SERIES 100 MASS FLOWMETER
AND
SERIES 200 MASS FLOW CONTROLLER
TECHNICAL AND USERS MANUAL
FOR
CARD EDGE
PRINTED
CIRCUIT BOARD ASSEMBLY

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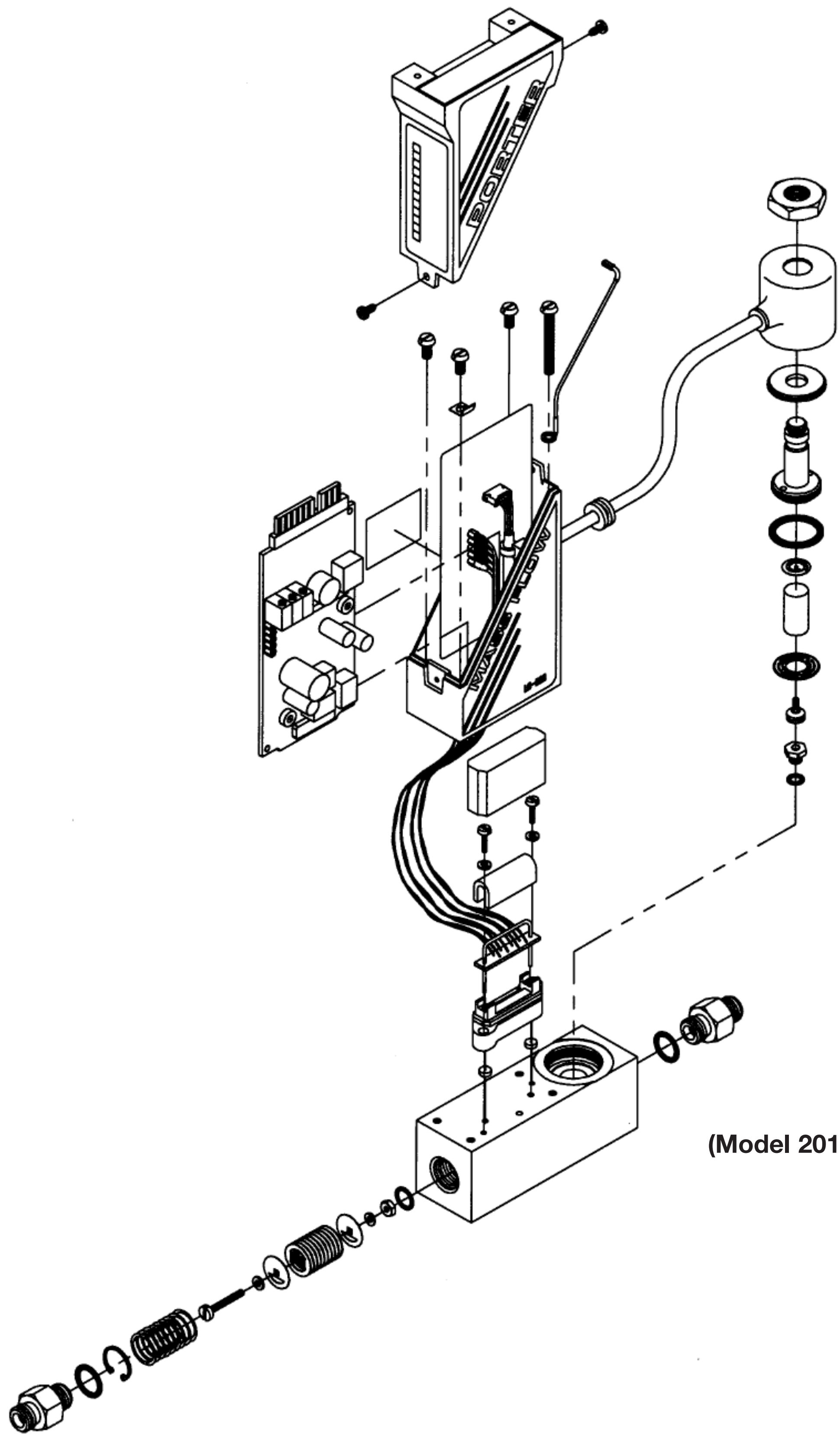
EXPLODED VIEW OF PORTER SERIES 200 MASS FLOW CONTROLLER



(Model 201 Illustrated)

SECTION 1

INTRODUCTION

System Description

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

Porter Series 100 MFM's and Series 200 MFC's accurately measure (Series 100 and 200) and control (Series 200 only) flow rates of a wide variety of gases from 5 standard cubic centimeters per minute (SCCM) to 1000 standard liters per minute (SLPM) full scale nitrogen flow for operating pressures up to 3000 PSIG. The MFM's and MFC's provide a linear flow signal output proportional to a calibrated flow rate. This output signal can be used to drive a digital display, such as the digital display included on Porter's Model CM2, CM4 and PCIM4 Interface Modules, or other customer-supplied data acquisition equipment.

The Series 100 MFM's & Series 200 MFC's incorporate an operating principle based on the thermodynamic properties of the process gas being monitored. Both the Series 100 MFM's & Series 200 MFC's employ a sensor assembly that includes a heater and two precision resistance-type temperature sensors. The integral printed circuit board (PCB) assembly performs amplification and linearization of the sensor assembly output signal and provides the flow signal output. Patented, restrictive laminar flow elements condition the main channel of gas flow while thermal measurement occurs in the gas flowing through the bypass sensor assembly. The Series 200 MFC's additionally incorporate an integral proportional control valve and closed loop control circuitry on the PCB assembly. Detailed explanation of operational theory is described in Section 4, Theory of Operation.

System Features

+ Fast Response

The Series 200 MFC's respond to a step change in setpoint in less than one (1) second. Actual flow is stabilized within two (2) seconds, virtually without overshoot.

+ Soft Recovery Valve Override (SRVO)

When automatic control action is disabled, the control valve action may be held open or closed. Return to its normal setpoint will be soft and smooth rather than violent, thereby preventing erratic control and potential damage to the valve or process system.

+ Stable Zero Control (SZC)

a. When the setpoint is adjusted to zero, the gas flow signal is prevented from decreasing to less than +0.3% of full scale value, regardless of any possible amplifier drift.
b. When the setpoint is subsequently adjusted up scale, no gas flow overshoot or flow signal overshoot will be produced as the gas flow error signal realigns the flow rate.

+ Attitude Insensitivity

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

+ Interchangeability

Electrical connector pin-out configuration is designed to easily retrofit competitive equipment.

+ Internal Voltage Regulation and Temperature Compensation Circuits

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

+ Laminar Flow Element Package

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

+ Valve Override (SIM-VO)

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

+ Fail-Safe Operation

Control valve is normally closed. Therefore, the valve will close for major equipment failure or power failure.

SECTION 2

SPECIFICATIONS

Specifications for Series 100 MFM's and Series 200 MFC's

Response Time:
2 seconds

Accuracy and Linearity:
±1% full scale (all models except Models 114 and 204A)
±1.5% full scale (Models 114 and 204A)

Repeatability:
Within ±0.2% full scale at any constant temperature within operating temperature range

Rangeability (Control Range):
50:1 (2%-100% full scale) (accuracy and control)

Ambient and Operating Temperature Range:
-10 to 70ºC (+14 to 158ºF)

Temperature Coefficient:
±0.1% full scale/ºC

Pressure Coefficient:
±0.1% full scale/atmosphere typical using nitrogen (N_2)

Setpoint Input/Flow Signal Output:
0-5 Vdc (output signal - 2K ohm minimum load resistance)

Power Supply Requirements:
+15 Vdc: <25 mAdc (MFM & MFC)
-15 Vdc: <25 mAdc (MFM) or <300 mAdc (MFC)

Mounting Orientation:
Attitude insensitive

Warm-up Time:
10 minutes

External Electrical Connector:
Twenty (20)-pin card edge

SECTION 3

INSTALLATION AND OPERATING PROCEDURES

General Information

Porter Series 100 MFM's and Series 200 MFC's must be installed in a clean, dry area with adequate space surrounding the MFM/MFC for ease of maintenance. Ambient temperature should not exceed the specified operating range of -10 – 70°C (14 – 158°F). The MFM's/MFC's are attitude insensitive, therefore, may be mounted in any position. Users may specify factory calibration in the exact attitude of the installation. Users must specify process gas, flow range, inlet pressure, outlet pressure (for Series 200 MFC's), operating temperature and calibration standard at the time of ordering. When supplying a MFC, Porter will computer-calculate the appropriate valve orifice for the application based on the user-specified operating parameters.

Gas Connections

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

System Purging

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

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

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

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

External Electrical Connections

Do not confuse the two "common" references noted herein. Circuit common acts as a common return for all functional circuit blocks. Valve common is the return wire for the solenoid control valve.

Figure 3-1 shows the diagram for external electrical connections to be made to the Series 100 MFM. Table 3-1 details the individual functions for the flowmeter's connector, which is designated as socket J2. For reference, J1 is the temperature sensor/heater power output socket located inside the instrument's housing. It accepts plug P1, which feeds the sensor/heater components. If the instrument to be operated is a Series 200 MFC, refer to Figure 3-2 and Table 3-2, the counterparts of those listed for the flowmeter.

Make the connections to socket J2 in accordance with the appropriate diagram previously noted. A separate control valve common wire (pin B, J2) is highly recommended. This connection keeps the high current related to the control valve independent of the more sensitive, low level, processing circuitry, thus avoiding potential noise problems and/or ground loops. For replacement applications, where the wiring already exists, it may not be feasible to add the extra control valve common wire. If so, the valve common may be connected to signal common by jumper switch J6 located on the plug-in card and shown as part of Figure 3-2. Use of this jumper, however, may add some degree of error to the flow signal, since the valve drive current must now be carried by the signal common and will generate a voltage drop proportional to valve current, wire resistance and length.

Note the circuit arrangement in Figure 3-2 for the setpoint control. Not only does this configuration do away with the separate +5 Vdc power supply called for with earlier wiring configurations, but it also permits viewing of the setpoint on the digital process meter, as well as the flow rate. Switch SW-1 is a spring return, SPDT push-button type, which causes the flow rate to be displayed under normal conditions and the setpoint valve to be viewed when it is depressed.

Valve Override for Series 200 MFC's

After wiring has been completed as described in the previous paragraphs, it may be well to consider certain valve override options. Although Soft Recovery Valve Override is preferred (refer to System Features, Section 1 for SRVO advantages), simple valve override functions have been included for replacement applications, where the existing wiring harness does not include the extra wires required to effect SRVO control. For simple close valve overide action pin D, J2 is shorted to pin B, J2. For simple open valve override action, short pin B, J2 to pin 5, J2.

For SRVO close valve override operation, short pin L, J2 to circuit common (pins 2 or C, J2). In some replacement applications where a competitive model instrument may have been employed, shorting pins L and 10 together may have been specified for simple close valve override operation. By activating Jumper switch J5 (see Figure 3.2) close valve override operation between pins L and 10 may be retained, but with SRVO operation rather than simple operation!

For SRVO open valve override operation short pin 9, J2 to circuit common (pins 2 or C) on J2.

Electrical Interfacing Data

When digital logic ICs, such as TTL or CMOS gates or drivers, etc., are used to interface an external computer/controller with the Series 200 MFC, it is important to observe the logic level values required for proper and reliable operation. Detailed listings for these values may be found in Appendix A of Section 7.

Basic Operating Procedures to Establish a Controlled Flow Rate

Introduce power to the system, allowing a ten (10) minute warm-up period prior to operation. For Series 200 MFC's, adjust SETPOINT to zero flow rate. Turn on the supply of gas to be monitored/controlled.

Using the circuit illustrated in Figure 3-2, to operate the MFC at a desired flow rate press the push-button switch shown to allow indication of the SETPOINT. The digital display will now indicate the flow rate as determined by the SETPOINT. Adjust the SETPOINT until the digital display indicates the desired flow. Releasing the push-button switch will cause the digital display to indicate the process flow rate.

It is recommended this switch be labeled PROCESS/SETPOINT or FLOW SIGNAL/SETPOINT.

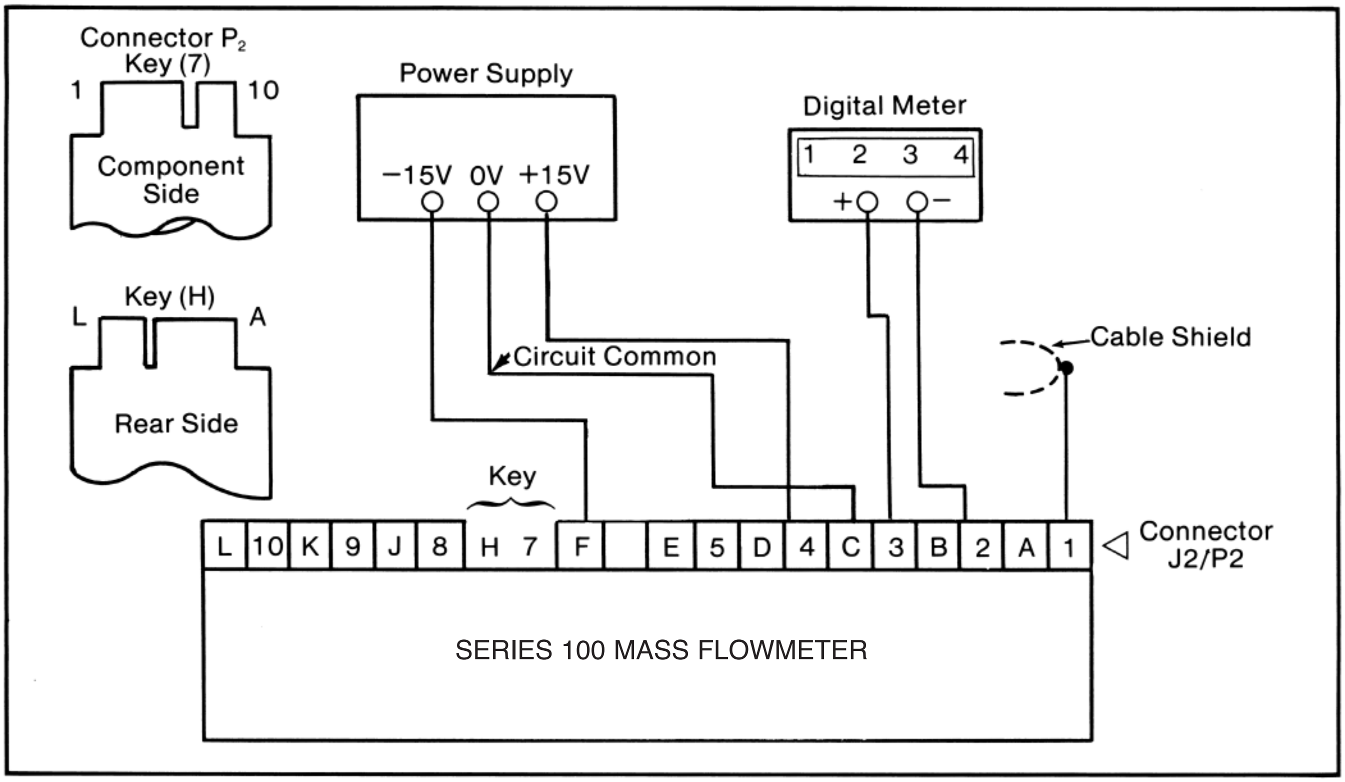


Figure 3-1. External Electrical Connections for Series 100 Mass Flowmeter

Table 3-1. Functions by Pin Number of Connector J2/P2 for Series 100 Mass Flowmeter

PC BOARD PIN NO.	FUNCTION	INSULATION COLOR (PORTER-SUPPLIED CABLE ASSEMBLY
1	Cable Shield	Shield (Drain Wire)
2	Circuit Common (with Pin C)	Violet or White
3	Flow Signal Output	Brown
4	+15 Vdc Power Input	Black
5	—	—
6	—	—
7	Key	—
8	—	—
9	—	—
10	—	—
A	—	Yellow*
B	—	Green*
C	Circuit Common (with Pin 2)	Red
D	—	Blue*
E	—	—
F	-15 Vdc Power Input	Orange
H	Key	—
J	—	—
K	—	—
L	—	—

Notes: Cable color codes are for reference only and are subject to change without notice.
***Not required for mass flowmeter operation.**

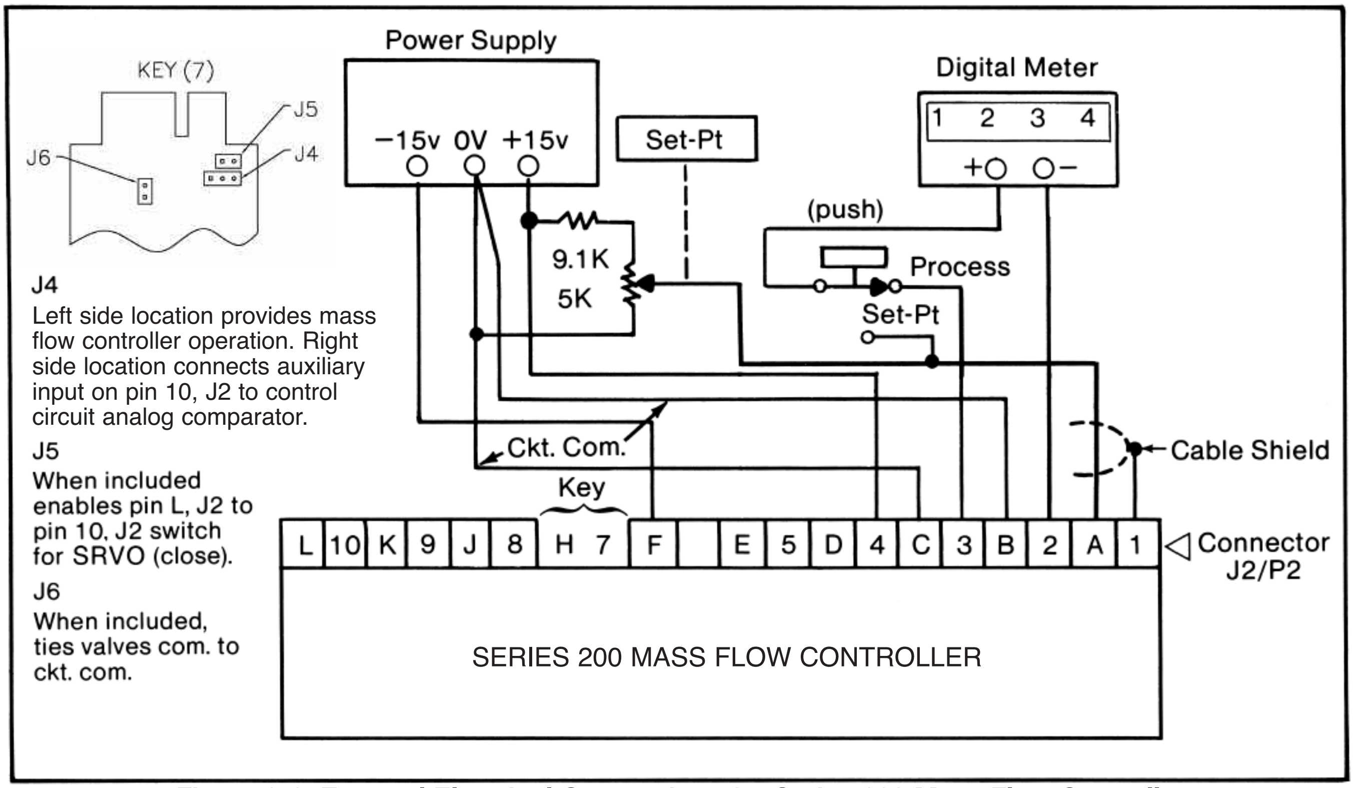


Figure 3-2. External Electrical Connections for Series 200 Mass Flow Controller

Table 3-2. Functions by Pin Number of Connector J2/P2 for Series 200 Mass Flow Controller

PC BOARD PIN NO.	FUNCTION	INSULATION COLOR (PORTER-SUPPLIED CABLE ASSEMBLY
1	Cable Shield	Shield (Drain Wire)
2	Circuit Common (with Pin C)	Violet or White
3	Flow Signal Output	Brown
4	+15 Vdc Power Input	Black
5	Sim-VO (Open) Input	—
6	—	—
7	Key	—
8	—	—
9	SRVO (Open) Input	—
10	Aux. Input to Comp. or Jumper Switch (see J4)	—
A	Setpoint Input	Yellow
B	Valve Common	Green
C	Circuit Common (with Pin 2)	Red
D	Sim-VO (Close) Input	Blue
E	—	—
F	-15 Vdc Power Input	Orange
H	Key	—
J	—	—
K	—	—
L	SRVO (Close) Input	—

Notes: Cable color codes are for reference only and are subject to change without notice.

SECTION 4

THEORY OF OPERATION

Porter's Series 100 Mass Flowmeters (MFM's) & Series 200 Mass Flow Controllers (MFC's) incorporate an operating principle based on the thermodynamic properties of the process gas being monitored.

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

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

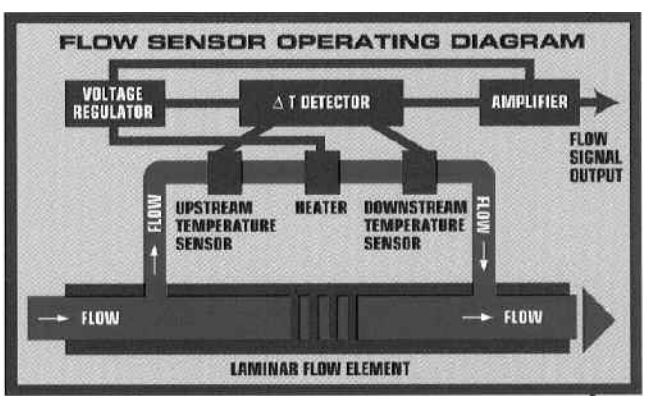


Figure 4-1 Block Diagram of Sensor Assembly

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

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

The upstream temperature sensor, downstream temperature sensor and heater are connected to the PCB assembly via a miniature flexible interconnecting cable.

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

Figure 4-2 illustrates three (3) of the five (5) available sizes of the laminar flow elements. The smallest flow element shown has only one (1) chemically-etched precision flow channel and would be used as part of a laminar flow element package in a low flow range MFM/MFC, for example Model 111 MFM or Model 201 MFC. In comparison, the largest flow element shown contains numerous flow channels. Varying the number

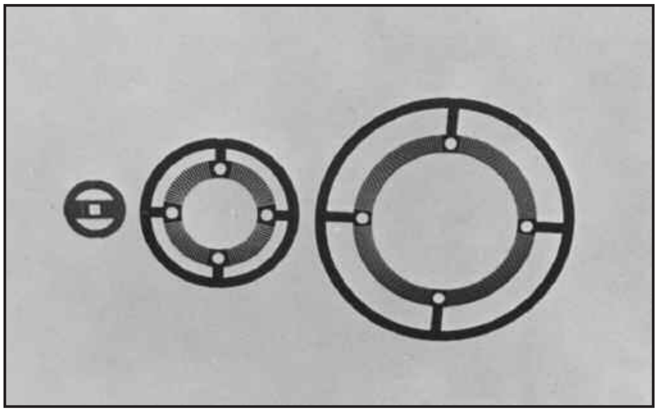


Figure 4-2 Laminar Flow Elements

of flow elements in the flow element package, using flow elements having more flow channels, combinations of similarly-sized flow elements or a physically larger flow element size would be used for the various available flow ranges. For example, a flow element package containing multiple flow elements provides a large number of parallel paths for gas flow, thereby obtaining a higher flow rate.

Mass Flowmeter /Mass Flow Controller Electronics

As briefly noted in Section 1, the PCB assembly performs three (3) general flowmeter functions: amplification, linearization, and flow signal output. If the instrument under discussion is an MFC, the required control circuitry to regulate a proportional control valve is included on the PCB. Refer to Figure 4-3 for the block diagram of the Porter Series 100/200 MFM's/MFC's.

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

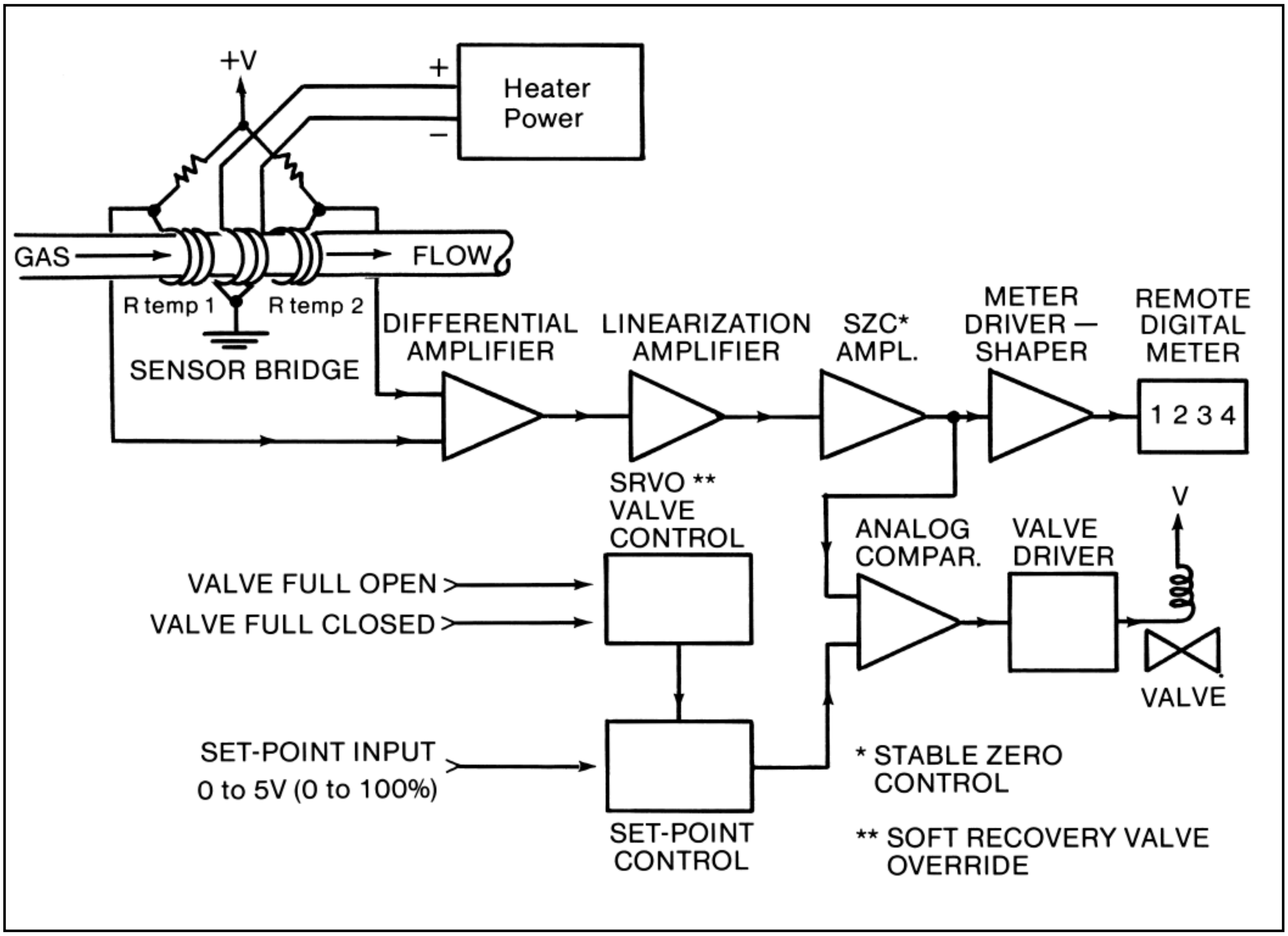
The output signal from the linearization stage drives a special signal conditioning amplifier providing Porter Instrument's exclusive Stable Zero Control (SZC) feature. In general, flow signals which approach zero volts may tend to be not well defined due to possible drift or variation in amplification. In some designs the flow signal may even drift over the zero line into the negative voltage region. This problem is eliminated in the SZC circuit because the low voltage limit is never less than +0.3% of full scale (refer to System Features in Section 1 for an explanation of Stable Zero Control).

The signal from the SZC stage is applied to the output meter driver/shaper stage. This dual-purpose stage is an active differentiator network having a tailored rapid response characteristic. In less technical language, the "peaked" response of the stage causes the slower changing flow signal to change in the same manner as the actual gas flow changes. Figure 4-4 illustrates how this circuit's signal closely duplicates a rapid step change in gas flow rate. The second purpose of this stage is to provide a 0-5 Vdc flow signal output for a 0 to 100 percent of full scale flow rate.

Control of the Proportional Control Valve

Closed-loop control of the proportional control valve adds circuitry to the MFC schematic diagram not required for the MFM. The additional circuitry includes a setpoint input channel, an analog comparator and a valve (power) driver stage. Generally speaking, the closed-loop control system works as follows: the setpoint input signal is compared with the flow signal output in the analog comparator stage. If the setpoint input signal commands a flow change, comparison between the setpoint input signal and the flow signal output is such that the analog comparator applies a signal of a given magnitude and polarity to the valve driver stage causing the valve to respond to the flow change. As this occurs, the flow signal output approaches and theoretically equals the setpoint signal stabilizing the valve's power drive signal, holding the valve in a relatively stable position. Typical valve displacement (i.e. valve travel) for an MFC sized for 1 SLPM of nitrogen, an inlet pressure of 20 PSIG & an outlet pressure of 0 PSIG (14.7 PSIA), is approximately 0.003 inch for 0 to 100 percent of full scale flow.

Figure 4-3 Block Diagram of Series 100 Mass Flowmeters and Series 200 Mass Flow Controllers



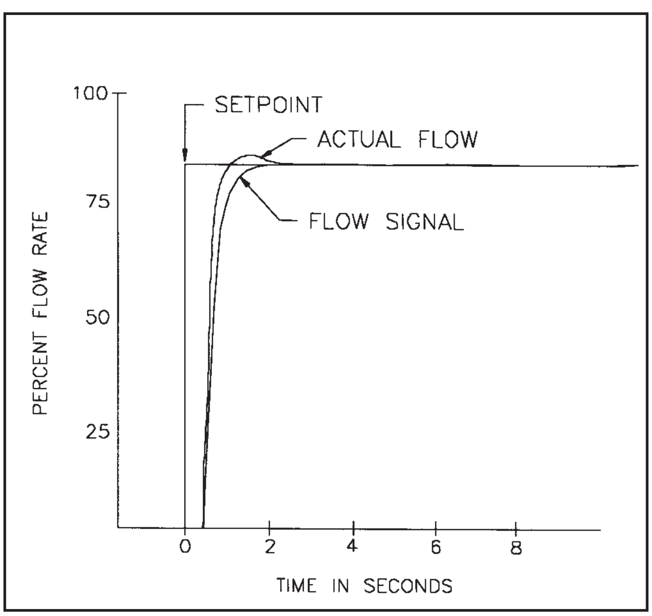


Figure 4-4 Response Curve: Comparison between Flow Signal and Actual Gas Flow

SECTION 5

MAINTENANCE

General

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

Preliminary Checks

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

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

Cleaning

If the instrument and control valve have been subjected to severe contamination, they may require disassembly for effective cleaning. If the laminar flow device requires changing or replacement, accurate volumetric calibration facilities are required for recalibration of the instrument. When disassembling the instrument, do not attempt to remove the flow sensor bypass element.

Proceed with the following steps for disassembly of the flowmeter/flow controller.

a. Unscrew and remove the inlet fitting.
b. Loosen and remove the circlip spring.
c. Remove the coil spring, laminar flow element and O-ring. Do not attempt to further disassemble the laminar flow element.
d. Clean or replace parts as required, reassemble, and recalibrate.

Control Valve Disassembly

Major maintenance procedures of cleaning and total MFC disassembly and recalibration are typically done at the factory. However for simple maintenance, the following steps explain how to disassemble the control valve for cleaning or service (refer to Troubleshooting & Repair Tools list):

a. If the valve is integral with the controller, disconnect the electrical connector.
b. Remove the hex nut from the top of the valve assembly and carefully remove the cover/coil assembly.
c. Unscrew the valve stem and remove the valve stem and valve stem O-ring.
d. Remove the internal valve assembly. Do not change any shim positions.
e. Unscrew the orifice and remove the orifice and orifice O-ring.
f. Parts may be cleaned ultrasonically in a suitable solvent. The valve stem and orifice O-rings should be replaced prior to reassembly. Replacement O-rings are available from Porter Instrument.
g. Reassemble parts in reverse order.
h. Test MFC performance for smooth opening flows and stable control at setpoint

Troubleshooting and Repair Tools

Part Number	Description
C-843-000	Eight (8)-inch adapter assembly to adapt a card edge electrical connector PC board to a 9-pin, D-connector cable assembly
KB20045-000	Four (4)-inch adapter assembly to adapt a 9-pin, D-connector PCB assembly to a card edge electrical connector cable assembly
A-3034-000	Valve stem spanner wrench for Models 001, 003A, 201, 202A, 203A & 204A
A-3033-000	Valve stem spanner wrench for Models 002 & 202
A-3048-001	Orifice removal socket (for use with ¼” drive) for Models 001, 003A, 201, 202A, 203A & 204A. On Models 003A, 202A, 203A & 204A, this socket will remove the bypass orifice.
A-3048-000	Orifice removal (for use with ¼” drive) for Models 002 & 202

System Troubleshooting

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

Table 5-1 System Troubleshooting Chart

Symptom	Possible Cause	Corrective Action
No output	No power input	Check power supply (with cable assembly connected) for ±15 Vdc at socket J2. Check power supply line fuse.
Signal offset at zero flow	Digital display shifted upscale	Check by shorting input to digital display (with pin 3, J2 open) or by depressing PROCESS/SETPOINT switch with SETPOINT control at zero.
Signal offset at zero flow (con't.)	MFM/MFC out of calibration	Refer to Section 6, Calibration.
Flow signal to setpoint is offset	Gas leak (MFM)	Check downstream gas connections. Check O-ring seals in MFM and valve.
Valve oscillates	Insufficient pressure drop	Increase supply pressure.
	Excessive pressure drop	Lower supply pressure.
	"Jumpy" supply pressure	Replace upstream pressure regulator.
Flow indication "pegged" (saturated) up or down scale	PCB assembly or sensor assembly failure (e.g. sensor open)	Return to factory for repair.
Flow indication appears to be erroneous	Digital display	Check digital display against digital voltmeter at pin 3, J2 to circuit common (e.g. full scale display should equal 5.0 Vdc on voltmeter)
	Change in composition of metered gas	Check gas supply.
	Gas leaks (MFM)	Check downstream connections.
	Drift or shift in PCB assembly	Replace PCB assembly. Recalibration required.

Return Shipments

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

SECTION 6

CALIBRATION

General

All of Porter's Series 100 MFM's and Series 200 MFC's are shipped calibrated to the customer's operating conditions within the tolerances given in the specifications stated in Section 2. If service is required, including replacement of the PCB assembly, recalibration may be required. This calibration section is general in nature and assumes the use of a qualified calibration facility.

Equipment Required

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

ATTENTION: Observe precautions for handling electrostatic sensitive devices.

Calibration Procedure

To calibrate Series 100 MFM's or Series 200 MFC's, proceed as outlined in the following steps.

For Series 100 MFM's:

1. Remove the cover to gain access to the PCB assembly.
2. Apply power and allow 10 minutes for system warm up and stabilization.
3. Slowly introduce gas flow to the system.
4. Connect the voltmeter to the output signal, pin 3 of J2.
5. Measure and adjust.
   5.1 Use the three (3) trimpots located at the top left corner of the PCB assembly, positions 1 (HIGH), 2 (MEDIUM) and 3 (LOW), from left to right.
   5.2

Step	Set Gas Flow (Vol. Cal. Device)	Adjust Trimpot (position/label)	Flow Signal Output (Vdc at pin 3)
1	50% of range	2/M	2.500
2	100% of range	1/H	5.000
3	0% of range	3/L	0.025 (±5mV)

H = HIGH; M = MEDIUM; L = LOW

   5.3 Repeat steps 1 through 3 above until the deviations between the desired values and the adjusted values are less than 0.2% FS. Please note trimpots H and L may be adjusted without requiring adjustment of trimpot M or each other. However, adjustment of trimpot M does require readjustment of trimpots H and L. Refer to Figure 6-1 for a graph of output voltage versus percent of full scale flow showing the transfer area affected by trimpots L, M and H.

For Series 200 MFC's:

1. Remove the cover to gain access to the PCB assembly.
2. Adjust SETPOINT input to 0 Vdc (0%).
3. Apply power and allow 10 minutes for system warm up and stabilization.
4. Slowly introduce gas flow to the system by adjusting SETPOINT input.
5. Connect the voltmeter to the output signal, pin 3 of J2.
6. Measure and adjust.
   6.1 Use the three (3) trimpots located at the top left corner of the PCB assembly, positions 1 (HIGH), 2 (MEDIUM) and 3 (LOW), from left to right.
   6.2

Step	Set Gas Flow (Vol. Cal. Device)	Adjust Trimpot (position/label)	Flow Signal Output (Vdc at pin 3)
1	50% of range	2/M	2.500
2	100% of range	1/H	5.000
3	0% of range	3/L	0.025 (±5mV)

H = HIGH; M = MEDIUM; L = LOW

6.3 Repeat steps 1 through 3 above until the deviations between the desired values and the adjusted values are less than 0.2% FS. Please note trimpots H and L may be adjusted without requiring adjustment of trimpot M or each other. However, adjustment of trimpot M does require readjustment of trimpots H and L. Refer to Figure 6-1 for a graph of output voltage versus percent of full scale flow showing the transfer area affected by trimpots L, M and H.

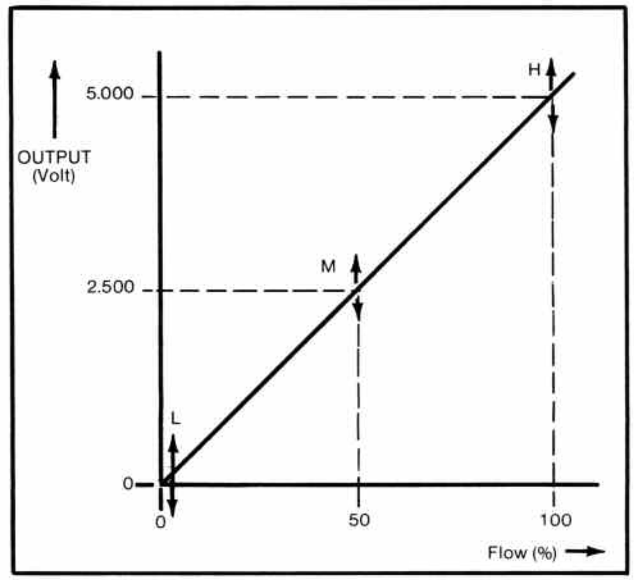


Figure 6.1 Flow Signal Output vs. Percent Actual Flow: Trimpots, L, M, and H areas of influence.

SECTION 7

INPUT/OUTPUT (I/O) DESIGNATIONS (Electrical Connections)

SERIES 100 MASS FLOWMETER

PC BOARD PIN NO.	FUNCTION	INPUT/OUTPUT	COMMENTS
1	Cable Shield	—	—
2	Circuit Common	Output	Flow signal return (signal common)
3	Flow Signal	Output	0-5 Vdc
4	+15 Vdc Power	Input	Power in
5	—	—	—
6	—	—	—
7	Key	—	Connector keying slot
8	—	—	—
9	—	—	—
10	—	—	—
A	—	—	—
B	—	—	—
C	Circuit Common	—	Power common
D	—	—	—
E	—	—	—
F	-15 Vdc Power	Input	Power in
H	Key	—	Connector keying slot
J	—	—	—
K	—	—	—
L	—	—	—

SERIES 200 MASS FLOW CONTROLLER

PC BOARD PIN NO.	FUNCTION	INPUT/OUTPUT	COMMENTS
1	Cable Shield	—	—
2	Circuit Common	Output	Flow signal return (signal common)
3	Flow Signal	Output	0-5 Vdc
4	+15 Vdc Power	Input	Power in
5	Sim-VO (Open)	Input/Output	Dual function: As input, used as simple valve override (open) (NOT RECOMMENDED FOR NEW SYSTEM DESIGN); As output, valve voltage test point
6	—	—	—
7	Key	—	Connector keying slot
8	—	—	—
9	SRVO (Open)	Input	Logic level valve override; low true
10	Auxiliary Input	Input	Dual function: Logic level valve return (J4 in left side location); Auxiliary input to control circuit analog comparator (J4 in right side location)
A	Setpoint	Input	0-5 Vdc
B	Valve Common	—	Isolated valve power common
C	Circuit Common	—	Power common
D	Sim-VO (Closed)	Input	Used as simple valve override (closed) (NOT RECOMMENDED FOR NEW SYSTEM DESIGN)
E	—	—	—
F	-15 Vdc Power	Input	Power in
H	Key	—	Connector keying slot
J	—	—	—
K	—	—	—
L	SRVO (Closed)	Input	Logic level valve override; low true

I/O ELECTRICAL SPECIFICATIONS
(Note — Values typical unless otherwise noted)

SERIES 100 MASS FLOWMETER (VOLTAGE OUTPUT)

+15 Vdc	
Voltage limits — max	+16.5v
— min	+11.4v
Current	<25 ma
-15 Vdc	
Voltage limits — max	–16.5v
— min	–13.5v
Current	<25 ma
Flow Signal	
Output voltage	+.025v to +5v for 0 to 100% f.s. flow
Output current limit	4 ma nom.
External load resistance	2k min. (ref. to sig. common)
Common ref.	Sig. common

I/O ELECTRICAL SPECIFICATIONS
(Note — Values typical unless otherwise noted)

SERIES 200 MASS FLOW CONTROLLER (VOLTAGE OUTPUT)

+15 Vdc	
Voltage limits - max	+16.5v
- min	+11.4v
Current	<25 ma
−15 Vdc	
Voltage limits - max	−16.5v
- min	−13.5v
Current - 0% flow	<25 ma
- 100% flow	<175 ma
- valve full open	<300 ma
Flow Signal	
Output Voltage	+.025v to +5v for 0 to 100% f.s. flow
Output current limit	4 ma nom.
External load resistance	2k min. (ref. to signal common)
Common ref.	Sig. common
Setpoint	
Input voltage	
Normal	0v to +5v for 0% to 100% flow control
Limits	−5v to +6.5v
Input current	
V_{in} =+5v	<+6 microamp
+5v, SRVO (close) = 0v	+500 microamp
0v, SRVO (open) = 0v	<−600 microamp
0v, SRVO (open & close) = 0v	<+1 microamp
Input impedence	>900k ohm, approx. .01 mF
Common ref	Sig. common
Soft Recovery Valve Override Control	
(SRVO open and close)	
Input voltage	
Absolute max.	+15v, −5v
Enable threshold	<+0.8v
Disable threshold	>+2.8v
Recommended logic levels	0v, +5v
Logic level compatibility	TTL, LPTTL, LPSTTL, CMOS, HLL
Input current	
SRVO (open) −	
for V_{in} = +15.0v	+1.8 ma
+ 5.0v	+320 microamp
0v	−480 microamp
− 5.0v	−1.4 ma
SRVO (close) −	
for V_{in} = +15.0v	+1.8 ma
+ 5.0v	+260 microamp
0v	−430 microamp
− 5.0v	−770 microamp
Aux. In	
Input voltage range	
Absolute max.	+/− 10v
Normal	0 to +5v
Input resistance	2.2 megohm

SECTION 8

GAS CONVERSION FACTORS

Gas	Chemical Formula	Conversion Factor	Specific Heat (kcal/kg°K @ 25°C & 1 Atm.)	Density (kg/m³ @ 0°C & 1 Atm.)
Acetylene	C_2H_2	0.602	0.391	1.162
Air	--------	1.000	0.240	1.293
Allene (Propadiene)	C_3H_4	0.430	0.352	1.787
Ammonia	NH_3	0.730	0.492	0.760
Argon	Ar	1.443	0.1244	1.782
Arsine	AsH_3	0.662	0.1167	3.478
Boron Trichloride	BCl_3	0.410	0.1279	5.227
Boron Trifluoride	BF_3	0.510	0.1778	3.025
Bromine	Br_2	0.810	0.0539	7.130
Bromine Pentafluoride	BrF_5	0.260	0.1369	7.803
Bromine Trifluoride	BrF_3	0.380	0.1161	6.108
Bromotrifluoromethane (Freon-13B1)	$CBrF_3$	0.370	0.1113	6.644
Butadiene	C_4H_6	0.320	0.3514	2.413
Butane	C_4H_{10}	0.260	0.4007	2.593
1-Butene	C_4H_8	0.295	0.3648	2.503
cis-2-Butene	C_4H_8	0.324	0.336	2.503
trans-2-Butene	C_4H_8	0.291	0.374	2.503
Carbon Dioxide	CO_2	0.745	0.2016	1.964
Carbon Disulfide	CS_2	0.600	0.1428	3.397
Carbon Monoxide	CO	1.001	0.2483	1.250
Carbon Tetrachloride	CCl_4	0.309	0.1655	6.860
Carbon Tetrafluoride (Freon-14)	CF_4	0.420	0.1654	3.926
Carbonyl Fluoride	COF_2	0.544	0.1710	2.045
Carbonyl Sulfide	COS	0.640	0.1651	2.680
Chlorine	Cl_2	0.852	0.1144	3.163
Chlorine Trifluoride	ClF_3	0.403	0.1650	4.125
Chlorodifluoromethane (Freon-22)	$CHClF_2$	0.456	0.1544	3.858
Chloropentafluoroethane (Freon-115)	C_2ClF_5	0.240	0.164	6.892
Chlorotrifluoromethane (Freon-13)	$CClF_3$	0.380	0.153	4.660
Cyanogen	C_2N_2	0.440	0.2613	2.322
Cyanogen Chloride	ClCN	0.610	0.1739	2.742
Cyclopropane	C_3H_6	0.460	0.3177	1.877
Deuterium	D_2	1.003	1.722	0.1799
Diborane	B_2H_6	0.434	0.508	1.235
Dibromodifluoromethane	CBr_2F_2	0.190	0.15	9.362
Dichlorodifluoromethane (Freon-12)	CCl_2F_2	0.354	0.1432	5.395

Gas	Chemical Formula	Conversion Factor	Specific Heat (kcal/kg°K @ 25°C & 1 Atm.)	Density (kg/m³ @ 0°C & 1 Atm.)
Dichlorofluoromethane (Freon-21)	$CHCl_2F$	0.417	0.140	4.592
Dichloromethylsilane	CH_4Cl_2Si	0.250	0.1882	5.758
Dichlorosilane	SiH_2Cl_2	0.400	0.150	4.506
1,2-Dichlorotetrafluoroethane (Freon-114)	$C_2Cl_2F_4$	0.220	0.160	7.626
1,1-Difluoroethylene (Freon-1132A)	$C_2H_2F_2$	0.430	0.224	2.857
Dimethylamine	$(CH_3)_2NH$	0.370	0.366	2.011
Dimethyl Ether	$(CH_3)_2O$	0.390	0.3414	2.055
2,2-Dimethylpropane	C_5H_{12}	0.220	0.3914	3.219
Ethane	C_2H_6	0.497	0.4097	1.342
Ethyl Acetylene	C_4H_6	0.320	0.3513	2.413
Ethyl Chloride	C_2H_5Cl	0.400	0.244	2.879
Ethylene	C_2H_4	0.622	0.351	1.252
Ethylene Oxide	C_2H_4O	0.520	0.268	1.965
Fluorine	F_2	0.978	0.1873	1.695
Fluoroform (Freon-23)	CHF_3	0.506	0.176	3.127
Germane	GeH_4	0.596	0.1404	3.418
Germanium Tetrachloride	$GeCl_4$	0.270	0.1071	9.565
Helium	He	1.444	1.241	0.1786
Hexafluoroethane (Freon-116)	C_2F_6	0.240	0.1843	6.157
Hydrogen	H_2	1.021	3.3852	0.0899
Hydrogen Bromide	HBr	0.985	0.0874	3.610
Hydrogen Chloride	HCl	0.998	0.1912	1.627
Hydrogen Cyanide	HCN	0.760	0.3171	1.206
Hydrogen Fluoride	HF	0.997	0.3479	0.893
Hydrogen Iodide	HI	0.999	0.5449	5.707
Hydrogen Selenide	H_2Se	0.780	0.1025	3.613
Hydrogen Sulfide	H_2S	0.799	0.2397	1.520
Iodine Pentafluoride	IF_5	0.250	0.1108	9.90
Isobutane	C_4H_{10}	0.260	0.3872	3.593
Isobutylene	C_4H_8	0.290	0.3701	2.503
Krypton	Kr	1.450	0.0593	3.739
Methane	CH_4	0.731	0.5223	0.716
Methyl Acetylene	C_3H_4	0.430	0.3547	1.787
Methyl Bromide	CH_3Br	0.560	0.1106	4.236
Methyl Chloride	CH_3Cl	0.630	0.1926	2.253
Methyl Fluoride	CH_3F	0.559	0.3221	1.517
Methyl Mercaptan	CH_4S	0.520	0.2459	2.146
Methyltrichlorosilane	CH_3SiCl_3	0.250	0.164	6.669

Gas	Chemical Formula	Conversion Factor	Specific Heat (kcal/kg°K @ 25°C & 1 Atm.)	Density (kg/m³ @ 0°C & 1 Atm.)
Molybdenum Hexafluoride	MoF_6	0.210	0.1373	9.366
Monoethylamine	$C_2H_5NH_2$	0.350	0.387	2.011
Monomethylamine	CH_3NH_2	0.450	0.4343	1.386
Neon	Ne	1.445	0.246	0.900
Nitric Oxide	NO	0.997	0.2328	1.339
Nitrogen	N_2	1.000	0.2485	1.250
Nitrogen Dioxide	NO_2	0.740	0.1933	2.052
Nitrogen Trifluoride	NF_3	0.480	0.1797	3.168
Nitrosyl Chloride	NOCl	0.610	0.1632	2.920
Nitrous Oxide	N_2O	0.713	0.2088	1.964
Octafluorocyclobutane (Freon-C318)	C_4F_8	0.170	0.185	8.937
Oxygen	O_2	0.994	0.2190	1.428
Oxygen Difluoride	OF_2	0.630	0.1917	2.409
Pentaborane	B_5H_9	0.260	0.38	2.816
Perchloryl Fluoride	ClO_3F	0.390	0.1514	4.571
Perfluoropropane	C_3F_8	0.170	0.194	8.388
Phosgene	$COCl_2$	0.440	0.1394	4.418
Phosphine	PH_3	0.760	0.2374	1.517
Phosphorous Pentafluoride	PF_5	0.300	0.1610	5.620
Propane	C_3H_8	0.372	0.3735	1.967
Propylene	C_3H_6	0.405	0.3541	1.877
Silane	SiH_4	0.596	0.3189	1.433
Silicon Tetrachloride	$SiCl_4$	0.288	0.1270	7.580
Silicon Tetrafluoride	SiF_4	0.350	0.1691	4.643
Sulfur Dioxide	SO_2	0.687	0.1488	2.858
Sulfur Hexafluoride	SF_6	0.270	0.1592	6.516
Sulfuryl Fluoride	SO_2F_2	0.390	0.1543	4.562
Tetrafluoroethylene	C_2F_4	0.330	0.1940	4.523
Tetrafluorohydrazine	N_2F_4	0.320	0.183	4.640
Trichlorofluoromethane (Freon 11)	CCl_3F	0.330	0.1357	6.129
Triisobutylaluminum	$(C_4H_9)_3Al$	0.061	0.508	8.848
Trimethylamine	$(CH_3)_3N$	0.270	0.3710	2.639
Tungsten Hexafluoride	WF_6	0.250	0.0810	13.28
Uranium Hexafluoride	UF_6	0.200	0.0888	15.70
Vinyl Bromide	C_2H_3Br	0.460	0.1241	4.772
Vinyl Chloride	C_2H_3Cl	0.480	0.2054	2.788
Vinyl Fluoride	C_2H_3F	0.551	0.2713	2.080
Xenon	Xe	1.410	0.0378	5.858

MFM's and MFC's are shipped factory-calibrated for use with a specific gas. The operating conditions for which the unit is calibrated are stated on the serial number label affixed to the electronics housing. If it is desired to use an MFM/MFC on a gas other than the gas for which it is calibrated, the calculation below is necessary. Please note when using an MFC on a gas other than which the MFC is factory-calibrated, valve operation may be compromised. Contact Porter Instrument should this occur.

1. Select the conversion factor for both the calibration gas and the gas for which the unit will be used.
2. Multiply the unit's output signal by the ratio of the conversion factor for the desired gas to the conversion factor for the calibration gas.

Example:
1. MFM calibrated on nitrogen (N_2) for a 200 SCCM maximum flow.
2. MFM being used on carbon dioxide (CO_2).
3. Flow signal output is 80% (4.000 Vdc).
4. Actual CO_2 flow = (80.0) (0.745/1.000) = 59.6% or (59.6%) (200 SCCM) = 119.2 SCCM.

SECTION 9

POLICIES

PRICES
All prices are F.O.B. Hatfield, PA, and subject to change without notice. All merchandise will be invoiced at prices in effect at time of shipment. Prices do not include insurance, freight, taxes or special handling. These charges, if applicable, will be shown separately on invoice. Minimum order $30.00.

PAYMENT TERMS
Net 30 days after invoice date. All invoices past due are subject to a finance charge of 1½% per month (18% annual rate).

SHIPMENTS
Shipment of merchandise shall at times be subject to credit approval and will be contingent upon fires, accidents, emergencies, acts of God or any other causes which are beyond Porter Instrument Division's control.

CANCELLATIONS
No cancellations will be accepted on non-standard or special merchandise, except by payment of full purchase price. If buyer requests cancellation of any order or part thereof, and is agreed to by Porter Instrument Division in writing, buyer will be subject to cancellation charges to cover the cost of material and/or fabrication incurred by Porter Instrument Division to date of cancellation.

CHANGES OF ORDER
A minimum of 90 days notice is required on all changes to orders and will be subject to rescheduling as a new order at Porter Instrument Division's discretion.

RETURNS
No returns will be accepted unless authorized in writing by Porter Instrument Division and accompanied by a properly completed Returned Goods Authorization. All returns are subject to restocking and possible rework charges to be determined by Porter Instrument Division.

Specifications and dimensions subject to change.

CERTIFICATE OF WARRANTY

THIS WARRANTY IS GIVEN IN PLACE OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR OTHERWISE. NO PROMISE OR STATEMENT MADE BY ANY REPRESENTATIVE OR AUTHORIZED DEALER OF PARKER HANNIFIN CORP. SHALL CONSTITUTE A WARRANTY BY PARKER HANNIFIN CORP.

Parker Hannifin Corporation, Porter Instrument Division, warrants this equipment to be free from defects in workmanship and materials, when used in accordance with applicable specifications and with appropriate maintenance, for one (1) year from date of delivery to the customer, unless otherwise specified in writing.

Equipment which malfunctions may be returned, shipment prepaid, to Parker Hannifin Corporation, Porter Instrument Division, for test and evaluation.
Equipment determined to be defective and in warranty will be repaired or replaced at no charge to the customer. Equipment out of warranty will be evaluated, and if the equipment does not meet original specifications and calibration, the customer will be notified of the costs before proceeding with repair or replacement. Repaired equipment will be warranted ninety (90) days from date of delivery to the customer or for the balance of the original warranty, whichever is longer.

Failures due to shipping damage, accident, misuse, improper mechanical or electrical installation or operation, or internal clogging or corrosion due to use of contaminated fluids or inadequate system purging are excluded from warranty coverage.

Parker Hannifin Corporation's obligation for breach of this warranty, or for negligence or otherwise, shall be strictly and exclusively limited to the repair or replacement of the equipment. This warranty shall be void as to any equipment on which the serial number, if applicable, has been altered, defaced, or removed. Parker Hannifin Corporation shall under no circumstances be liable for incidental or consequential damages.

No other promise or statement about the equipment by any representative or authorized dealer of Parker Hannifin Corporation shall constitute a warranty by Parker Hannifin Corporation or give rise to any liability or obligation of Parker Hannifin Corporation.