INSTRUCTIONS FOR MASS FLOW SENSORS AND MASS FLOW CONTROL MODULES

THIS BOOKLET CONTAINS PROPRIETARY INFORMATION OF ADVANCED SPECIALTY GAS EQUIPMENT CORP. AND IS PROVIDED TO THE PURCHASER SOLELY FOR USE IN CONJUNCTION WITH MODEL FRM MASS FLOW SENSORS AND MODELS FRC AND HPC MASS FLOW CONTROL MODULES.

Model 18FRC

IMPORTANT

These instructions are for experienced operators who know the general principles and safety precautions to be observed in handling specialty gases and operating specialty gas equipment. If you are not certain you fully understand the safety precautions for handling gases, we urge you to obtain and read the Material Safety Data Sheet (MSDS) for each gas being used.

Do not permit untrained persons to install, operate, or maintain this equipment. Do not attempt to install or operate this equipment until you have read and fully understand these instructions. If you do not fully understand these instructions, contact your Advanced Specialty Gas Equipment Distributor.

Be sure this information reaches the operator. Your supplier has extra copies.

ADVANCED
Specialty Gas Equipment

SAFETY PRECAUTIONS

Protect yourself and others. Read and understand the following instructions before attempting to use this equipment. Failure to understand and follow these instructions could result in serious personal injury and/or damage to equipment.

- Know and understand the physical and chemical properties of the gas being used.
- Observe general precautions for the use of gases.
- Observe safety precautions for the gas being used.
- Read and follow precautions on cylinder labels.
- Never use this equipment with gases not compatible with the materials of construction. The use of gases not compatible with the materials of construction may cause damage to equipment or injury to personnel.
- If flammable gases are used with this equipment do not locate it near open flames or any other source of ignition.
- If toxic or flammable gases are used with this equipment, emergency equipment applicable to the gases in use should be available in the operating area.
- Many gases can cause asphyxiation by displacing oxygen in the atmosphere. Make certain the area where this equipment is operated is well ventilated. Provide a device to warn personnel of oxygen depletion in the work area.
- Do not release toxic or flammable gases in the vicinity of personnel. Use this equipment only in well ventilated areas. Vent gases to the outside atmosphere, and in an area away from personnel. Be sure that venting and disposal methods are in accordance with Federal, State and local requirements. Locate and construct vent lines to prevent condensation or gas accumulation. Be sure the vent outlet cannot be obstructed by rain, snow, ice, insects, birds, etc. Do not interconnect vent lines; if more than one vent is needed, use separate lines.
- Never use oil or grease on this equipment. Oil and grease are easily ignited and may combine violently with some gases under pressure.
- Never connect Mass Flow Sensors or Control Modules to a supply source having a pressure greater than the maximum rated pressure of the unit. Refer to Product Specifications (see page 9) for maximum inlet pressures.
- Follow all warnings, cautions, and instructions marked on and supplied with the product.
- This instrument contains electronic components that are susceptible to damage by static electricity. Proper handling procedures must be observed during the removal, installation or other handling of internal circuit boards or devices.

MANUFACTURER STATEMENT

The information contained in this instruction booklet has been compiled by Advanced Specialty Gas Equipment Corp., (the Company), from what it believes are authoritative sources and is offered solely as a convenience to its customers. While the Company believes that this information is accurate and factual as of the date printed, the information including design specifications is subject to change without prior notice.

DESCRIPTION

Mass Flow Sensors – The Model FRM is a mass flow measurement device designed to measure gas flow with a 1% full scale accuracy. The heart of the system is the mass flow sensor which produces an electrical output signal linear with flowrate. Since they do not control gas flow, these sensors are only used in applications requiring flow measurement. Capable of working with any of Advanced's Operator Consoles, Model FRM Mass Flow Sensors are available for measuring flowrates in ranges as low as 0.1–5 sccm to ranges as high as 20–1000 slpm.

Mass Flow Control Modules – Models FRC and HPC measure flow using the same principle as our Mass Flow Sensors. They also, however, feature an integral electromagnetic control valve, which additionally gives them the ability to control gas flows with a 1% full scale accuracy. The Flow Control Modules have a user-selectable "soft-start" feature that provides a flow ramping function which slows down the introduction of process gas for those processes which cannot tolerate rapid flow transition. Both Models FRC and HPC are capable of working with either Models FM4595, FM4575 or FM4660A Operator Consoles.

The Model FRC Fast Response Control Modules are offered in flow ranges from 0.1–5 sccm through 20–1000 slpm. They feature a 3 second response time with minimal overshoot and undershoot.

The Model HPC High Pressure Control Modules can operate at inlet pressures as high as 4500 psig. They are available in flow ranges from 2–100 sccm up to 0.4–20 slpm.

The parts of the Mass Flow Control Modules and Sensors in contact with process gases (wetted parts) are constructed of stainless steel and Viton®. Buna-N® and Kalrez® seals are available on special order for use with gases not compatible with Viton.

OPTIONAL EQUIPMENT

Inlet Filter (FM4800 Series) – A Type 316 Stainless Steel Inlet Filter with Viton Seals* used to protect mass flow instruments from contamination, thus preserving accuracy. The sintered stainless steel filter element is mounted in a protective housing and can be easily removed for cleaning or replacement. These filters are designed to fit between the mass flow body and inlet fitting thus adding 2.0" to the installed length of the mass flow instrument. (See page 6, step #6 for installation instructions).

Part No.	Nominal Filtration Rating
FM4800	0.5 Micron Filter
FM4802	2 Micron Filter
FM4805	5 Micron Filter
FM4810	10 Micron Filter
FM4840	40 Micron Filter

* Buna-N or Kalrez Seals available on special order.

IMPORTANT

Mass Flow Sensors and Control Modules are factory calibrated to operate at the pressures specified with the order. In addition, the valve orifice on the mass flow control modules has been sized to ensure proper operation at these pressures. The calibrated pressure conditions are detailed on the product label and the calibration data sheet supplied with each unit. Attempts to operate them under conditions different than ordered may result in less than desirable performance or may cause the unit to fail to function. If you have any questions concerning the calibration of this equipment, contact you local Advanced Specialty Gas Equipment distributor.

INSTALLATION

WARNING: Before attempting to install and operate this equipment, read and fully understand the safety precautions on page 2 in this booklet. Failure to follow the safety precautions may result in serious personal injury and/or damage to equipment.

1. When the equipment is received, the outside packing case should be checked for damage incurred during shipment. If the packing case is damaged, the local carrier should be notified at once regarding his liability.

   Carefully remove the equipment from the packing case. Inspect the equipment for physical damage. If evidence of damage is found contact your Advanced Specialty Gas Equipment Distributor immediately.

   CAUTION: When installing the equipment, care should be taken that no foreign materials enter the inlet or outlet of the instrument. Do not remove the protective end caps until time of installation.

2. The module should be located in a clean dry atmosphere relatively free from shock and vibration. Leave sufficient room for access to the electrical components and install in a manner that permits easy removal if the instrument requires cleaning.

   Note: When used with reactive gas, contamination or corrosion may occur as a result of plumbing leaks or improper purging. Plumbing should be checked carefully for leaks and the controller purged with dry nitrogen before use. See the Technical Appendix for recommended contamination control procedures when installing and operating mass flow sensors and control modules.

3. The modules can be installed in any position. However, mounting orientations other than the original factory calibration (see calibration data sheet supplied with unit) will result in a ±0.5% maximum full scale shift after re-zeroing.

4. When installing sensors or control modules with full scale flowrates of 10 slpm or greater, be aware that sharp abrupt angles in the system piping directly upstream of the unit may cause a small shift in accuracy. If possible have at least 10 pipe diameters of straight tubing upstream of the unit.

5. Insure the service gas is compatible with the materials used to construct the mass flow sensor or control module.

INSTALLATION (Continued)

6. For installation of optional FM4800 Series Inlet Filter:
   a. Perform installation in a clean area to prevent debris from contaminating the mass flow device or filter.
   b. Remove the existing inlet connection fitting from the mass flow device.
   c. Carefully remove the FM4800 Series filter from the protective plastic bag.
   d. Install the filter into the inlet cavity of the mass flow device.
   e. Tighten the filter housing until it seats firmly against the body of the mass flow device.
   f. Install the original inlet connection fitting into the inlet of the FM4800 Series filter housing.
   g. Tighten the inlet connection fitting until it is firmly sealed against the filter housing.
7. Ensure that the inlet and outlet process lines are at atmospheric pressure before connecting the module to the process line.
8. Attach the modules using the threaded mounting holes located on the bottom of the body (See Figs. 3–9 , pgs. 16–22).
9. Connect the inlet of the flow sensor or control module to the gas source and the outlet to your process connection using appropriate tubing and connectors. The direction of gas flow is indicated on the module.
10. For connection of sensors or control modules with Swagelok® compression fittings:

    Note: Tube ends must be clean. Remove all filings, chips and grit before attachment. Burrs must be removed from inside and outside of tubing for proper entry into fitting and to prevent system contamination and/or restricted flow.

    a. Insert the tube into the compression connection until the tube bottoms out in the connection body.
    b. Care should be exercised to insure the tube is properly aligned with the connection.
    c. Advance the nut to a finger-tight position.
    d. Scribe both the nut and body hex.
    e. While holding a back-up wrench stationary on the connection body, tighten the nut 1¼ turn past the finger-tight position.

11. For connection of sensors or control modules with VCR® male vacuum-type face seal connections:

    Note: To insure the highest performance the protector caps should remain in place on the face seal bead during handling, utilize back up wrenches during assembly and use care to install in the same plane to prevent misalignment and galling.

    a. Remove the protector cap from the face seal beads on the connection.

    b. Place the metal face seal gasket into the female nut where applicable.

    c. Assemble components and snug finger tight.

    d. Scribe both the nut and body hex.

    e. While holding a back-up wrench stationary, tighten the female nut ⅛ turn past finger tight when using 316 Stainless Steel or nickel gaskets.

12. Leak test all connections after installation at the maximum system operating pressure using a clean, dry inert gas (e.g. Nitrogen) and a suitable leak detection fluid such as Snoop®.

13. A 25-foot long interconnecting cable is provided with each Flow Sensor or Control Module. The cable has a 15-pin Type D subminiature connector on each end. Plug the female connector into the connector on the Flow Sensor or Control Module and tighten the retaining screws. Plug the male connector into the "Channel" connector on the back panel of the operator console. Tighten the two securing screws on the connector. Refer to the instructions shipped with your Operator Console and complete the installation as directed.

OPERATION

WARNING: Never operate the mass flow sensor or control module under any circumstances if it is leaking or otherwise malfunctioning. DO NOT repair any leaks while system is under pressure. Damage to equipment and/or injury to personnel may result.

Operation of mass flow control and blending systems using Advanced Mass Flow Sensors and Control Modules is covered in the instructions for the Operator Console, a copy of which accompanied your equipment. Additional copies may be obtained from Advanced Specialty Gas Equipment.

MAINTENANCE AND REPAIRS

If a module malfunctions or a component fails, take it out of service immediately. Do not attempt to repair these modules. Repairs should be made only by Advanced Specialty Gas Equipment Corp. who has the special tools, test equipment and trained personnel required to make a safe repair. Tampering with the module voids the warranty. Contact your Advanced Specialty Gas Equipment Distributor to arrange for repair.

Repairs to modules done after the initial warranty period has expired are chargeable to the customer. Upon receipt at the factory, the module will be inspected and you will be contacted with a repair cost estimate. No item will be repaired until approval is received. There will be an evaluation charge assessed for equipment not repaired. All repairs should be arranged through your Advanced Specialty Gas Equipment Distributor.

Note: All equipment being returned for service must be cleaned and decontaminated in accordance with good industrial practices and returned in compliance with OSHA and DOT regulations. A signed "Decontamination Statement Form" supplied by Advanced Specialty Gas Equipment, must be attached to outside of shipping container for unit to be accepted for repair.

SPECIFICATIONS

Model FRM Flow Sensors

Operating Pressure Range	
1FRM–17FRM	570 torr to 4500 psig
18FRM–24FRM	570 torr to 1500 psig
Operating Temp. Range	40°F to 150°F
Maximum Flow Capacity	Call your Adv. Distributor
Minimum Flow Capacity	2% of max. flow capacity
Accuracy	±1% of full scale at calibrated conditions
Repeatability	±0.25% of full scale
Response Time	3 seconds max[1]
Pressure Drop	10" water column at max. flow
Mounting Attitude Sensitivity	±0.5% of Full Scale[2]
Inlet and Outlet Connections	
1FRM–17FRM	¼" Swagelok[3]
18FRM–19FRM	⅜" Swagelok[3]
20FRM–24FRM	½" NPT Female[4]
Dimensions	
1FRM–17FRM	See Figure 3
18FRM–19FRM	See Figure 4
20FRM–24FRM	See Figure 5
Weight (approximate)	
1FRM–19FRM	2 lbs.
20FRM–24FRM	13 lbs.
Electrical Connection	15-pin Type D male connector
Power Requirements	+15 VDC at 35mA –15 VDC at 35mA
Flow Output Signal	
1FRM–19FRM	0–5 VDC into 3000 ohm (or greater) load
20–24FRM	0–5 VDC into 2000 ohm (or greater) load

1. To within 2% of set points.
2. Maximum deviation from stated accuracy specification.
3. VCR connections are available on special order.
4. 1" or 1½" NPT F or ½", ¾" or 1" Swagelok Connections available on special order.

SPECIFICATIONS (Continued)

Model FRC and HPC Mass Flow Control Modules

Operating Pressure Range	
1FRC–24FRC	570 torr to 1500 psig
6HPC-16HPC	570 torr to 4500 psig
Operating Temperature Range	40°F to 150°F
Maximum Flow Capacity	Call your Adv. Distributor
Minimum Flow Capacity	2% of max. flow capacity
Accuracy	±1% of full scale at calibrated conditions
Repeatability	
1FRC–24FRC	± 0.25% of reading
6HPC-16HPC	± 0.25% of full scale
Response Time	
1FRC–24FRC	3 seconds max.[1]
6HPC-16HPC	15 seconds max.[1]
Maximum Pressure Drop	
1FRC–19FRC, 6HPC-16HPC	50 psi differential
20FRC–24FRC	290 psi differential
Minimum Pressure Drop	
1FRC–17FRC, 6HPC-16HPC	5 psi differential
18FRC–19FRC	10 psi differential
20FRC–24FRC	22 psi differential
Mounting Attitude Sensitivity	
1FRC–24FRC	± 0.5% full scale[2]
6HPC-16HPC	± 0.25% full scale[2]
Inlet and Outlet Connections	
1FRC–17FRC, 6HPC-16HPC	¼" Swagelok[3]
18FRC–19FRC	⅜" Swagelok[3]
20FRC–24FRC	½" NPT Female[4]
Leak Integrity	1 x 10^{-9} atm. scc/sec Helium
Dimensions	
1FRC–17FRC	See Figure 6
18FRC–19FRC	See Figure 7
20FRC–24FRC	See Figure 8
6HPC-16HPC	See Figure 9

Weight (approximate)	
1FRC–17FRC	2.5 lbs.
18FRC–19FRC	3 lbs.
20FRC–24FRC	15 lbs.
6HPC-16HPC	1.5 lbs.
Electrical Connection	15-pin Type D male connector
Power Requirements	
1FRC–17FRC, 20FRC–24FRC	+15 VDC at 35mA –15 VDC at 180mA
18FRC–19FRC	+15 VDC at 350mA –15 VDC at 350mA
6HPC-16HPC	+15 VDC at 215mA –15 VDC at 15mA
Flow Output Signal	
1FRC–24FRC	0–5 VDC into 2000 ohm (or greater) load
6HPC-16HPC	0–5 VDC into 1000 ohm (or greater) load
Command Signal	0–5 VDC

1. To within 2% of set point. Response time specification shown is with "soft start" feature disabled. With soft start enabled, response time will increase by a factor of approximately 4 to 5 times stated specification. Modules are shipped with this feature disabled.
2. Maximum deviation from stated accuracy specification.
3. VCR connections are available on special order.
4. 1" or 1½" NPT F or ½", ¾" or 1" Swagelok Connections available on special order.

MATERIALS OF CONSTRUCTION

Metal Parts Exposed to Gas	Type 316 Stainless Steel
Seals	Viton (Buna-N or Kalrez available on special order)

TECHNICAL APPENDIX

This section contains reference information about Advanced's Mass Flow Sensors and Control Modules. Included here are: Instructions on the Soft Start Feature, dimensional drawings, wiring diagrams, Contamination Control Procedures and directions for using conversion factors for other gases not used in calibration.

Soft Start Feature

Models FRC and HPC Mass Flow Control Modules have a user-selectable "soft-start" feature that provides a flow ramping function which slows down the introduction of process gas for those processes which cannot tolerate rapid flow transition or flow "overshoot". Figure 1 compares response times with and without soft start enabled. Flow Control Modules are shipped with soft start disabled. To enable soft start feature, refer to the instructions on page 14.

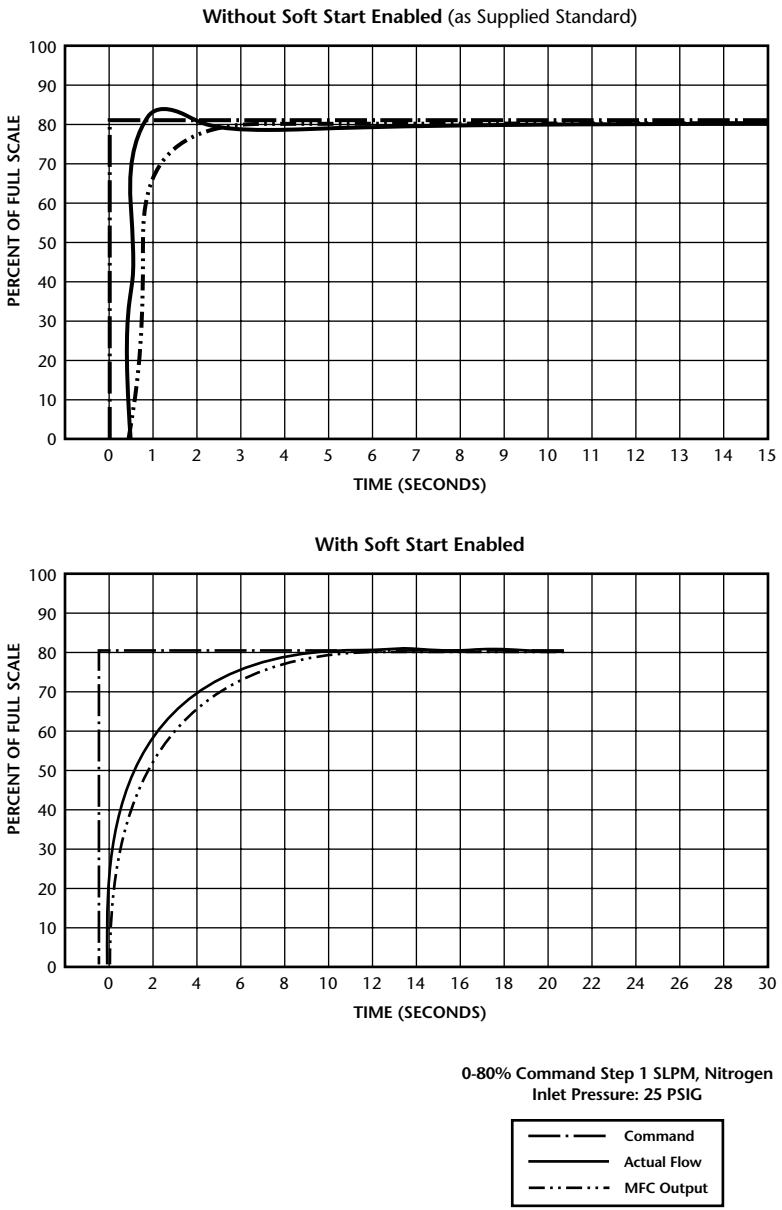


Figure 1 – Response Comparison of Model FRC With and Without Soft Start Feature Enabled

ENABLING SOFT START FEATURE

Model FRC (Fig. 2, see pg. 15)

CAUTION: These instruments contain electronic components that are susceptible to damage by static electricity. Proper handling procedures must be observed during the removal, installation or other handling of internal circuit boards or devices.

1. Power to unit must be removed.
2. Personnel must be grounded, via a wrist strap or other safe, suitable means before device is adjusted.
3. Remove the black metal cover on the Model FRC by removing the three Phillips head screws near the base of the black metal cover and loosen the top hex head locking screws, used to secure the interconnecting cable, with a 3/16 inch open-end wrench.
4. Lift the black metal cover up exposing the printed circuit board component side. Locate red soft start jumper on the controller printed circuit board at J2 position.
5. Remove the red jumper block from the left hand (N) position.
6. Install the red jumper block over the right hand (SS) position.
7. Reattach the black metal cover with the three Phillips head screws and hex head locking screws.

Model HPC (Fig. 11, see pg. 24)

To enable soft start, connect a jumper between connector pin 15 and either pin 3 or pin 9 on the Model HPC Type D male connector.

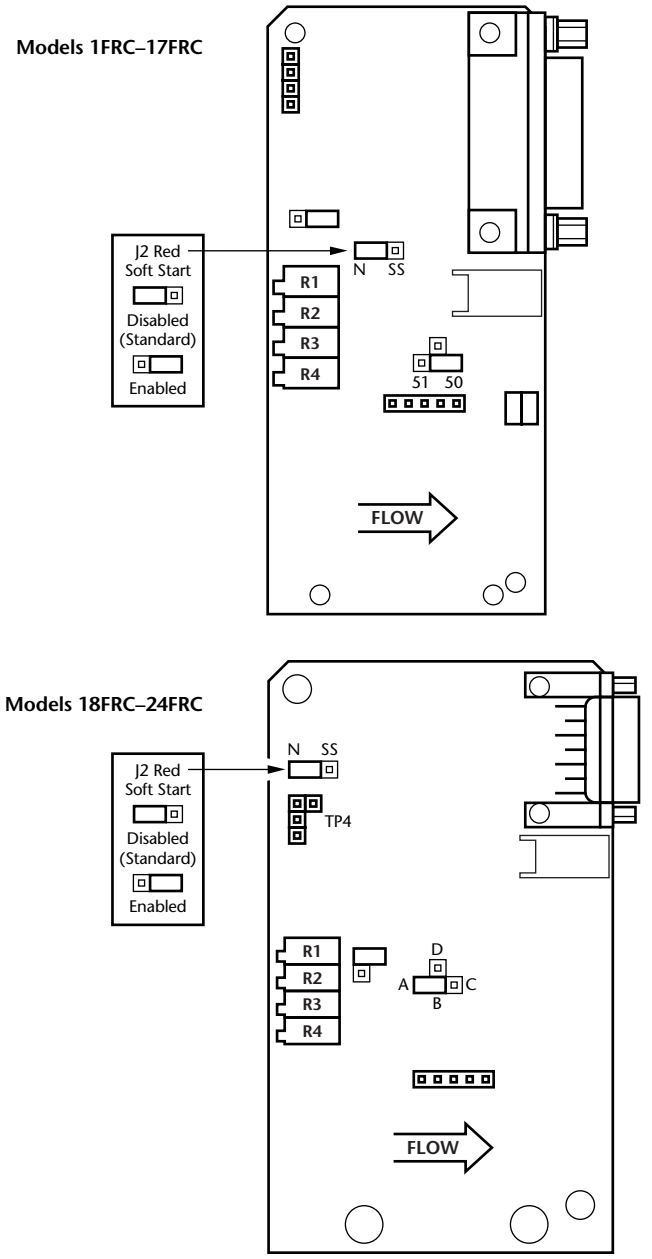
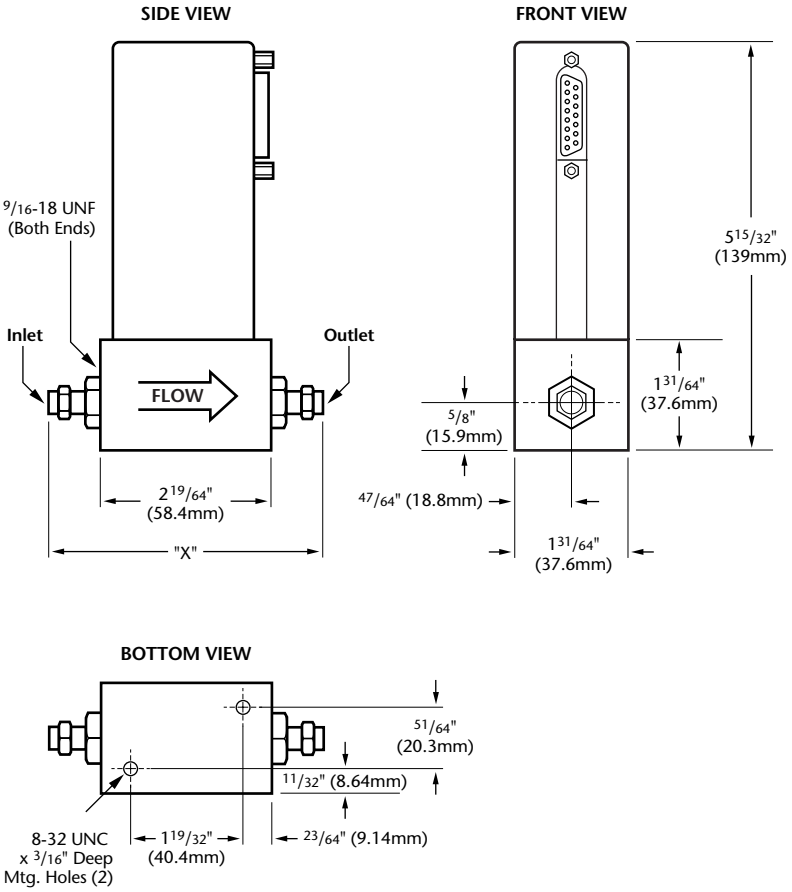
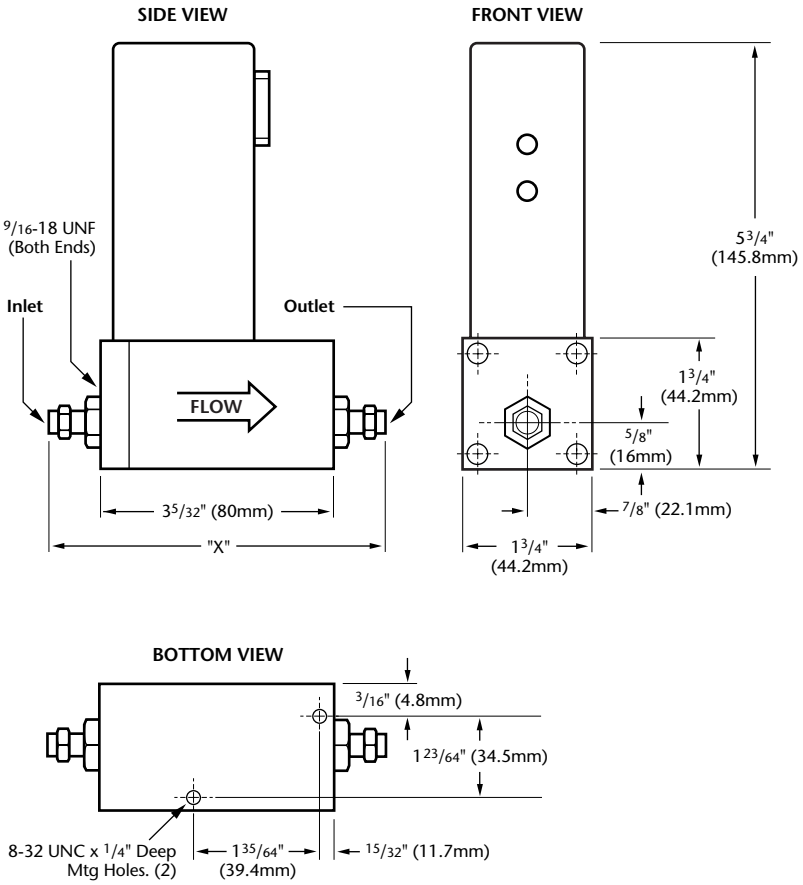


Figure 2 – Location of Soft Start Jumpers on FRC Model PC Boards



Connection	"X" Dimension
1/4" Compression Fitting	4 5/16" (109.7mm)
1/4" Tube VCR	4 3/16" (106.2mm)
3/8" Compression Fitting	4 7/16" (112.8mm)

Figure 3 – Dimensions for Models 1FRM – 17FRM



Connection	"X" Dimension
1/4" Compression Fitting	5 5/32" (131mm)
1/4" Tube VCR	5 1/32" (128mm)
3/8" Compression Fitting	5 9/32" (134mm)
3/8" or 1/2" Tube VCR	5 5/16" (135mm)

Figure 4 – Dimensions for Models 18FRM – 19FRM

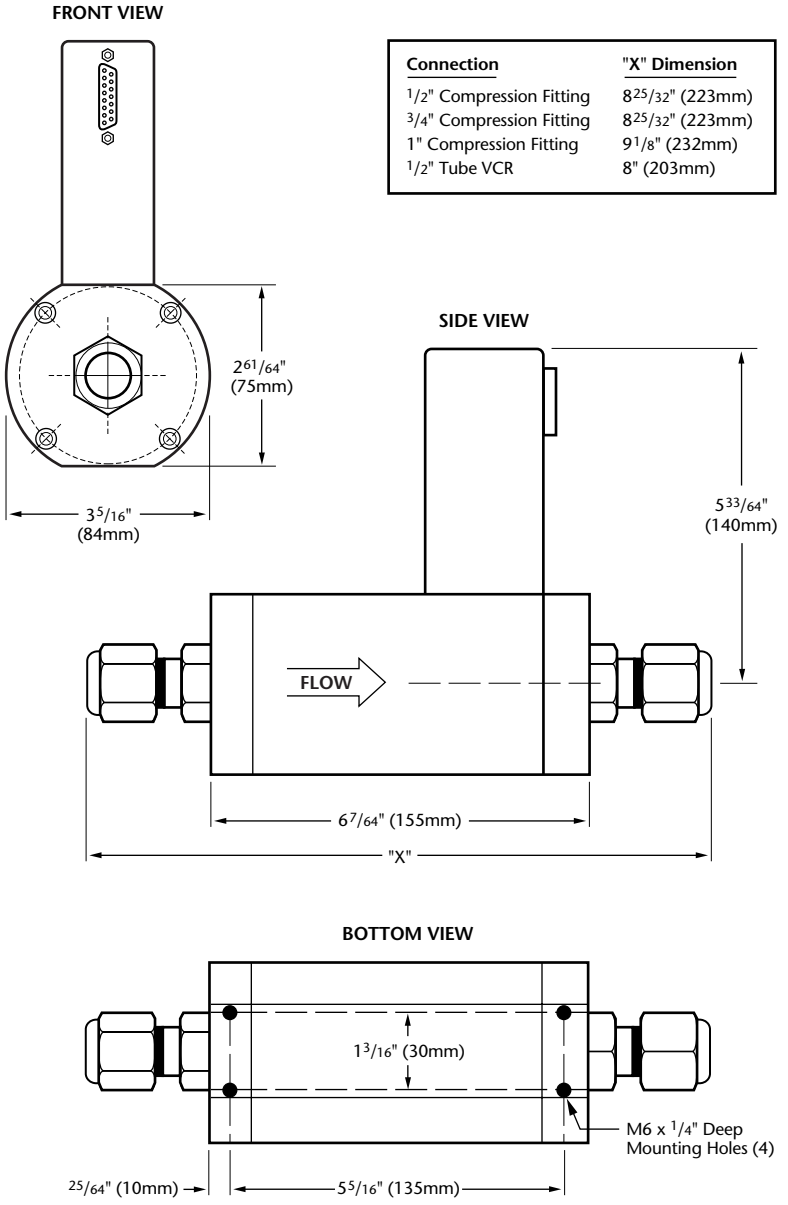
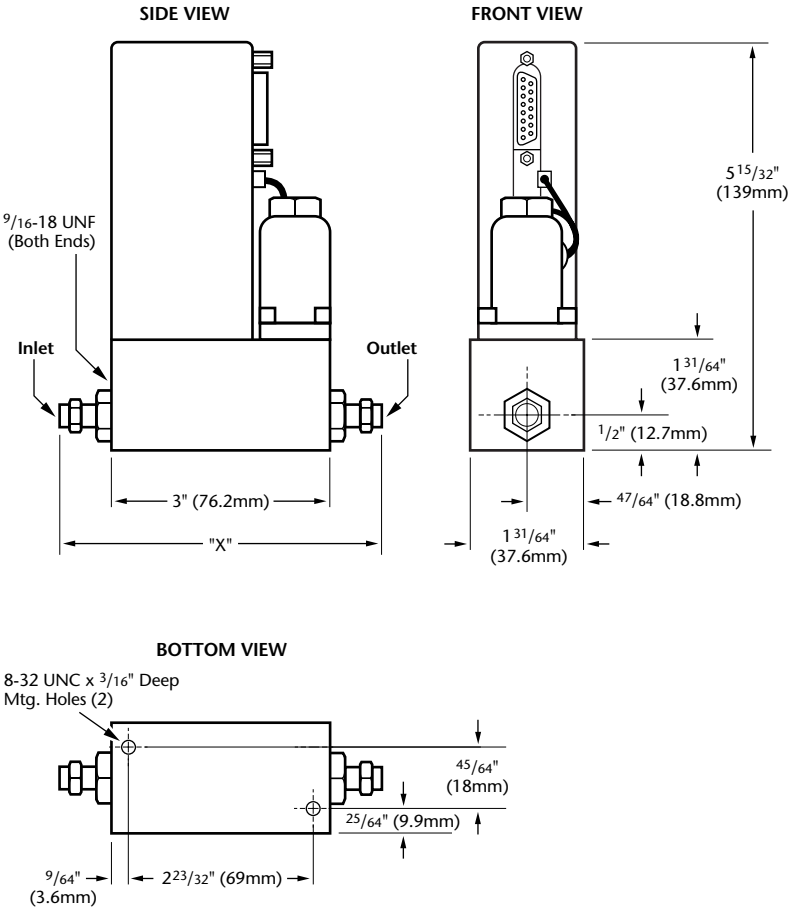
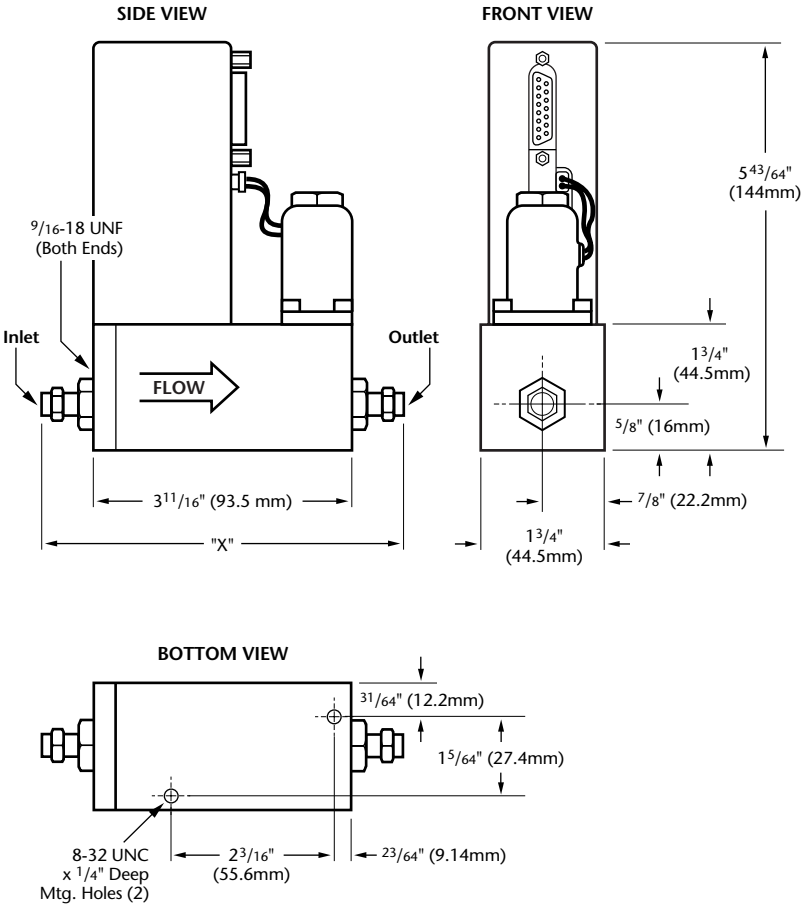


Figure 5 – Dimensions for Models 20FRM – 24FRM



Connection	"X" Dimension
1/4" Compression Fitting	5 1/64" (127.5mm)
1/4" Tube VCR	4 7/8" (124mm)
3/8" Compression Fitting	5 9/64" (130.5mm)

Figure 6 – Dimensions for Models 1FRC – 17FRC



Connection	"X" Dimension
1/4" Compression Fitting	5 45/64" (145mm)
1/4" Tube VCR	5 35/64" (141mm)
3/8" Compression Fitting	5 53/64" (148mm)

Figure 7 – Dimensions for Models 18FRC – 19FRC

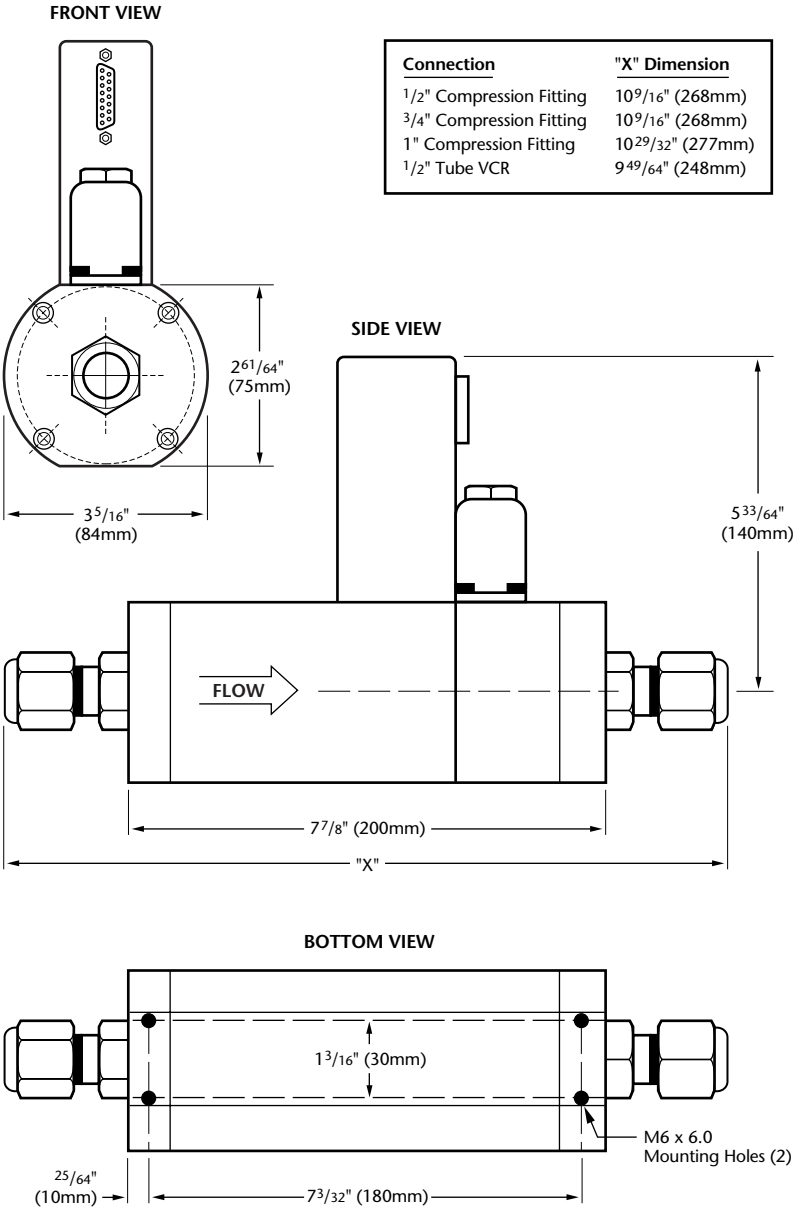
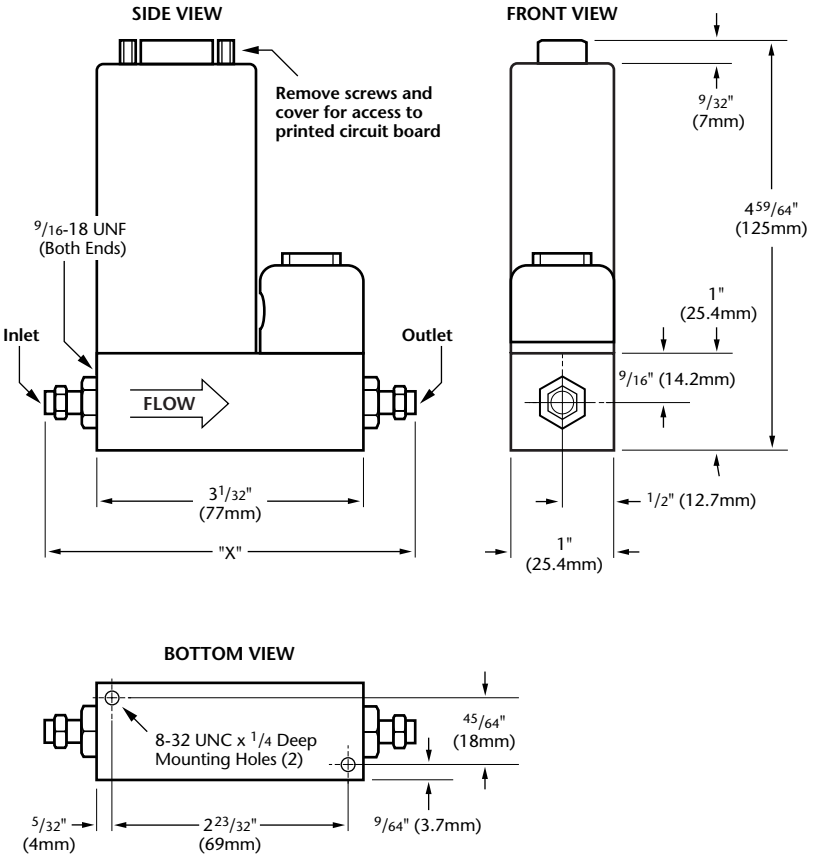


Figure 8 – Dimensions for Models 20FRC – 24FRC



Connection	"X" Dimension
1/4" Compression Fitting	5 1/32" (128mm)
1/4" Tube VCR	4 7/8" (124mm)

Figure 9 – Dimensions for HPC Models

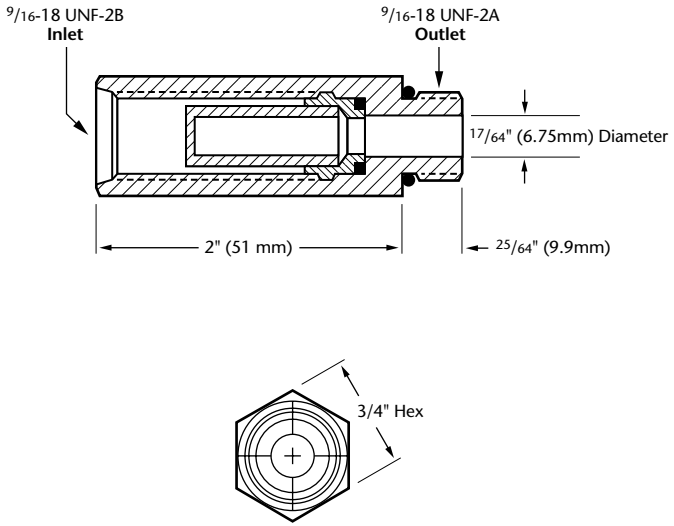
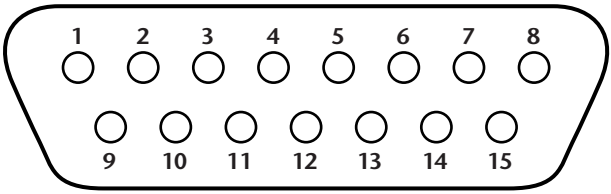


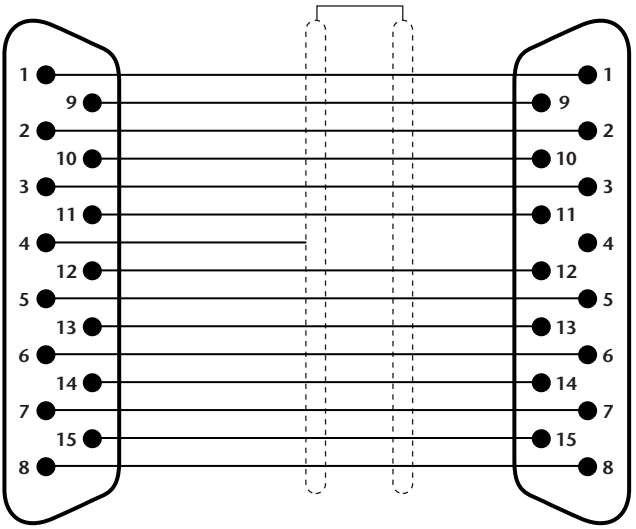
Figure 10 – Dimensions for FM4800 Series Filters



Pin No.	Function
1.	Cmd. Common (Command Pot "CCW")*
2.	Flow Signal Output (0–5 Vdc full scale)
3.	Supply Common
4.	Valve Off *
5.	+15 Vdc Supply
6.	-15 Vdc Supply
7.	Valve Test Point/Purge*
8.	0–5 Vdc Set Signal (Command)*
9.	Supply Voltage Common
10.	0–5 Volt Signal Return Common
11.	+5 Volt Reference Output (Command Pot "CW")*
12.	Valve Override*
13.	Not Used (+15 Vdc input\valve – Model HPC only)
14.	Chassis Ground
15.	Soft Start (Model HPC only)

* This connection is available for use on control modules only

Figure 11 – Model FRM Mass Flow Sensor,
Model FRC and HPC Mass Flow Control Module Connector
(15-Pin Subminiature Type D Male) wiring data.



Type D Female Connector **Type D Male Connector**

Pin No.	Function
1.	Not Used
2.	Flow Signal Output (0–5 Vdc full scale)
3.	Supply Common
4.	Shield Common
5.	+15 Vdc Supply
6.	-15 Vdc Supply
7.	Not Used
8.	0–5 Vdc Set Signal (Command)*
9.	Supply Voltage Common
10.	0–5 Volt Signal Return Common
11.	Not Used
12.	Not Used
13.	Not Used
14.	Chassis Ground
15.	Not Used

* This connection is used with control modules only

Figure 12 – Wiring Diagram for Mass Flow Sensor and Control Module Cable.

MASS FLOW CONTAMINATION CONTROL

Principle of Operation

A basic knowledge of Mass Flow Controller (MFC) operation is necessary to better understand the effects of contamination on the controller. Figure 13 shows a cross section view of a typical MFC. Flow enters the inlet fitting and passes through the restrictor (bypass element). This element produces a pressure drop which forces a percentage of the total flow through the sensor tube. Very small passages in the bypass element are required to insure linear pressure drop with flowrate, thus maintaining a constant ratio of the flow through the bypass element to the flow through the sensor tube (bypass ratio). The sensor tube always measures approximately the same full scale flowrate of the entire MFC. By varying the bypass element's passage dimensions and exposed area, the bypass ratio and thus the full-scale flowrate of the MFC is varied.

The flow through the sensor tube is measured thermodynamically. Heat is applied to the middle of the tube and the temperature is measured with resistance wire sensors located upstream and downstream of the heating winding. The difference in heat transferred to the upstream sensor relative to the downstream sensor is proportional to the mass flowrate. Signal conditioning electronics measure this difference and generate a 0–5 volt output signal. Integral control electronics compare this output signal to the setpoint, supplied externally, and open or close the control valve accordingly. The control valve contains a magnetically actuated plunger which moves the valve seat up and down relative to the orifice. The inside diameter of the orifice determines the maximum amount of flow which can be passed for a given inlet pressure, pressure drop and gas density.

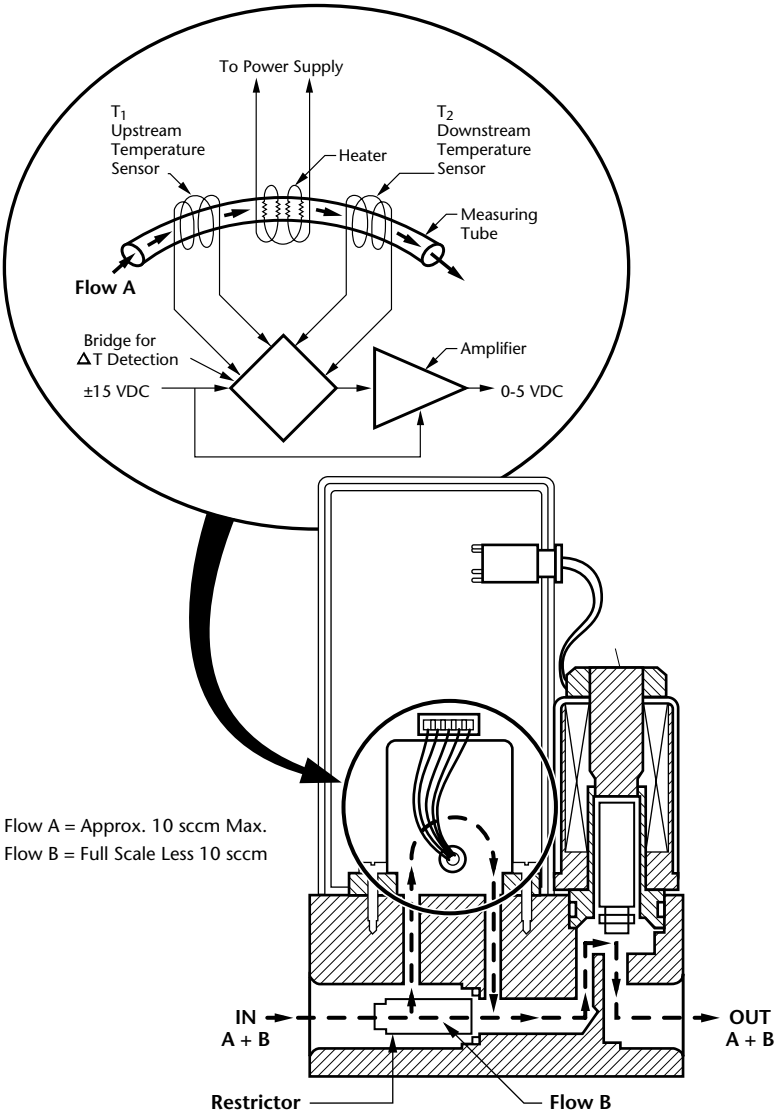


Figure 13 – Mass Flow Controller Operational Diagram

CONTAMINATION AND ITS EFFECT ON MFC PERFORMANCE

CAUTION: The following contamination control procedures should be followed only if they comply with your company's established safety practices.

Contamination within an MFC comes from three main sources:

1. Foreign materials in the flow stream
2. Condensation of the process gas.
3. Moisture and Oxygen combining with a reactive gas to form precipitates

These contaminates can clog the small passages in the MFC causing shifts in the calibration, loss of capacity or even a complete failure.

Contamination of the sensor tube causes less flow in the sensor for a given flow through the MFC. The control electronics respond to the corresponding decrease in output signal by further opening the control valve and thus increasing the flowrate through the MFC. Contamination of the bypass element has the reverse effect. For a given flowrate, more flow is diverted through the sensor tube as the element clogs. This increases the sensor output. The control electronics respond by further closing the valve thus reducing the flowrate through the entire MFC. The bypass element generally clogs at a faster rate than the sensor tube does in the presence of contaminants, since it has smaller passages. This is usually safer because the flowrate through the MFC gradually decreases. If the reverse were true, the MFC could increase the flowrate past the capacity of the downstream effluent handlers creating a hazardous situation.

If the valve orifice becomes contaminated and begins decreasing the flow, the control electronics automatically respond to the decrease by opening the valve further to maintain the desired flowrate. If the clogging is severe, the valve is fully opened, insufficient flow is passed and the signal output from the MFC is significantly less than the set-point.

Summary

Problem	Cause
Increase in overall flowrate and the setpoint matches the output signal	Contaminated Sensor
Decrease in overall flowrate and the setpoint matches the output signal	Contaminated Bypass Element
Decrease in overall flowrate and the output signal is significantly less than the setpoint	Contaminated orifice or insufficient inlet pressure or pressure drop

PREVENTING CONTAMINATION

As previously mentioned, there are three main causes of contamination.

1. Foreign materials are generally not a problem in most processes if adequate start-up cleaning is performed and the MFC upstream filter requirements are fulfilled. Start-up cleaning must remove all weld debris, tube scale and other loose particles before the MFC is installed. A filter such as the FM4800 Series Inlet Filter upstream of the MFC is recommended. The filter with the greatest filtration (smallest micron size) that will produce less than a 1 psi pressure drop at the maximum gas flow and minimum inlet pressure should be selected.

   The following table lists the recommended FM4800 Series filter for use with Nitrogen at 25 psi inlet pressure with maximum full scale flowrates.

MFC Full Scale Flowrate (slpm)	Filter Part Number	Nominal Filtration Rating (Micron)
Up to 1	FM4800	0.5
1 to 10	FM4802	2
10 to 15	FM4805	5
15 to 25	FM4810	10
25 to 80	FM4840	40

2. Condensation of the process gas generally occurs when a low vapor pressure liquid, BCl3 for example, is allowed to decrease in temperature in the process manifold. This can be prevented by cooling the gas cylinder 2 or 3 degrees Centigrade below ambient (chilled water circulated around the cylinder) and heating the MFC 10 to 20 degrees Centigrade above ambient with a resistant heater. Heating the process lines is not always recommended because the process may condense in the MFC even if the MFC is only a few degrees cooler than the lines. If the MFC does become clogged due to condensed process gas, evacuating the MFC and piping with a vacuum pump helps to evaporate the condensed gas. Heat applied to the lines and MFC during this "pumpdown" aids in the evaporation process.

   CAUTION: Do not exceed the temperature rating of the MFC or other gas manifold elements. Heating the process gas may increase the pressure beyond the limits of the process piping.

3. Moisture and oxygen present the biggest source of contamination to the MFC. By using the highest grade of process gases, the contamination caused by any impurities the container may contain, is minimized.

The most common source of moisture and oxygen is in the air which can enter the system in primarily four ways:

- Leaks in the process manifold
- During gas cylinder changes
- While servicing the system
- Air backflowing into the MFC when the chamber is opened between process runs

Leaks – Even though the system may be under positive pressure, leaks in the process manifold allow air to exchange with the process gas (osmotic action). Leak detection with a suitable helium mass spectrometer, pressure decay method or liquid soap solution (such as Snoop) is needed before initial start-up and after any pressure-bound seal has been broken for servicing.

Cylinder Changes – Improper procedures during cylinder changes can result in a significant amount of air entering the system and mixing with the process gas. Purge panels or cross purge assemblies (such as a Model SG3897 or Model SG3898) using dry nitrogen should be installed on all reactive gas lines and the following purge procedure should be followed for all cylinder changes:

a. Shut-off the reactive gas cylinder valve and the blocking (isolation) valve located upstream of the cylinder regulator.

b. Purge and vent (cycle-purge) with 8 to 10 cycles as follows:
   1. Open the nitrogen purge source valve to pressurize system (maximum process pressure is recommended), then close it.
   2. Open the system vent valve to vent system pressure to 0 psig, then close it.

c. Replace the reactive gas cylinder.

d. Open the nitrogen purge source valve to pressurize system (maximum process pressure is recommended), then close it.

e. Leak check the gas cylinder connection with either a soap solution, such as Snoop or a gas leak detector.

f. Purge and vent with 8 to 10 cycles as described in step b to remove entrapped air that has entered the system while changing the cylinder.

g. Slowly open the gas cylinder valve and blocking (isolation) valve upstream of the regulator.

Servicing the Process Manifold – To minimize contamination during servicing, four basic rules must be followed:

a. Cycle-purge the process manifold (see "Purging" Section) with an inert gas before and after servicing.

b. Maintain 5 to 10 psig pressure of inert gas while removing and installing any element in the manifold.

c. Cap any lines that remain open for more than a few seconds, again under a positive inert gas pressure.

d. Leak check all seals affected in the servicing.

PURGING

Purging the process lines is required after the lines have been running a reactive gas before exposing the lines to air. Purging is also required after the lines have been exposed to air before running a reactive gas. Purging is not recommended between runs unless the system is not operated for more than 12 hours. For shorter period of non-use (1 shift), leave the manifold pressurized with the reactive gas and shut off the gas at the cylinder valve.

Purge Procedure

Cycle-Purging – Using a dry inert gas (usually nitrogen), raise the line pressure to a minimum of 30 psig (maximum process pressure is recommended) and then vent (exhaust) it to 0 psig. Repeat this cycle a minimum of 8–10 times. The repeated increase and decrease in pressure combined with the flowing nitrogen assures that all dead space is adequately purged. This method can be combined with sustained periods of high vacuum for 12 to 48 hours to further insure a "clean" system.

USE OF CONVERSION FACTORS

If a Mass Flow Sensor or Control Module is operated on a gas other than the gas with which it was calibrated, a scale shift will occur in the relationship between the output signal and the mass flowrate. This is due to the difference in heat capacities between the two gases. The scale shift can be approximated by using the ratio of the molar specific heat of the two gases, or sensor conversion factor. Table A-1 is a list of sensor conversion factors. The relationship is explained below.

$$\textbf{Output Reading} \times \frac{\textbf{New Gas Sensor Conversion Factor}}{\textbf{Calibration Gas Sensor Conversion Factor}} = \textbf{Corrected Flow Reading} \text{ (Actual Gas Flowrate)}$$

EXAMPLE: To calculate the corrected flow reading for Carbon Dioxide at the following conditions:

- The control module is calibrated for nitrogen
- The desired gas is carbon dioxide
- The output reading is 75 sccm when carbon dioxide is flowing

$$\textbf{75 sccm} \text{ Output Reading} \times \frac{\textbf{0.78} \text{ New Gas Factor}}{\textbf{1.00} \text{ Calibration Gas Factor}} = \textbf{58.50 sccm} \text{ Corrected Flow Reading}$$

It is generally accepted that the mass flowrate derived from this equation is accurate only to ±5%. The sensor conversion factors in Table A-1 are calculated based on a gas temperature of 21°C and a pressure of one atmosphere. The specific heats of most gases are not strongly pressure and temperature dependent; however, conditions that vary widely from the reference conditions may cause additional error due to the change in specific heat from temperature and/or pressure.

Table A-1. Conversion Factors

Gas	Symbol	Specific Heat Cp at 25°C and 1 Atm J/mole K	Sensor Conv. Factor*	Specific Gravity (SG)
Acetylene	C_2H_2	44.308	0.66	0.908
Air	——	29.130	1.00	1.000
Allene	C_3H_4	60.840	0.48	1.385
Ammonia	NH_3	36.953	0.79	0.588
Argon	Ar	20.830	1.40	1.376
Arsine	AsH_3	38.522	0.76	2.660
Boron Trichloride	BCl_3	65.655	0.44	4.028
Boron Trifluoride	BF_3	50.242	0.58	2.375
Bromine Pentafluoride	BrF_5	101.400	0.29	6.037
Bromine Trifluoride	BrF_3	66.650	0.44	4.726
Butane	C_4H_{10}	100.365	0.29	2.076
Butene	C_4H_8	87.329	0.33	1.985
Carbon Dioxide	CO_2	37.564	0.78	1.518
Carbon Monoxide	CO	29.204	0.99	0.964
Carbon Tetrachloride	CCl_4	84.438	0.35	5.304
Carbonyl Fluoride	COF_2	108.500	0.27	2.290
Carbonyl Sulfide	COS	42.752	0.68	2.000
Carbon Tetrafluoride	CF_4	61.270	0.48	3.021
Chlorine	Cl_2	35.317	0.83	2.462
Chlorform	$CHCl_3$	65.756	0.44	4.117
Chlorine Trifluoride	ClF_3	67.117	0.43	3.165
Cyanogen	$(CN)_2$	38.338	0.50	1.798
Cyclopropane	C_3H_6	57.559	0.51	1.445
Deuterium	D_2	29.204	1.00	0.138
Diborane	B_2H_6	53.346	0.55	0.964
Dichlorosilane	SiH_2Cl_2	65.730	0.44	3.471
Dimethylamine	$(CH_3)_2NH$	43.428	0.67	1.545
Dimethyl Ether	$(CH_3)_2O$	49.400	0.59	1.583
Ethane	C_2H_6	55.346	0.55	1.038
Ethyl Chloride	C_2H_5Cl	102.090	0.29	2.217
Ethylene	C_2H_4	43.428	0.62	0.964
Ethylene Oxide	C_2H_4O	49.400	0.59	1.514
Fluorine	F_2	31.449	0.93	1.310
Fluoroform	CHF_3	51.557	0.57	2.418
Germane	GeH_4	45.020	0.63	2.645
Halocarbon 11	CCl_3F	77.613	0.38	4.858
Halocarbon 12	CCl_2F_2	74.469	0.39	4.248
Halocarbon 13	$CClF_3$	67.655	0.43	3.799
Halocarbon 13B1	$CBrF_3$	70.590	0.41	5.117
Halocarbon 14	CF_4	61.271	0.48	3.021
Halocarbon 21	$CHCl_2F$	60.994	0.46	3.799
Halocarbon 23	CHF_3	51.560	0.57	2.418
Halocarbon 113	CCl_2FCClF_2	126.100	0.23	6.126

Table A-1. Conversion Factors (Continued)

Gas	Symbol	Specific Heat Cp at 25°C and 1 Atm J/mole K	Sensor Conv. Factor*	Specific Gravity (SG)
Halocarbon 114	$C_4Cl_2F_4$	112.992	0.26	5.811
Halocarbon 115	C_2ClF_5	105.860	0.24	5.784
Halocarbon 116	C_2F_6	126.650	0.23	4.748
Helium	He	20.967	1.39	0.138
Hydrogen	H_2	28.851	1.01	0.070
Hydrogen Bromide	HBr	29.791	0.98	2.769
Hydrogen Chloride (dry)	HCl	29.576	0.99	1.254
Hydrogen Fluoride	HF	16.155	1.00	0.689
Hydrogen Iodine	HI	30.497	0.96	4.431
Hydrogen Selenide	H_2Se	34.752	0.84	2.769
Hydrogen Sulfide	H_2S	34.218	0.85	1.184
Isobutane	$CH(CH_3)_3$	94.163	0.31	2.045
Isobutylene	C_4H_8	86.883	0.34	1.985
Krypton	Kr	21.037	1.39	2.883
Methane	CH_4	35.941	0.81	0.561
Methyl Bromide	CH_3Br	45.020	0.65	3.244
Methyl Chloride	CH_3Cl	42.326	0.69	1.750
Methyl Fluoride	CH_3F	38.171	0.76	1.171
Methyl Mercaptan	CH_3SH	49.491	0.59	1.663
Neon	Ne	20.786	1.40	0.696
Nitric Oxide	NO	29.227	1.00	1.022
Nitrogen	N_2	28.980	1.00	0.964
Nitrogen Dioxide	NO_2	36.974	0.76	2.829
Nitrogen Trioxide	N_2O_3	65.618	0.44	2.621
Nitrogen Trifluoride	NF_3	53.371	0.55	2.462
Nitrous Oxide	N_2O	38.635	0.75	1.528
Oxygen	O_2	29.427	0.99	1.098
Perchloryl Fluoride	$Cl0_3F$	64.733	0.45	3.501
Phosgene	$COCl_2$	57.693	0.51	3.411
Phosphine	PH_3	37.126	0.79	1.166
Phosphorous Pentafluoride	PF_5	—	0.35	4.289
Propane	C_3H_8	74.010	0.39	1.565
Propylene	C_3H_6	62.345	0.47	1.468
Silane	SiH_4	42.844	0.68	1.105
Silicon Tetrafluoride	SiF_4	73.492	0.40	3.595
Sulfur Dioxide	SO_2	39.884	0.73	2.253
Sulfur Hexafluoride	SF_6	97.152	0.30	5.318
Trimethylamine	$(CH_3)_3N$	91.931	0.32	2.076
Vinyl Bromide	C_2H_3Br	55.531	0.53	3.799
Vinyl Chloride	C_2H_3Cl	53.607	0.54	2.146
Vinyl Fluoride	C_2H_3F	50.459	0.58	1.583
Xenon	Xe	21.012	1.39	4.584

* Air equals 1.000 for conversion factors.

WARRANTY

Advanced Specialty Gas Equipment Corp., (the Company), warrants to the initial purchaser of each flow sensor or control module described herein, that such equipment will be free from defects in material and workmanship which result in breakdown or failure under normal use during a period of 12 months from date of shipment by the Company if used and maintained according to Advanced Specialty Gas Equipment written instructions. This warranty does not cover damage or malfunction due to corrosion. Purchaser is aware that this equipment is designed for specific applications and that using this equipment for the wrong application may damage or corrode the unit and cause personal injury. If there is any doubt about application, consult your Advanced Specialty Gas Equipment Corp. distributor.

The Company's liability under this warranty shall be limited to the repair, or at its option, replacement or refund of the purchase price, of such equipment which proves to be defective, provided; however, that this warranty shall only apply if the purchaser (1) gives the Company written notice within (10) days after discovery of such defect, (2) immediately on discovery of the claimed defect, discontinues all use of such equipment, and (3) returns such equipment freight prepaid to plant of manufacture.

THERE ARE NO EXPRESS WARRANTIES OTHER THAN THOSE SPECIFIED HEREIN. NO WARRANTIES BY ADVANCED SPECIALTY GAS EQUIPMENT CORP. (OTHER THAN WARRANTY OF TITLE AS PROVIDED IN THE UNIFORM COMMERCIAL CODE) SHALL BE IMPLIED OR OTHERWISE CREATED UNDER ANY APPLICABLE LAW, INCLUDING BUT NOT LIMITED TO WARRANTY OF MERCHANTABILITY AND WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE. No claim against the Company of any kind, whether as to equipment delivery or for nondelivery of equipment and whether or not based on contract, warranty, negligence, strict liability in tort or otherwise, shall be greater in amount than the purchase price of the equipment in respect of which such claim is made. Without limiting the generality of the foregoing, Advanced Specialty Gas Equipment Corp. shall not be liable for any special, indirect, or consequential damage, such as failure of parts resulting from corrosion.

If it is determined by Advanced Specialty Gas Equipment Corp. that the equipment is to be repaired or replaced under the terms of this warranty, the cost of returning said equipment to the initial purchaser will be paid by the Company. If, however, equipment returned to the Company in connection with a claim under this warranty is found by the Company not to be defective hereunder, then such equipment will be returned to the initial purchaser, shipping charges collect, and additionally, a service will be paid by the purchaser to the Company to cover the cost of handling and testing such equipment.

ADVANCED
Specialty Gas Equipment

241 Lackland Drive, Middlesex, NJ 08846
Phone: 732-271-9300 Fax: 732-271-1630 www.asge-online.com

Printed In U.S.A.

AI 2063
04/99