation

2.4 Plumbing Connections

Figure 2-1
Plumbing Requirements
for Model's 1100/2100



EXAMPLE: Cross Section



CORRECT
1/2" NPT pipe for
1/2" NPT flow body



INCORRECT
Avoid use of compression fitting on inlet of flow body. The reduction of internal diameter of the fitting results in a "jet", creating noise and affecting calibration. **DO NOT** reduce down right at the inlet with 1/4" pipe.

CAUTION! 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.

CAUTION! All instruments are leak-tested prior to shipping. To check your installation, test the fittings only. Do not use liquid leak detectors such as Snoop® to search for leaks inside or outside the MAS. Instead, monitor pressure decay.

MAS flowmeters require a single +12 to +15 VDC power supply capable of providing a minimum current of 100 mA. The MAS can also be configured for +24 VDC power at 100 mA.

**2.5
Electrical
Connections**

Operating power input is via either the DC power jack or the 9-pin "D" connector on the side of the enclosure. Kobold offers the Model MAS-5000 single channel power supplies for single transducer applications and the Model MAS-5100 for powering up to eight transducers through the "D" connector.

**2.5.1
9-Pin "D"-Connector
Pin Assignments**

CAUTION! Do not supply + DC power at the "D" connector while using an MAS-5000 power supply at the DC power jack. Do not plug power connector into DB9 connector. Damage to electronics will result.

The standard MAS is provided with a 9-pin "D" subtype connector located on the side of the MAS enclosure as shown in Figure 2-2. The pin numbers for this "D" connector are also shown in Figure 2-2, and the pin assignments are given in Table 2-1 on the next page. The output signal is obtained from the 9-pin "D" connector. A 0 to 5 VDC output signal linearly proportional to gas mass flow rate is standard. A 4-20 mA current loop signal is optionally available. The mating connector is included.

When the MAS is configured for a remote display, connections are made via the 9-pin "D" connector. Power connections for the display and transducer are shared in this mode unless the accessory MAS-5000 power supply is used.

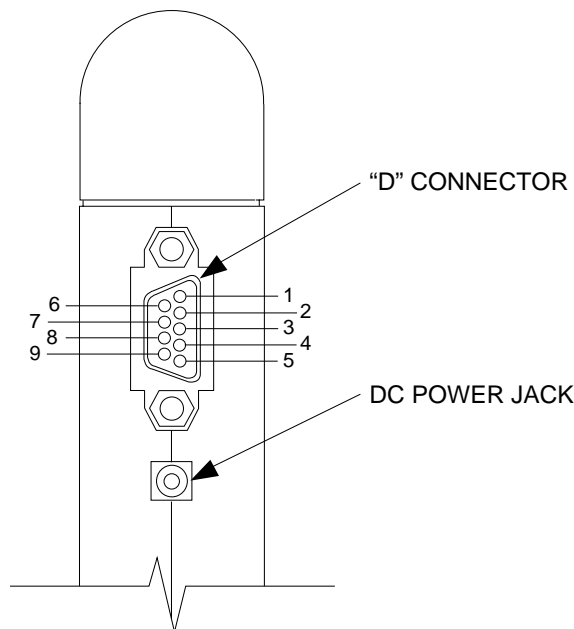
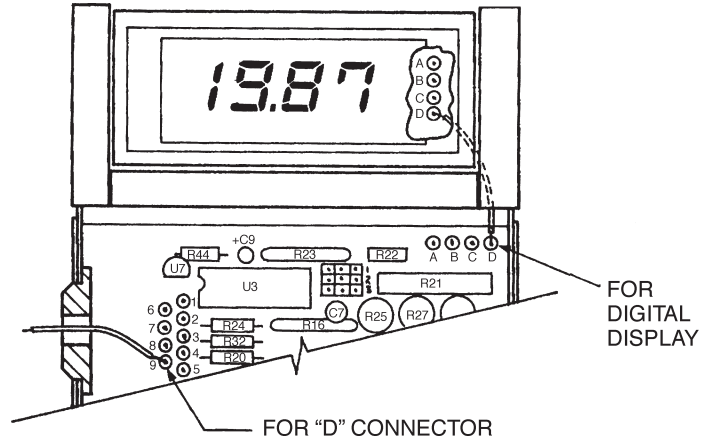


Figure 2-2
"D" Connector and DC
Power Jack Location and
Number Assignments

Figure 2-3
 Printed Circuit Board
 Input/Output Solder Pad
 Assignments (wires shown
 are typical)



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.

Table 2-1

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) *1,*2	(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: the numbers on the connector plug may not agree with the numbering system as it appears on our Figure 2-2 (on previous page). It is important to make sure that the proper wires are in the proper location rather than the proper number. Most connectors utilize a standard numbering scheme but there are a few that do not.

The 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.

*1 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.

*2 Do not supply +DC power at the “D” connector while using a power supply at the DC power jack. Both supplies may be damaged.

As shown in Figure 2-4, the digital display on your MAS may be removed and mounted remotely on a front panel. The MAS transducer is mounted at any convenient location in your system.

2.5.2 Remote Installation of Digital Display

Remote installation is not recommended unless you possess the proper soldering tools and skills to accomplish the job. Remote installation of the digital display is accomplished by following these steps:

1. Remove the digital display from your MAS by following the procedure described in Section 2.5.3, OEM ELECTRICAL CONNECTIONS.
2. Gain access to the printed circuit board (PCB) also by following the procedure in Section 2.5.3, OEM ELECTRICAL CONNECTIONS.
3. Very carefully unsolder the four short leads from the PCB to the display.
4. Gain access to the display circuit board by removing the two snaprings (No. 36) and opening the “clam shell” display enclosure. Remove the four short wires by carefully unsoldering. Solder the longer four wires (26AWG, 100ft. max shielded cable recommended) to the digital display and solder the other ends to the appropriate pin numbers of the 9-pin “D” connector as shown in Figure 2-3 and Table 2-1 (on previous page).
5. Reassemble the MAS, replacing the display base (No. 35) with the Model TP Plain Top Cover (No. 28).
6. Make the necessary plumbing connections to the unit.
7. Mount the digital display as shown in Figure 2-4 referring to the panel mounting hole dimensions in Section 1.3, SPECIFICATIONS.

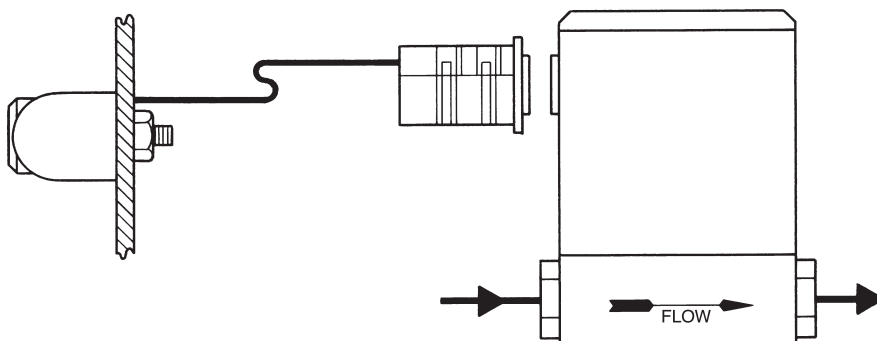


Figure 2-4
Remote Installation of
Digital Display

2.5.3 OEM Electrical Connections

The OEM version MAS flowmeter has an electrical port (hole) on its side for electrical input/outputs. This port is just above the input power jack (see Figure 2-2). Wires entering the MAS 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.

How to Gain Access to the MAS's Printed Circuit Board (PCB):
To gain access to the PCB to make the solder connections, please refer to the exploded view in Appendix A and follow these simple steps.

1. If your MAS has the digital display:
 - (a) First, remove the display by carefully rotating the display until it hits the top plate. Slowly continue to rotate until this lever arm action snaps out the two yokes holding the display (Nos. 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 (Nos. 21) in the display base (No. 35) and the two screws (also Nos. 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 your MAS does not have the digital display:
 - (a) Remove the label (No. 29) from the plain top cover (No. 28) to expose the two screws (Nos. 21).
 - (b) Then follow steps 1(b) and 1(c) above.

To reassemble, just reverse the process.

2.5.4 Using Kobold's Single, Dual, and Flo-Box™ Electronics

For applications requiring flow totalization or alarms simply order the optional Model EC-() cable to connect to the rear panel of Kobold Instruments' Single-Channel, Dual-Channel, or Flo-Box (1-5 Channels) Electronics. The Kobold electronics will provide you with a selectable digital readout for each channel, input power, high, low, or window alarms, and optional flow totalization.

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

Following are important notes and comments regarding the Quick Operating Instructions.

NOTE 1 REFERENCING THE FLOW RATE TO OTHER TEMPERATURE AND PRESSURE CONDITIONS:

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

NOTE 2 ACCURACY:

The standard accuracy of the MAS is $\pm 1.5\%$ of full scale. The $\pm 1.5\%$ 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 ± 0.4 mA. 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 your MAS is malfunctioning. For MAS’s with the digital readout, the accuracy is simply 1.5% times the full scale flow rate listed on your MAS’s 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.

NOTE 3 OVERRANGING:

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

The MAS 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

**3
OPERATION**

**3.1
Quick Operating
Instructions**

**3.2
Notes to Operating
Instructions**

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 seconds for the MAS to recover and resume normal operation. This will not harm the instrument.

NOTE 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 (see Section 2.5.1, 9-PIN “D” CONNECTOR PIN ASSIGNMENTS). Figures 3-1 and 3-2 illustrate single and multiple installations with current loop outputs.

NOTE 5 ZERO AND SPAN ADJUSTMENTS:

The zero and span potentiometers are accessed through marked ports on the right side of your MAS. If your zero output is more than $\pm 1.5\%$ 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. To complete the zero adjustment, slowly turn the pot counterclockwise until zero is reached.

Normally, span adjustments are not made unless you are calibrating your MAS, 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.

NOTE 6 ATTITUDE:

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

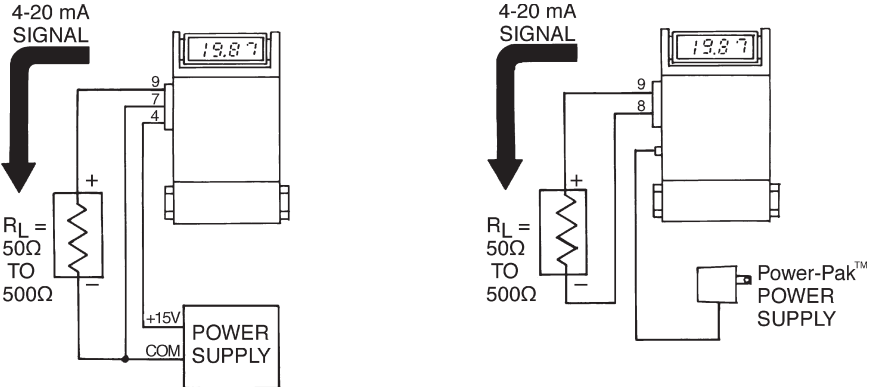


Figure 3-1
Single Unit 4-20 Hookup

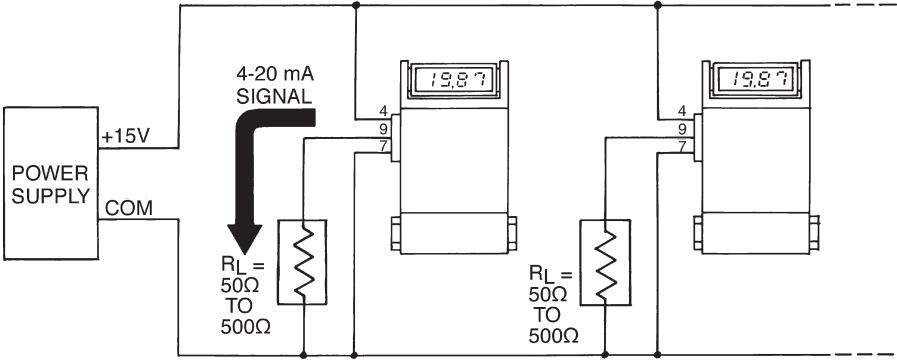


Figure 3-2
Multiple Installation
4-20 Hookup

4 MAINTENANCE

Your MAS 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 General Statement

It is recommended that your MAS be returned to Kobold Instruments if cleaning, repair, or recalibration are needed. This is usually your most cost-effective and reliable alternative.

4.2 Flow Path Cleaning

The flow path (wetted parts) of the MAS are 5% glass-filled Polyamide 6/6; 316 stainless steel (sensor tube); and FKM "O"-rings (standard).

CAUTION! IF YOU WISH TO CLEAN YOUR MAS PURGE IT THOROUGHLY BEFORE DISCONNECTING FROM THE GAS LINE WHEN TOXIC OR CORROSIVE GASES ARE USED. NEVER RETURN AN MAS TO KOBOLD INSTRUMENTS OR ANY OTHER REPAIR OR CALIBRATION FACILITY WITHOUT FULLY NEUTRALIZING ANY TOXIC GASES TRAPPED INSIDE.

Please refer to the exploded drawing of the MAS transducer in Appendix A when using the following procedures. All cleaning of the flow path can be accomplished with Freon™, alcohol, or any cleaner safe for the listed materials.

4.2.1 Inlet and Outlet Screen

Remove inlet and outlet fittings (Nos. 13), pull out the LFE hold-downs (Nos. 12) and either replace or clean the inlet and outlet screens (Nos. 14).

4.2.2 Laminar Flow Element (LFE)

Remove the inlet and outlet fittings as in Section 4.2.1, INLET AND OUTLET SCREEN. The LFE (either No. 24 or No. 25) has a slightly tapered shape with the larger diameter upstream (on the inlet side). To remove the LFE for cleaning, simply push it out the inlet side from the outlet side using a blunt object which does not mar the flow channels. A $\frac{3}{8}$ " (9 mm) nut driver is perfect for the job. When cleaning, be sure to carefully clean all active flow channels in the LFE.

IMPORTANT: When reinstalling the LFE it is of utmost importance to press it in the correct distance. Refer to Figure 4-1 for the correct distance.

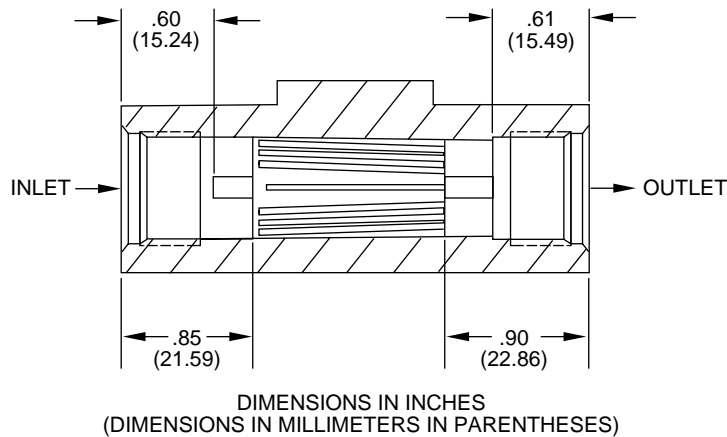


Figure 4-1
Proper LFE Location
Within The Flow Body

CAUTION! Opening the sensor cavity will shift calibration.

4.2.3
Sensor Tube

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 1.5%. The remaining parts of the flow path are disassembled as shown in the exploded view in Appendix A. Note the position of the insulation blanket before removal and re-install in the same fashion. After removal, the sensor tube (No. 5) can be cleaned by purging, washing with a solvent, or by rodding out the 0.031 inch (.787 mm) internal diameter tube with a 0.029-0.030 inch (.737-.762 mm) outside diameter rod or wire or with the Model CK Cleaning Stylet available from Kobold Instruments. To maximize the time response of your MAS, Kobold has designed the sensor tube with 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 **EXTREME** care to not disturb or unravel the sensor windings.

5 FLOW CALIBRATION

Flow calibration of your MAS requires a calibration standard of at least double accuracy and preferably an order of magnitude better.

5.1 General Flow Calibration Procedure

NOTE: The factory calibration of your unit was done to MIL-STD-45662 A, which has a 4:1 accuracy requirement. Most calibrations can be done using dry nitrogen and the “K”-factors and gas tables given in Appendix D. The standard 1.5% calibration of your MAS is best accomplished with the Kobold Instruments’ Series 100 Cal-Bench™.

5.2 Recalibration Over the Same Flow Range

Flow recalibration is performed by using the following procedure. Please refer to the electrical schematics in Appendix B. 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 through 8. If linearity does not need adjustment, complete only STEPS 1 through 3.

STEP 1 WARM-UP: Plug in the MAS 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 of your MAS. Be careful to gently slide open and not bend back access port covers, as bending back may break covers. 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 MAS under test. Compare the indicated flow rate with the flow standard reading. If they agree to within $\pm 10\%$, adjust the span potentiometer (R21) for exact agreement.

If the readings do not agree within $\pm 10\%$, 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 MAS
- 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 MAS enclosure by using the procedure described in Section 2.5.3, OEM ELECTRICAL CONNECTIONS. 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).

	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 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.

STEP 7 CALIBRATE 50%: Increase the flow rate to 50% of full scale. If the output is within ± 100 mV, no adjustment is necessary. If the output is beyond these limits, install a jumper block at J1 in the appropriate position (increment (INC.) or decrement (DEC.)); 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 R9 if necessary.

NOTE: 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 your MAS over a different flow range and/or gas is identical to that described in Section 5.2, **RECALIBRATION OVER THE SAME FLOW RANGE**, 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 for Kobold Instruments. Appendix C is helpful in this regard. You must then use the K-factor tables in Appendix D.

The next step is to procure from Kobold Instruments the Model EL Laminar Flow Bypass Set. This set of two patented Model EL LFE’s covers all ranges from 0-10 SCCM to 0-40 SLM, when the proper combination of “gates” to the individual laminar flow channels have been opened (see Section 1.2, **PRINCIPLE OF OPERATION**). The instruction manual for the Model EL LFE’s describes this procedure in detail.

NOTE: Potentiometer R15 shown in Appendix B is for speed of response and does not require any adjustment.

**6
TROUBLE-
SHOOTING**

**6.1
General**

When it is suspected that your MAS 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.

This guide is provided to help locate the section of the MAS at fault. It is not intended to be an all-inclusive repair manual. In the case of most repairs, your MAS should be returned to the factory for service.

**6.2
Troubleshooting Guide**

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 D
	Gas leak	Find and correct leaks
	PCB defective	Repair or replace
	LFE dirty	Clean
	Inlet filter screen clogged	Clean or replace

Kobold Instruments will provide technical assistance over the phone to qualified repair personnel. Please call Customer Service Department, Technical Assistance, (412) 788-2830, Fax (412) 788-4890. European customers can contact Kobold Messring GmbH for customer service and technical assistance at 49(0)61-92-29-90, Fax 49(0)61-92-23-398. Please have your Serial Number and Model Number when you call.

If your MAS requires servicing or recalibration, please refer to the following ordering numbers. Kobold's current Price List gives the respective prices.

IMPORTANT NOTE: For all servicing and recalibration, please return the entire MAS flow body to the factory.

- R1 Standard Recalibration (1.5%) and Cleaning
- R2 Standard Recalibration (1.5%), Cleaning and Repair
- R3 Replacement Sensor and Standard Recalibration (1.5%)

If you wish to have Kobold calibrate with a different flow range and/or gas, please take note of the following.

NOTE 1 FLOW RANGE:

The standard flow ranges given in Section 1.3, SPECIFICATIONS, are for nitrogen at standard conditions of 1 atmosphere and 21°C (70°F). For a given MAS Flowmeter, the range may vary for other gases depending on their molecular weight and thermal properties.

NOTE 2 CALIBRATION:

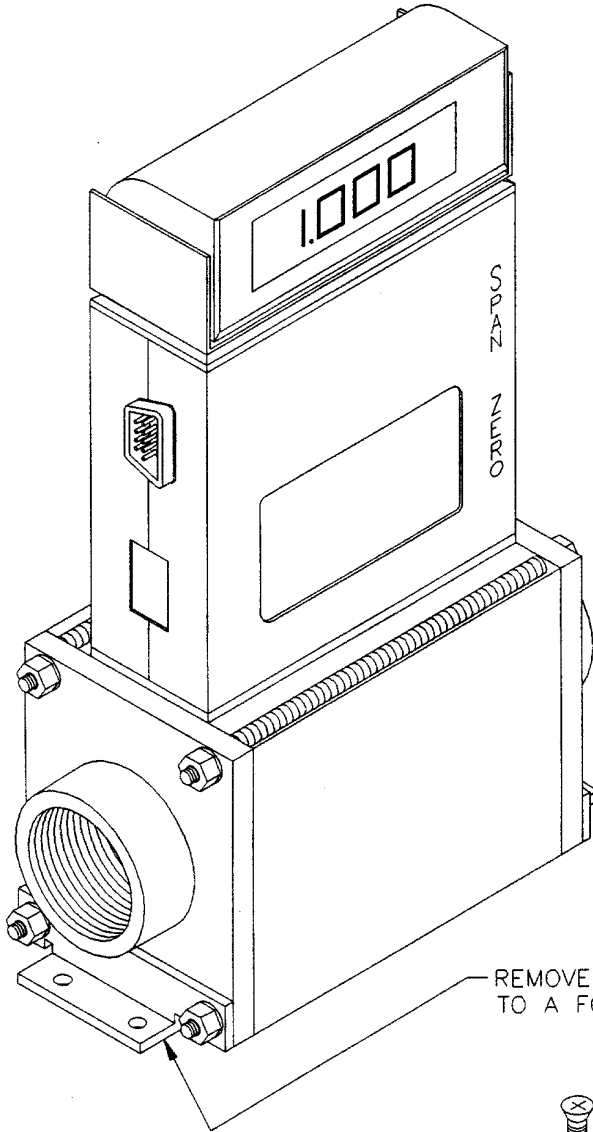
Please specify the actual gas you intend to use. If you are using several gases, inform us and we will give you the required conversion factors. Unless otherwise specified, "standard" conditions shall be 1 atmosphere pressure and 21°C (70°F) temperature. For example, if you require a 0°C (32°F) "standard" temperature, please specify when ordering.

7 STANDARD SERVICING AND RECALIBRATION

APPENDIX A

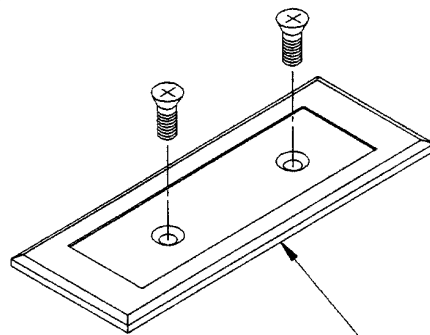
Exploded View of MAS Transducers and Parts Lists

Aluminum Assembly
High-Flow, MAS-1100/2100
M82-0022



NOTE:
THIS DRAWING IS FOR REFERENCE ONLY,
END PRODUCT SHOULD LOOK LIKE DRAWING,
UNLESS OTHERWISE SPECIFIED.

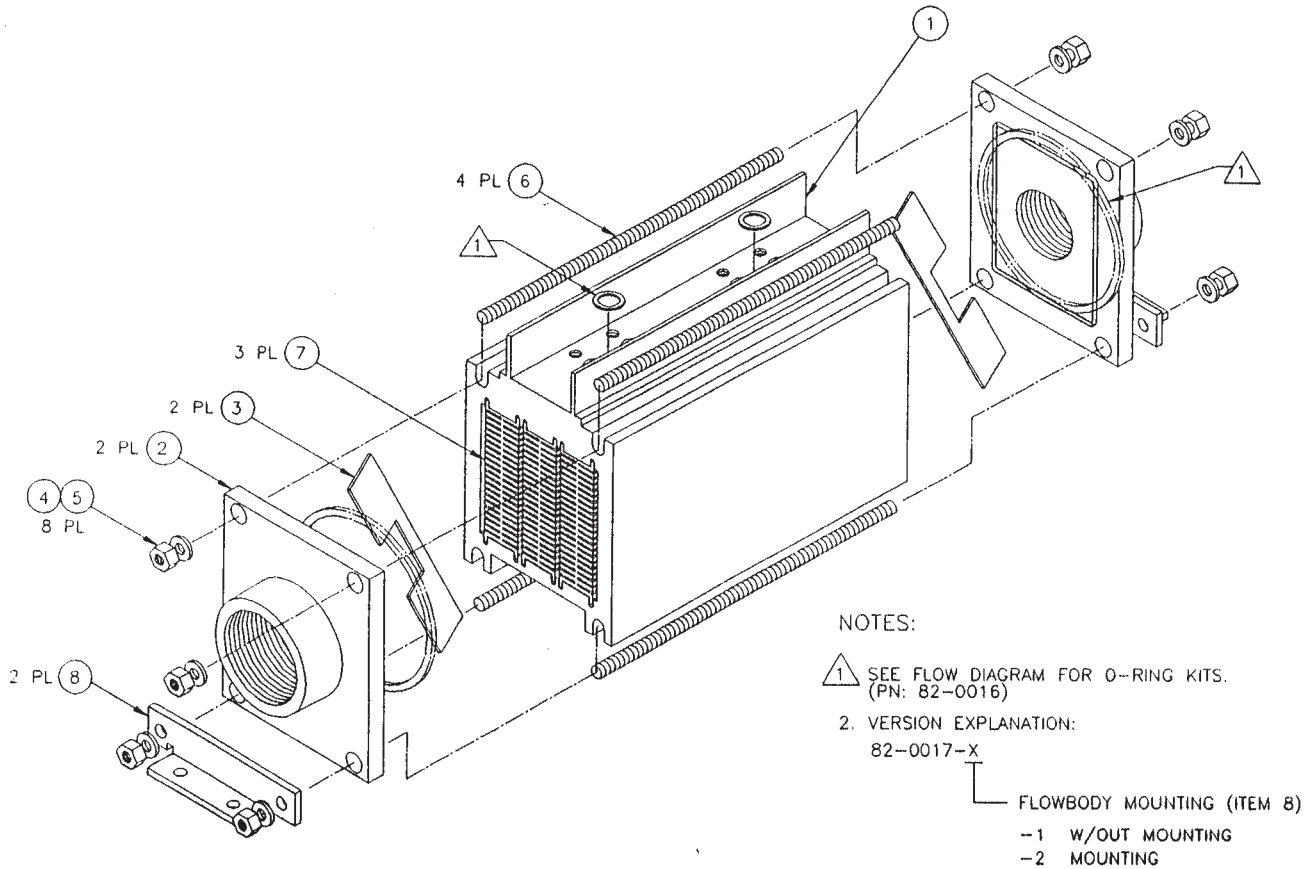
REMOVE FEET WHEN NOT MOUNTING
TO A FOUNDATION.



WHEN DISPLAY IS NOT BEING USED
REPLACE WITH TOP COVER.

MAS Instruction Manual

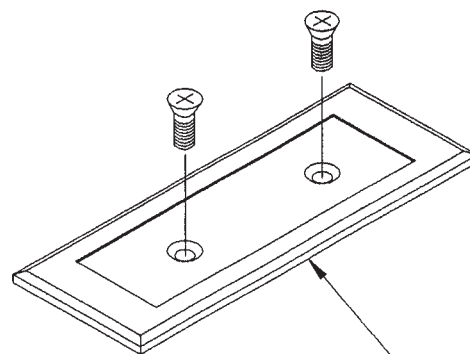
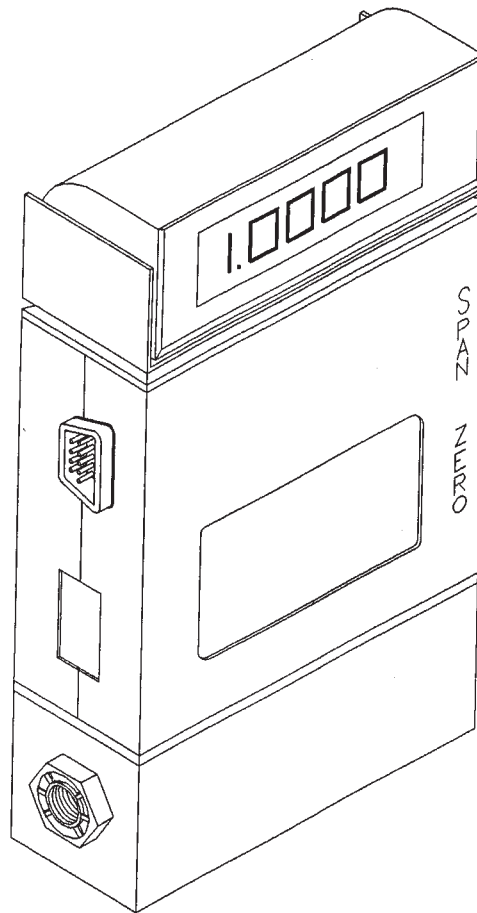
Aluminum Flowbody High-Flo, MAS-1100/2100 M82-0017-X



Parts List M82-0017-X

ITEM:	PIN:	DESCRIPTION:
1	41-0175	Body, 820, Hi-Flow, Al
2	41-0176	Cap. End. 820. HighFlow
3	40-0037	Holder. LFE. Mod 820
4	35-0084	Washer, Split, #06
5	35-0326	Nut, Hex. 6-32, SS
6	35-0174	Rod. Threaded, 6-32X5"L
7	42-0098	LFE, Hi-Flow, Mod 820
8	40-0127	Bracket, Mounting, 820H

MAS Assembly
MAS-1000/2000
M82-0023

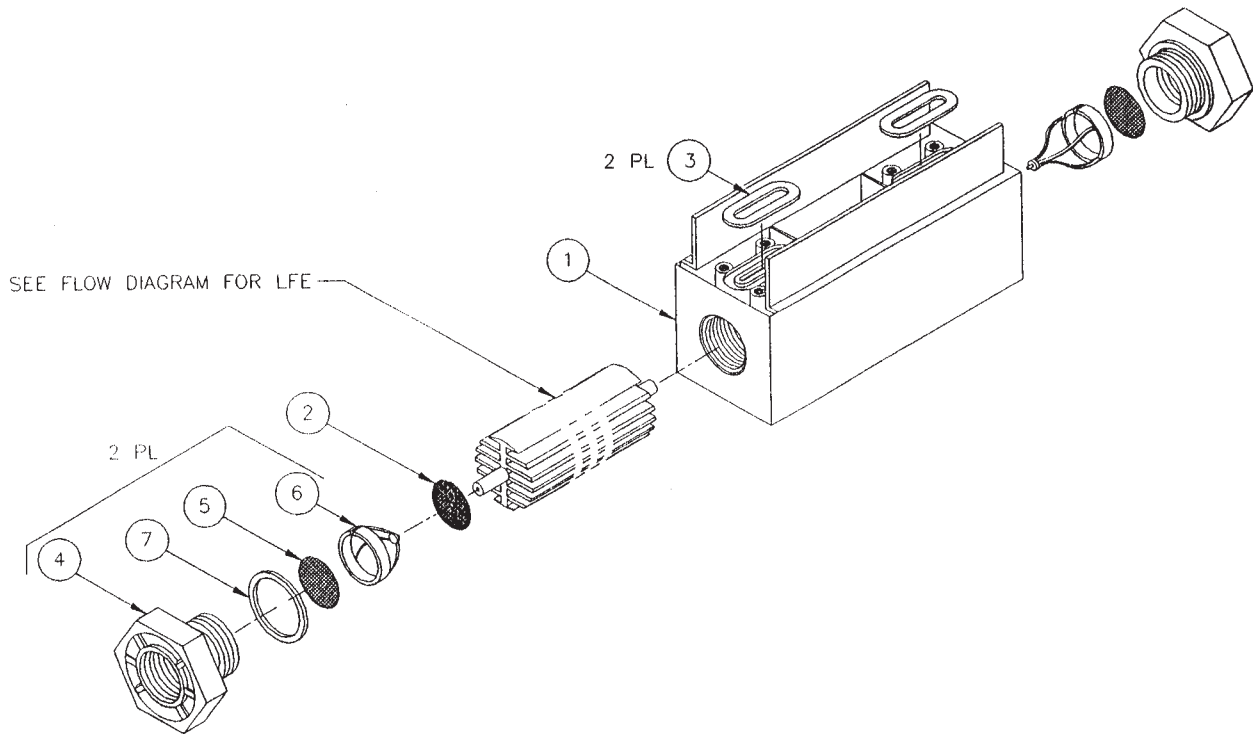


WHEN DISPLAY IS NOT BEING USED
REPLACE WITH TOP COVER.

NOTE:
THIS DRAWING IS FOR REFERENCE ONLY,
END PRODUCT SHOULD LOOK LIKE DRAWING,
UNLESS OTHERWISE SPECIFIED.

MAS Instruction Manual

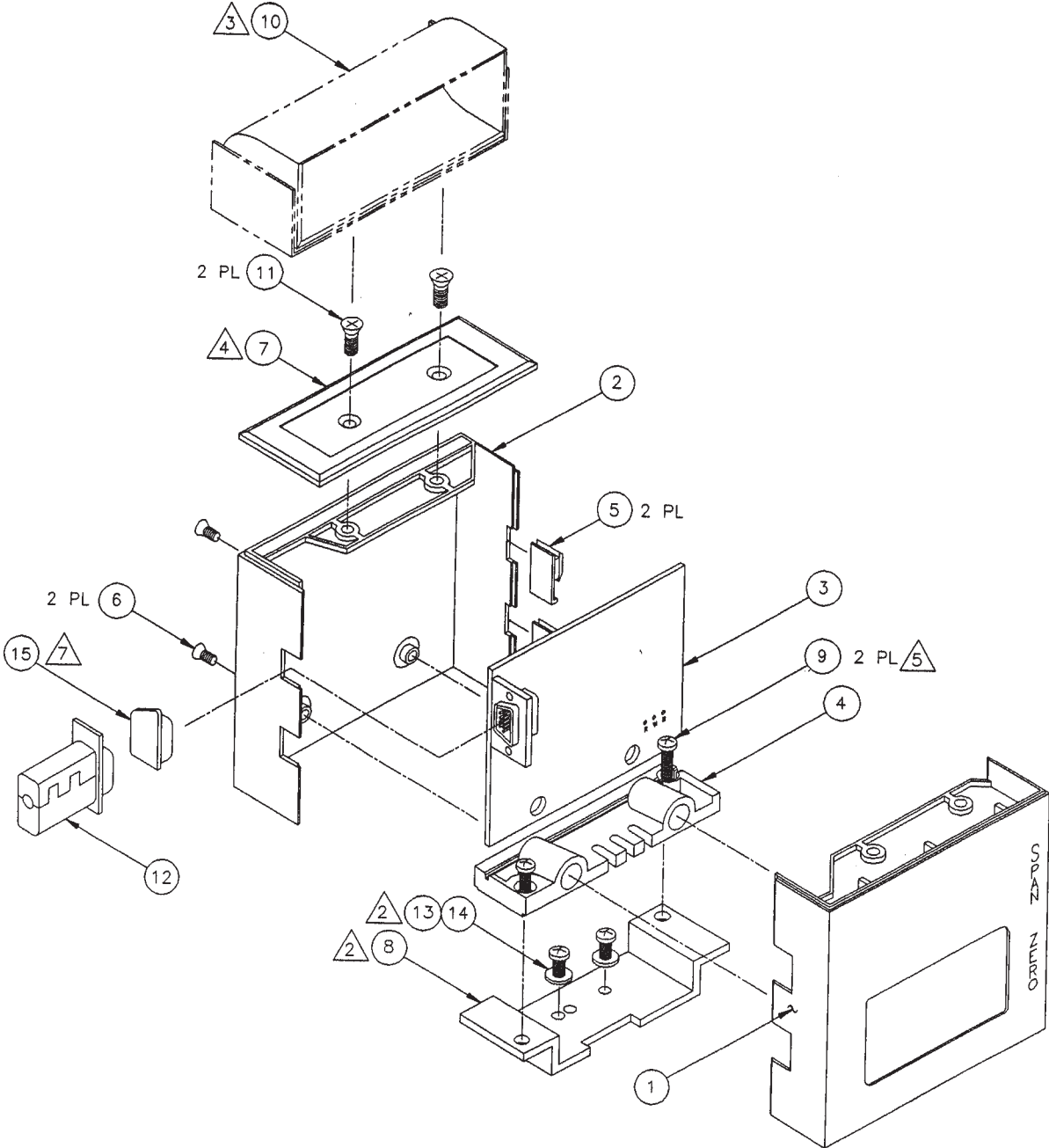
**Polyamide
Flowbody
MAS-1000/2000
M82-0018 A**



Parts List M82-0018-X

ITEM:	PIN:	DESCRIPTION:
1	42-0053	Body, 820, Black
2	40-0043	Screen, Mod 820 (for > 10SLPM Flows)
3	31-0001-906	O-Ring, FKM3-906
4	42-0105	Adaptor, Numb. Mod 850, 3/4-16 to 0.250 FNPT
5	40-0042	Screen, Inlet, Mod 820
6	42-0041	Hold Down, LFE
7	31-0001-908	O-Ring, FKM, 3-908, Brown

Electronics Enclosure
Sub-Assembly MAS
M82-0019-XXXX B

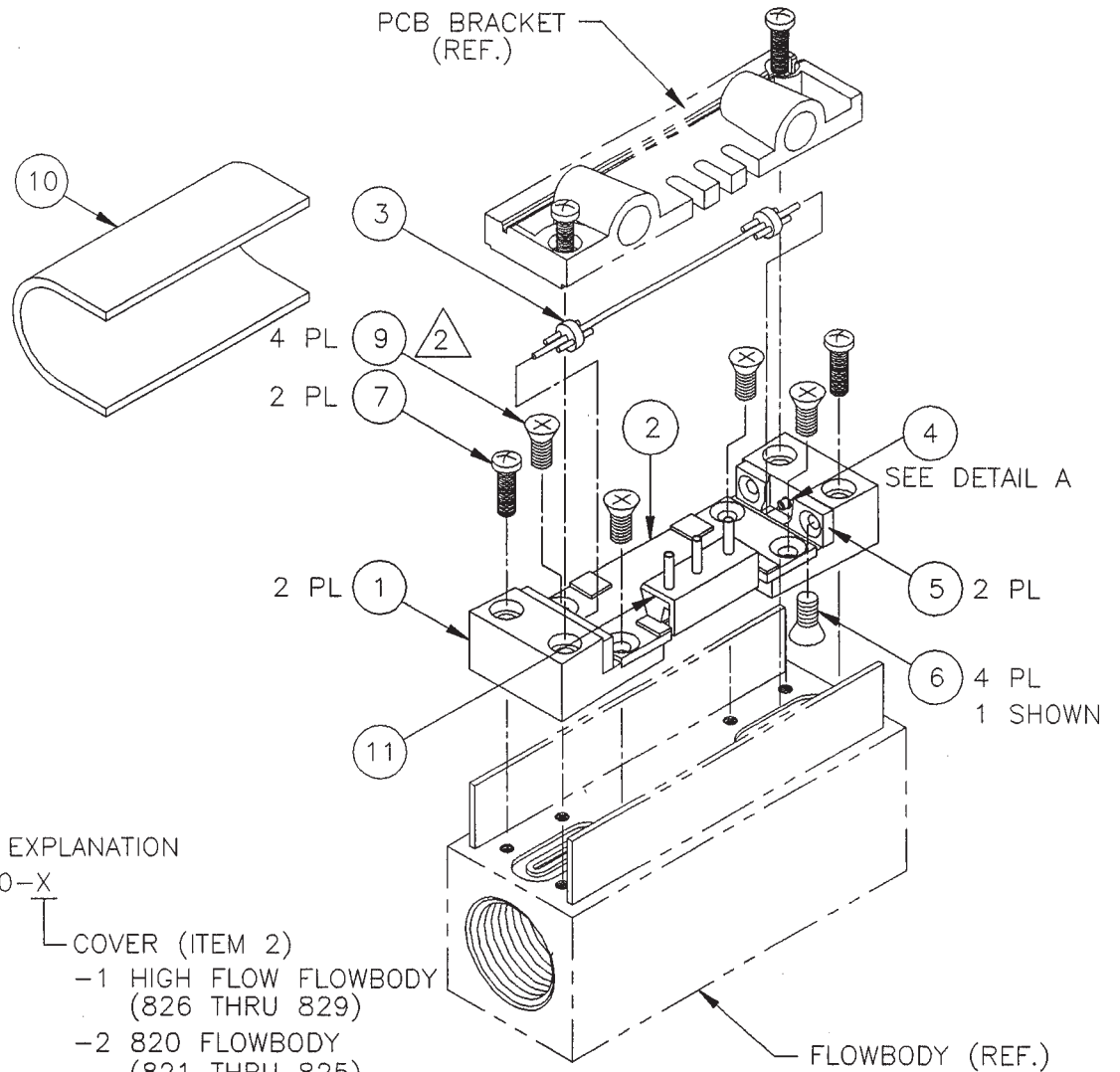


Parts List M82-0019-XXXX

<i>ITEM:</i>	<i>PIN:</i>	<i>DESCRIPTION:</i>
1	42-0033	Encl, 820, Front, White
2	42-0034	Encl, 820, Back, White
3*	52-0038-11	PCA, 820 Flow Meter: 110/220 VAC; 0-5 VDC
4	42-0038	Bracket, PCB, 820
5	42-0044	Slides, Zero & Span
6	35-0346	Scr, FLH, Phl, #4 x 0.500"L, SLF TPG, Zinc
7*	42-0052	Cover, Top, Mod 820
8*	40-0038	Bracket, Adapter, 820 Display to 830 Body
9*	35-0288	Scr, FLH, Phl. 4-40 X 0.750"L, Type "B" Zinc
10*	82-0021	Display Sub-Assy: 820
11*	35-0024	Scr, Flh, Sch, 4-40 X 0.375"L
12	55-0018	Conn, Kit, "DCD" Vend# TGA-46-00633
13*	35-0075	Scr, Pnh. Phl. 4-40 X 0.250"L
14*	35-0037	Washer, Split, #04
15	39-0211	D-Connector Cover, 9-Pin

*Change with application, consult factory for specifics.

Sensor Compartment
 Assembly: MAS
 M82-0020-X B

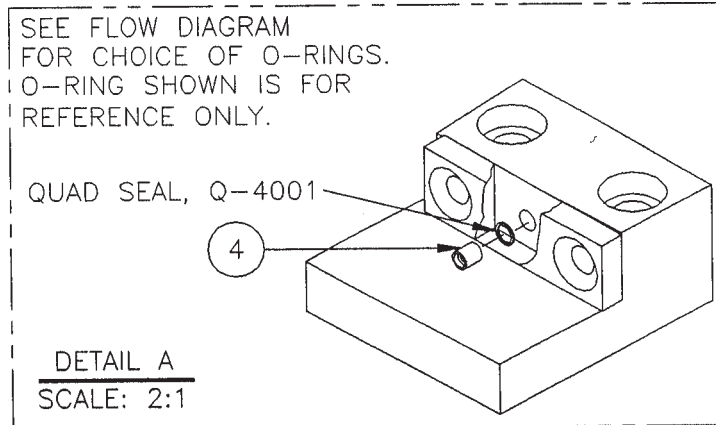


NOTES:

1. VERSION EXPLANATION
 82-0020-X

- COVER (ITEM 2)
- 1 HIGH FLOW FLOWBODY (826 THRU 829)
- 2 820 FLOWBODY (821 THRU 825)

△ ITEM 9 CHANGES WHEN ITEM 2 CHANGES.



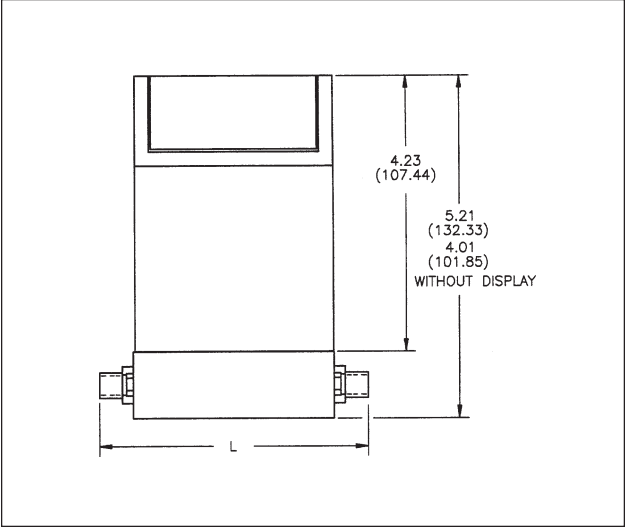
Parts List M82-0020-X

ITEM:	PIN:	DESCRIPTION:
1	41-0207	Plate, Sensor Mounting (Die Cast)
2*	41-0173	Heat Sink (Die Cast)
3	43-0037-01	Sensor, Flow Capillary
4	41-0171	Bushing, Sensor O-Ring (Die Cast)
5	41-0170	Plate, Sensor Ring, 820 (Die Cast)
6	35-0130	Scr, Flh, Phl. 4-40 X 0.250"L
7*	35-0092	Scr, Pnh, Phl. #4 X 0.562"L, Zinc, Type "B"
9*	35-0142	Scr, Flh, Phl. #4 X .375 L, Self Tpg, Zinc Type "B"
10	39-0149	Insulation, Pcf. 1.2 for Sensor Compartment
11	45-0052	Plate, Sensor Feed Thru Mod 820

*Change with application, consult factory for specifics.

**Stainless Steel Low Flow
Dimensional Drawing**

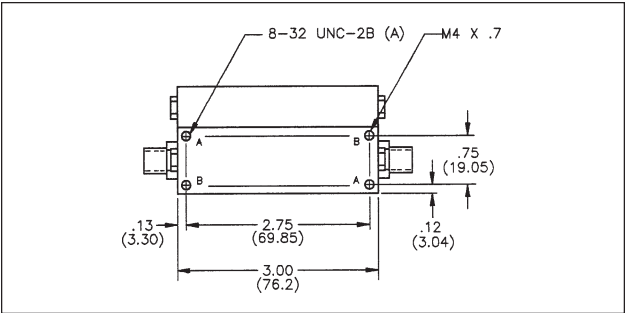
Side View



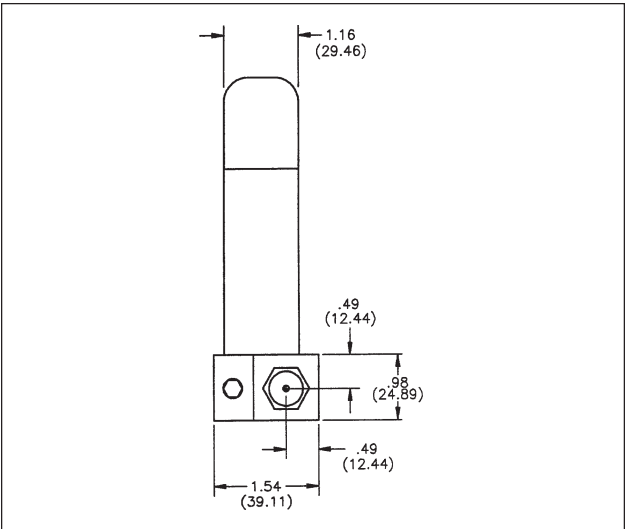
Tables

1/4" O.D. Tube Fitting Type (9/16"-18 Thd.)	Comp.	VCO (male)	VCR (male)
Dim. "L"	4.8	5.0	4.8

Bottom View



Outlet End View



Stainless Steel Medium Flow Dimensional Drawing

Tables

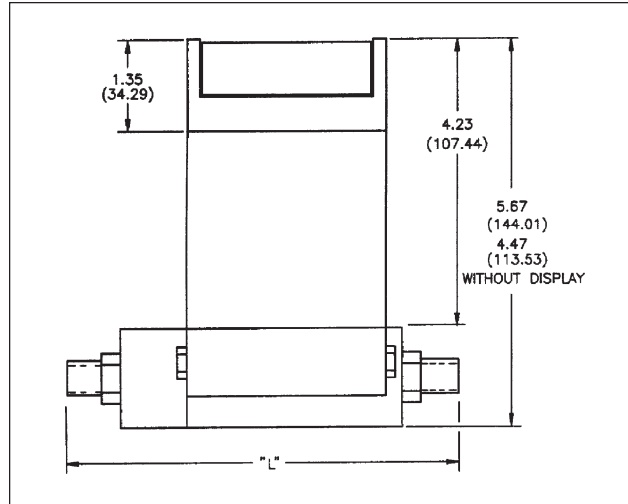
Flow Range SLM	0-20	0-30	0-50
Tube O.D., Inches	1/4", 3/8"	1/4", 3/8"	1/4", 3/8"

Flow Range, SCFM	0.706	1.06	1.77
Tube O.D., Inches	3/8"	3/8"	3/8"

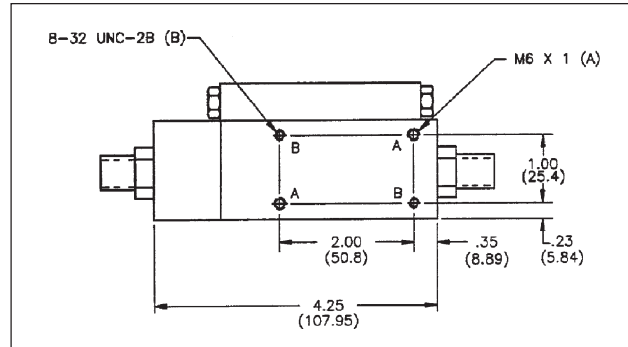
Fitting Type (9/16"-18 Thd.)	1/4" Comp.	1/4" VCO (male)	1/4" VCR (male)
Dim. "L"	6.27	6.01	6.13

Fitting Type (9/16"-18 Thd.)	3/8" Comp.	3/8" VCO (male)	3/8" VCR (male)
Dim. "L"	6.39	5.25	6.43

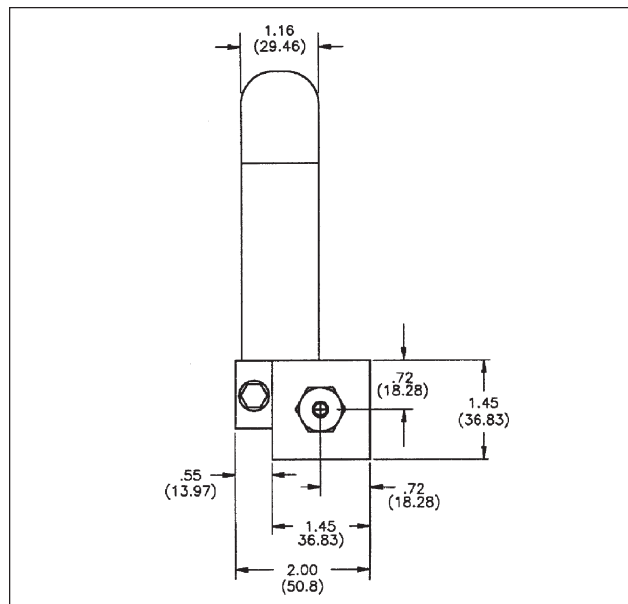
Side View



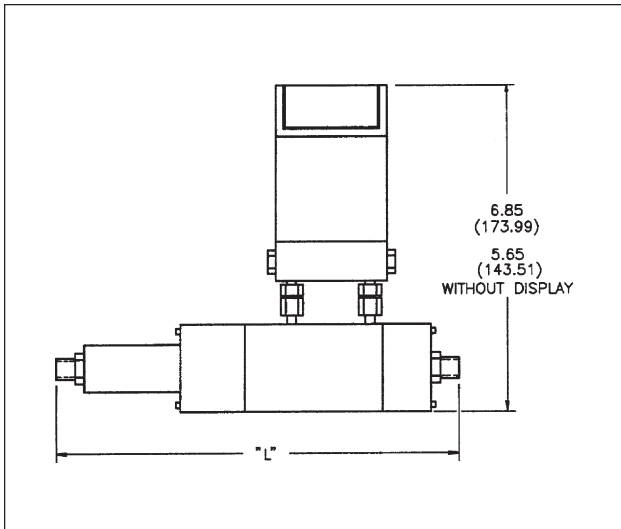
Bottom View



Outlet End View



**Stainless Steel High Flow
Dimensional Drawing**



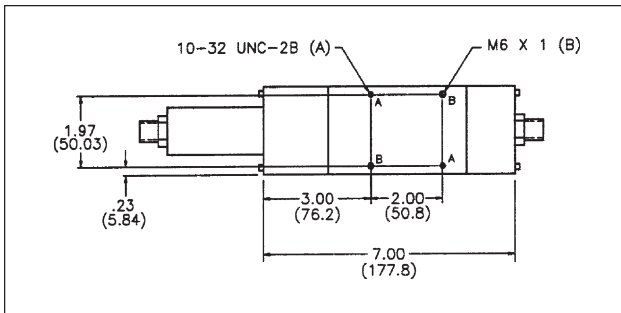
Side View

Tables

Flow Range SLM	0-100	0-200	0-300
Tube O.D., Inches	3/8", 1/2"	3/8", 1/2"	1/2"

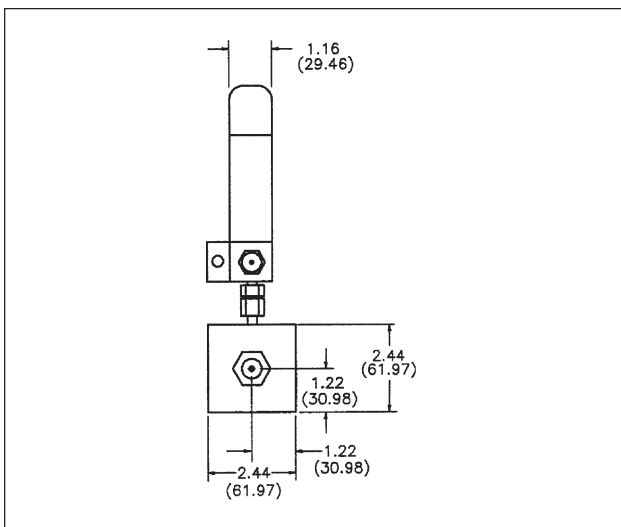
Flow Range, SCFM	3.53	7.06	10.6
Tube O.D., Inches	1/2"	1/2"	1/2"

Fitting Type (3/4"-16 Thd.)	3/8" Comp.	3/8" VCO (male)	3/8" VCR (male)
Dim. "L"	11.36	11.81	11.93



Bottom View

Fitting Type (3/4"-16 Thd.)	1/2" Comp.	—	—
Dim. "L"	11.36	—	—



Outlet End View

APPENDIX B
Conversion of Flow
Rate to Other T and P
Conditions

The flow rate of your MAS 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 MAS is installed, use the following relationship:

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

()₁ = Refers to the standard conditions with which your MAS was calibrated,

()₂ = Refers to the new standard conditions or to the actual temperature and pressure conditions in the pipe,

Q₁ = The gas mass flow rate referenced to the calibrated standard conditions (SCCM or SLM),

Q₂ = 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/cm² or psia), and

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

EXAMPLE 1 CHANGING “STANDARD” CONDITIONS:

If your MAS 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:

$$Q_2 = \frac{14.7}{14.7} \frac{460 + 32}{460 + 70} (10.00) = 9.28 \text{ SLM}$$

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:

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

APPENDIX C
K Factors and
Gas Tables

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:

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 meter or flow controller which has been calibrated with a gas other than the actual gas.

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

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

Where:

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

K = The “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, as described in Section 1.2, PRINCIPLE OF OPERATION:

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

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,

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

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

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 $K_{\text{actual}}/K_{\text{reference}}$, 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 r , 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.

Kobold calibrates every MAS mass flowmeter and controller with primary standards using the actual gas or a molecularly equivalent reference gas. The calibration certificate accompanying your MAS

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:

AMAS is calibrated for nitrogen (N₂), 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:

AMAS is calibrated for hydrogen (H₂), and the flow rate is 100 SCCM for a 5,000 VDC output signal. The flow rate for nitrous oxide (N₂O) 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 MAS to be calibrated for use with dichlorosilane (SiH₂CL₂) at a 100 SCCM full scale flow. We wish to use the preferred reference gas Freon-14 (CF₄). What flow of CF₄ 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/rC_p for the mixture. The equivalent values of r, C_p, and N for a dual gas mixture are given as follows:

For Dual-Gas Mixtures

The equivalent gas density is:

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

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:

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

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

The equivalent value of N is:

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

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

IMPORTANT NOTE ABOUT K-FACTORS:

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

It should also be noted that certain gases, in similar “families,” will work exceptionally well with K-factors; however, those instances are only true when similar thermal properties of the gas are present.

Actual Gas	Chemical Symbol	Ref. Gas	KFactor Rel. to Ref. Gas	KFactor Relative N2	Cp (Cal/g)	Density (g/ l) @ 0°C	Elastomer O-Ring*	Valve Seat
Acetylene	C ₂ H ₂	N ₂	.58		.4036	1.162		
Air		N ₂	1.00		.240	1.293		
Allene (Propadiene)	C ₃ H 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
Bromotrifluoromethane (Freon-13 B1)	CBrF ₃	N ₂	.37		.1113	6.644		
1,3-Butadiene	C ₄ H ₆	N ₂	.32		.3514	2.413		
Butane	C ₄ H ₁₀	N ₂	.26		.4007	2.593	NEO	KR
1-Butane	C ₄ H ₈	N ₂	.30		.3648	2.503	NEO	KR
2-Butane	C ₄ H ₈ CIS	N ₂	.324		.336	2.503	NEO	KR
2-Butane	C ₄ H 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 ₂ ClF ₅	N ₂	.24		.164	6.892		KR
Chlorotrifluoromethane (Freon-13)	CClF ₃	N ₂	.38		.153	4.660		KR
Cyanogen	C ₂ N ₂	N ₂	.61		.2613	2.322		
Cyanogen Chloride	CICN	N ₂	.61		.1739	2.742		KR
Cyclopropane	C ₃ H ₅	N ₂	.46		.3177	1.877		KR
Deuterium	D ₂	N ₂	1.00		.1722	1.799		
Diborane	B ₂ H ₆	N ₂	.44		.508	1.235		KR
Dibromodifluoromethane	CBr ₂ F ₂	N ₂	.19		.15	9.362		KR
Dibromomethane		N ₂	.47		.075	7.76		KR
Dichlorodifluoromethane (Freon-12)	CCl ₂ F ₂	N ₂	.35		.1432	5.395		KR
Dichlorofluoromethane (Freon-21)	CHCl ₂ F	N ₂	.42		.140	4.952		KR
Dichloromethylsilane	(CH ₃) ₂ SiCl ₂	N ₂	.25		.1882	5.758		KR
Dichlorosilane	SiH ₂ Cl ₂	N ₂	.40		.150	4.506		KR
Dichlorotetrafluoroethane (Freon-114)	C ₂ Cl ₂ F ₄	N ₂	.22		.1604	7.626		KR
1,1-Difluoroethylene (Freon-1132A)	C ₂ H ₂ F ₂	N ₂	.43		.224	2.857		KR
Dimethylamine	(CH ₃) ₂ NH	N ₂	.37		.366	2.011		KR

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*NOTE: If no O-Ring is specified then O-Ring to be used is FKM.

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Actual Gas	Chemical Symbol	Ref. Gas	KFactor Rel. to Ref. Gas	KFactor Relative N2	Cp (Cal/g)	Density (g/ l) @ 0°C	Elastomer O-Ring*	Valve Seat
Dimeyl Ether	(CH ₃) ₂ O	N ₂	.39		.3414	2.055		KR
2,2-Dimethylpropane	C ₅ H ₁₂	N ₂	.22		.3914	3.219		KR
Ethane	C ₂ H ₆	N ₂	.50		.4097	1.342		
Ethanol	C ₂ H ₆ O	N ₂	.39		.3395	2.055		KR
EthylAcetylene	C ₄ H ₆	N ₂	.32		.3513	2.413		KR
Ethyl Chloride	C ₂ H ₅ Cl	N ₂	.39		.244	2.879		KR
Ethylene	C ₂ H ₄	N ₂	.60		.1365	1.251		
Ethylene Oxide	C ₂ H ₄ O	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 ₃ F	N ₂	.33		.1357	6.129		KR
Freon-12	CCl ₂ F ₂	N ₂	.35		.1432	5.395		KR
Freon-13	CCIF 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 ₂ F	N ₂	.42		.140	4.952		KR
Freon-22	CHClF ₂	N ₂	.46		.1544	3.858		KR
Freon-113	CCl ₂ FCCIF ₂	N ₂	.20		.161	8.360		KR
Freon-114	C ₂ Cl ₂ F ₄	N ₂	.22		.160	7.626		KR
Freon-115	C ₂ ClF ₅	N ₂	.24		.164	6.892		KR
Freon-C318	C ₄ F ₆	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
Helium	He	He	1.000	1.454	1.241	.1786		
Hexafluoroethane (Freon-116)	C ₂ F ₆	N ₂	.24		.1834	6.157		KR
Hexane	C ₆ H 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 ₂ Se	N ₂	.79		.1025	3.613		KR
Hydrogen Sulfide	H ₂ S	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 ₄ H 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 ₃ OH	N ₂	.58		.3274	1.429		
Methyl Acetylene	C ₃ H ₄	N ₂	.43		.3547	1.787		KR
Methyl Bromide	CH ₂ Br	N ₂	.58		.1106	4.236		
Methyl Chloride	CH ₃ Cl	N ₂	.63		.1926	2.253		KR
Methyl Fluoride	CH ₃ F	N ₂	.68		.3221	1.518		KR
Methyl Mercaptan	CH ₃ SH	N ₂	.52		.2459	2.146		KR
Methyl Trichlorosilane	(CH ₃) ₃ SiCl ₃	N ₂	.25		.164	6.669		KR
Molybdenum Hexafluoride	MoF ₆	N ₂	.21		.1373	9.366		KR
Monoethylamine	C ₂ H ₅ NH ₂	N ₂	.35		.387	2.011		KR
Monomethylamine	CH ₃ NH 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		

*NOTE: If no O-Ring is specified then O-Ring to be used is FKM.

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Actual Gas	Chemical Symbol	Ref. Gas	KFactor Rel. to Ref. Gas	KFactor Relative N2	Cp (Cal/g)	Density (g/l) @ 0°C	Elastomer	
							O-Ring*	Valve Seat
Nitrogen Trifluoride	NF ₃	N ₂	.48		.1797	3.168	KR	
Nitrosyl Chloride	NOCl	N ₂	.61		.1632	2.920	KR	
Nitrous Oxide	N ₂ O	N ₂	.71		.2088	1.964		
Octafluorocyclobutane (Freon-C318)	C ₄ F ₆	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 ₅ H ₉	N ₂	.26		.38	2.816	KR	
Pentane	C ₅ H ₁₂	N ₂	.21		.398	3.219	KR	
Perchloryl Fluoride	ClO ₃ F	N ₂	.39		.1514	4.571	KR	
Perfluoropropane	C ₃ F 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	PF ₅	N ₂	.30		.1610	5.620	KR	
Phosphorous Trichloride	PCl ₃	N ₂	.30		.1250	6.127	KR	
Propane	C ₃ H ₈	N ₂	.36		.3885	1.967	KR	
Propylene	C ₃ H 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 ₂ F ₂	N ₂	.39		.1543	4.562	KR	KR
Teos		N ₂	.090				KR	KR
Tetrafluorahydrazine	N ₂ F ₄	N ₂	.32		.182	4.64	KR	KR
Trichlorofluoromethane (Freon-11)	CCl ₃ F	N ₂	.33		.1357	6.129	KR	KR
Trichlorosilane	SiHCl ₃	N ₂	.33		.1380	6.043	KR	KR
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon-113)	CCl ₂ FCFCl ₂	N ₂	.20		.161	8.360	KR	KR
Trisobutyl Aluminum	(C ₄ H ₉)Al	N ₂	.061		.508	8.848	KR	KR
Titanium Tetrachloride	TiCl ₄	N ₂	.27		.120	8.465	KR	KR
Trichloro Ethylene	C ₂ HCl ₃	N ₂	.32		.163	5.95	KR	KR
Trimethylamine	(CH ₃) ₃ N	N ₂	.28		.3710	2.639	KR	KR
Tungsten Hexafluoride	WF ₆	N ₂	.25		.0810	13.28	KR	PTFE
Uranium Hexafluoride	UF ₆	N ₂	.20		.0888	15.70	KR	KR
Vinyl Bromide	CH ₂ CHBr	N ₂	.46		.1241	4.772	KR	KR
Vinyl Chloride	CH ₂ CHCl	N ₂	.48		.12054	2.788	KR	KR
Xenon	Xe	Ar	.993	1.44	.0378	5.858		

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*NOTE: If no O-Ring is specified then O-Ring to be used is FKM.

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CAUTIONS!

CAUTION! Any application whatsoever related to human respiration must have the written consent of Kobold Instruments Inc.

CAUTION! The maximum pressure and temperature in the flow line in which your MAS is to be installed shall not exceed 150 psig (10 kg/cm² gauge) or 150°F (65.556°C), respectively.

CAUTION! Be sure the arrow on the side of the transducer points in the direction of flow.

CAUTION! Over-tightening will crack the fittings and shift calibration.

CAUTION! Do not supply + DC power at the “D” connector while using a MAS-5000 power supply at the DC power jack. Do not plug power connector into DB9 connector. Damage to electronics will result. The “D” connector pinout is in Section 2.5.1.

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

CAUTION! All instruments are leak-tested prior to shipping. To check your installation, test the fittings only. Do not use liquid leak detectors such as Snoop® to search for leaks inside or outside the MAS. Instead, monitor pressure decay.

CAUTION! If you wish to clean your MAS, purge it thoroughly before disconnecting from the gas line when toxic or corrosive gases are used. Never return a MAS to Kobold Instruments or any other repair or calibration facility without fully neutralizing any toxic gases trapped inside.

CAUTION! Opening the sensor cavity will shift calibration.

**QUICK START
INSTRUCTIONS**

Refer to Section 3, OPERATION, for detailed instructions.

1. Install your MAS into the gas flow line. If you are using $1/4$ -inch pipe use a good quality paste pipe thread sealant for sealing and tighten $1\frac{1}{2}$ turns beyond hand-tight. Do not over-tighten. (Refer to Section 2.4, PLUMBING CONNECTIONS.)

CAUTION! Over-tightening will crack the fittings and shift calibration.

CAUTION! Be sure the arrow on the side of the transducer points in the direction of flow.

The line pressure and temperature should not exceed 150 psig (10 kg/cm² gauge) or 150°F = 65.556°C.

2. Apply power to your MAS. If you are using the Kobold MAS-5000 power supply, plug the power supply into line power and the connector into the input power jack on the side of your MAS. (Refer to Figure 2-2 in Section 2, INSTALLATION.) If you are providing your own power, use 12 to 15 VDC at 100 mA max. (24 VDC operation is made possible by board changes provided by Kobold.)

CAUTION! Do not supply + DC power at the “D” connector while using an MAS-5000 power supply at the DC power jack. **DONOT** plug power connector into DB9 connector. Damage to electronics will result. The “D” connector pinout diagram is in Section 2.5.1.

IMPORTANT! Failure to follow proper power-up procedures will result in a blown integrated circuit. Blown integrated circuits are the most common cause of instrument failure.

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 zero (or 4 mA, depending on output configuration). Allow at least 15 minutes for warm-up.
4. After the warm-up period, your MAS is now monitoring the gas mass flow rate.
5. Output Signals: The output signal of MAS 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 of your MAS. Section 2.5, ELECTRICAL CONNECTIONS, 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 your MAS; 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. The MAS with Integral or Remote Display: The $3\frac{1}{2}$ digit LCD display reads directly in engineering units or percent of full scale. The full scale range and gas are shown on the front label of your MAS. 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 overrange condition has been removed, it may take several seconds for the MAS to recover and resume normal operation.

CUSTOMER CAUTION! RE: OXYGEN SERVICE

Kobold Instruments Inc is not liable for any damages or personal injury, whatsoever, resulting from the use of Kobold Instruments' Mass Flow Meters or Controllers for oxygen gas. Although Kobold does clean its mass flow meters and controllers prior to shipment, Kobold makes no claim or warranty that their cleanliness renders them safe for oxygen service. The customer must clean Kobold's Mass Flow Meters or Controllers to the degree that the customer requires for his oxygen flow applications.

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