APEX

16 Series

Mass and Volumetric Flow Controllers

**Precision Gas Flow Controller
Operating Manual**

Warranty

Table of Contents	Page

Table of Contents	Page

Thank you for purchasing an Apex MC or VC Series Gas Flow Controller. Please take the time to find and read the information contained in this manual. This will help to ensure that you get the best possible service from your instrument. This manual covers the following Apex instruments:

MC Series 16 Bit Mass Gas Flow Controllers
VC Series 16 Bit Volumetric Gas Flow Controllers

Installation

Plumbing

All MC and VC Series Gas Flow Controllers are equipped with female inlet and outlet port connections. Because the flow meters set up a laminar flow condition within the flow body, no straight runs of pipe are required upstream or downstream of the controller. The inlet and outlet ports are equal in size and symmetric (in-line). The port sizes (process connections) and mechanical dimensions for different flow ranges are shown on pages 34-37.

Controllers with 10-32 ports have o-ring face seals and require no further sealant or tape. On other controllers, avoid the use of pipe dopes or sealants on the ports as these compounds can cause permanent damage to the controller should they get into the flow stream. Use of thread sealing Teflon tape is recommended to prevent leakage around the threads. When applying the tape, avoid wrapping the first thread or two to minimize the possibility of getting a piece of shredded tape into the flow stream. When changing fittings, always clean any tape or debris from the port threads.

It is also recommended that a 20 micron filter be installed upstream of controllers with full scale ranges of 1(S)LPM or less and a 50 micron filter be installed upstream of controllers with full scale ranges above 1(S)LPM.

Mounting

All MC and VC Series Gas Flow Controllers have mounting holes for convenient mounting to flat panels. The sizes and dimensions for the mounting holes are shown on pages 38-40. Position sensitivity is not generally an issue with small valve controllers. Large valve controllers are somewhat position sensitive because of the fairly massive stem assembly. It is generally recommended that they be mounted so that the valve cylinder is vertical and upright. The primary concern in mounting a large valve controller in a position other than the recommended position is the increased risk of leakage when the controller is given a zero set-point and is being held closed by the spring force.

Application

Maximum operating line pressure is 125 PSIG (862 kPa).

> **Caution:** *Exceeding the maximum specified line pressure may cause permanent damage to the solid-state differential pressure transducer.*

If the line pressure is higher than 125 PSIG (862 kPa), a pressure regulator should be used upstream from the flow meter to reduce the pressure to 125 PSIG (862 kPa) or less if possible. Many of our controllers are built after extensive consultations with the customer regarding the specific application. The result is that two controllers with the same flow range and part number may look and act quite differently depending upon the application the controller was built for. Care should be taken in moving a controller from one application to another to test for suitability in the new application. *Note that volumetric meters and controllers are not recommended for high pressure or high backpressure applications (see page 31).*

Power and Signal Connections

Power can be supplied to your MC or VC Series controller through either the power jack or the 8 pin Mini-DIN connector as shown in Figure 1. An AC to DC adapter which converts line AC power to DC voltage and current as specified below. The power jack accepts 2.1 mm female power plugs with positive centers. Cables and AC/DC adaptors may purchased from the manufacturer (see Accessories page 43) and are commonly available at local electronics suppliers. Alternatively, power can be supplied through the Mini-DIN connector as shown below:

Small Valve: If your controller utilizes a small valve (about the size of your thumb), a 12-18 Vdc (standard 68ohm valve coil) or 19-28 Vdc (optional 136ohm valve coil) power supply with a 2.1 mm female positive center plug capable of supplying 300 mA is recommended. **Note:** 4-20mA output requires at least 15 Vdc.

Large Valve: If your controller utilizes a large valve (about the size of your fist), a 24-30 Vdc power supply with a 2.1 mm female positive center plug capable of supplying at least 750mA is required.
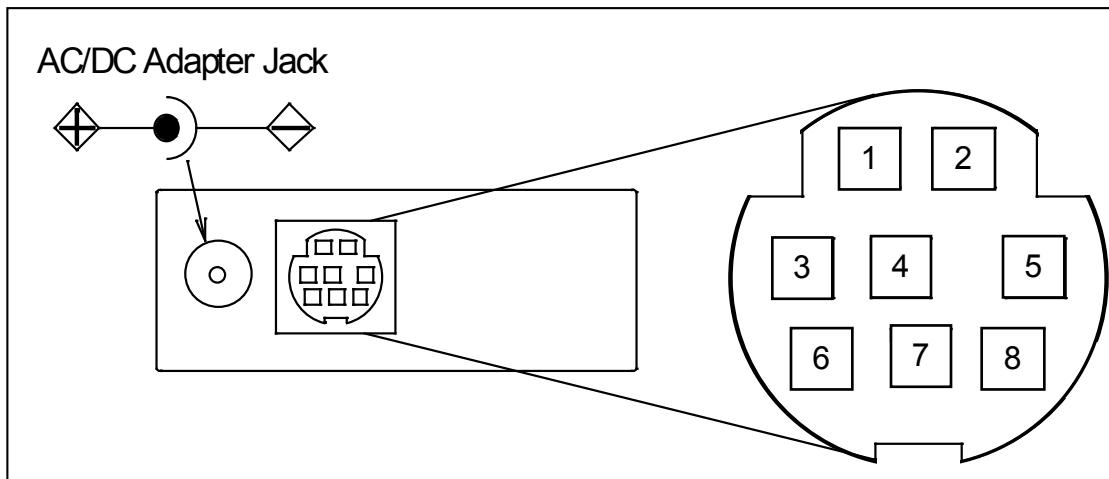
Pin	Function	Mini-DIN cable color
1	Inactive or <u>4-20mA Primary Output Signal</u>	Black
2	Static 5.12 Vdc or <u>Secondary Analog Output (4-20mA, 5Vdc, 10Vdc)</u> or <u>Basic Alarm</u>	Brown
3	RS-232 Input Signal	Red
4	Analog Input Signal	Orange
5	RS-232 Output Signal	Yellow
6	0-5 Vdc (or <u>0-10 Vdc</u>) Output Signal	Green
7	Power In (as described above)	Blue
8	Ground (common for power, communications and signals)	Purple

Note: The above pin-out is applicable to all the flow meters and controllers available with the Mini-DIN connector. The availability of different output signals depends on the flow meter options ordered. <u>**Underlined** **Items**</u> in the above table are optional configurations that are noted on the unit's calibration sheet.

Figure 1. 8 Pin Mini-DIN Connector

CAUTION: *Do not connect power to pins 1 through 6 as permanent damage can occur!*

Note: Upon initial review of the pin out diagram in Figure 1, **it is common to mistake Pin 2 (labeled 5.12 Vdc Output) as the standard 0-5 Vdc analog output signal!** In fact Pin 2 is normally a constant 5.12 Vdc that reflects the system bus voltage and can be used as a source for the set-point signal.

Input Signals

Analog Input Signal

Apply analog input to Pin 4 as shown in Figure 1.

Standard 0-5 Vdc: Unless ordered otherwise, 0-5 Vdc is the standard analog input signal. Apply the 0-5 Vdc input signal to pin 4, with common ground on pin 8. The 5.12 Vdc output on pin 2 can be wired through a 50K ohm potentiometer and back to the analog input on pin 4 to create an adjustable 0-5 Vdc input signal source as shown below.
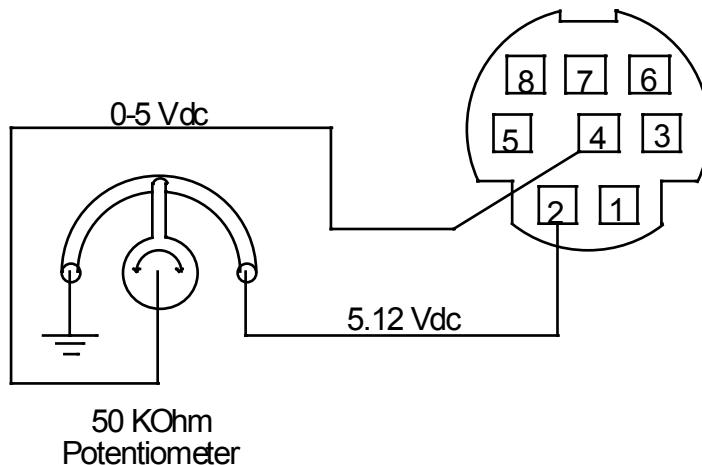
Figure 2. Simple method for providing set-point to controllers

Optional 0-10 Vdc: If specified at time of order, a 0-10 Vdc input signal can be applied to pin 4, with common ground on pin 8.

Optional 4-20 mA: If specified at time of order, a 4-20 mA input signal can be applied to pin 4, with common ground on pin 8. **Note:** 4-20mA output requires at least 15 Vdc power input.

RS-232 Digital Input Signal

If you will be using the RS-232 input signal, it is necessary to connect the RS-232 Output Signal (Pin 5), the RS-232 Input Signal (Pin 3), and Ground (Pin 8) to your computer serial port as shown in Figure 3. Adapter cables are available from the manufacturer or they can be constructed in the field with parts from an electronics supply house. In Figure 3, note that the diagrams represent the "port" side of the connections, i.e. the connector on top of the meter and the physical DB-9 serial port on the back of the computer. The cable ends will be mirror images of the diagram shown in Figure 3. (See page 20 for details on accessing RS-232 input.)

Output Signals

Note: Upon initial review of the pin out diagram in Figure 1 (page 6), **it is common to mistake Pin 2 (labeled 5.12 Vdc Output) as the standard 0-5 Vdc analog output signal!** In fact Pin 2 is normally a constant 5.12 Vdc that reflects the system bus voltage and can be used as a source for the input signal. This allows the user in the field to run this output through a 50K ohm potentiometer and back into the analog set-point pin to create a 0-5 Vdc set-point source.

RS-232 Digital Output Signal

If you will be using the RS-232 output signal, it is necessary to connect the RS-232 Output Signal (Pin 5), the RS-232 Input Signal (Pin 3), and Ground (Pin 8) to your computer serial port as shown in Figure 3. Adapter cables are available from the manufacturer or they can be constructed in the field with parts from an electronics supply house. In Figure 3, note that the diagrams represent the "port" side of the

connections, i.e. the connector on top of the meter and the physical DB-9 serial port on the back of the computer. The cable ends will be mirror images of the diagram shown in Figure 3. (See page 20 for details on accessing RS-232 output.)

Standard Voltage (0-5 Vdc) Output Signal

All MC and VC Series flow controllers have a 0-5 Vdc (optional 0-10 Vdc) output signal available on Pin 6. This is generally available in addition to other optionally ordered outputs. This voltage is usually in the range of 0.010 Vdc for zero flow and 5.0 Vdc for full-scale flow. The output voltage is linear over the entire range. Ground for this signal is common on Pin 8.

Optional 0-10 Vdc Output Signal

If your controller was ordered with a 0-10 Vdc output signal, it will be available on Pin 6. (See the Calibration Data Sheet that shipped with your controller to determine which output signals were ordered.) This voltage is usually in the range of 0.010 Vdc for zero flow and 10.0 Vdc for full-scale flow. The output voltage is linear over the entire range. Ground for this signal is common on Pin 8.

Optional Current (4-20 mA) Output Signal

If your controller was ordered with a 4-20 mA current output signal, it will be available on Pin 1. (See the Calibration Data Sheet that shipped with your controller to determine which output signals were ordered.) The current signal is 4 mA at 0 flow and 20 mA at the controller's full scale flow. The output current is linear over the entire range. Ground for this signal is common on Pin 8. (Current output units require 15-30Vdc power.)
    Note: *This is a current sourcing device. Do not attempt to connect it to "loop powered" systems.*

Optional 2nd Analog Output Signal

You may specify an optional 2nd analog output on Pin 2 at time of order. (See the Calibration Data Sheet that shipped with your controller to determine which output signals were ordered.) This output may be a 0-5 Vdc, 0-10 Vdc, or 4-20 mA analog signal that can represent any measured parameter. With this optional output, a volumetric flow controller could output the volumetric flow rate with a 0-5 Vdc signal (on pin 6) and a 4-20 mA signal (on pin 2), or a mass flow controller could output the mass flow rate (0-5 Vdc on pin 6) and the absolute pressure (0-5 Vdc on pin 2).
    Note: *This is a current sourcing device. Do not attempt to connect it to "loop powered" systems.*
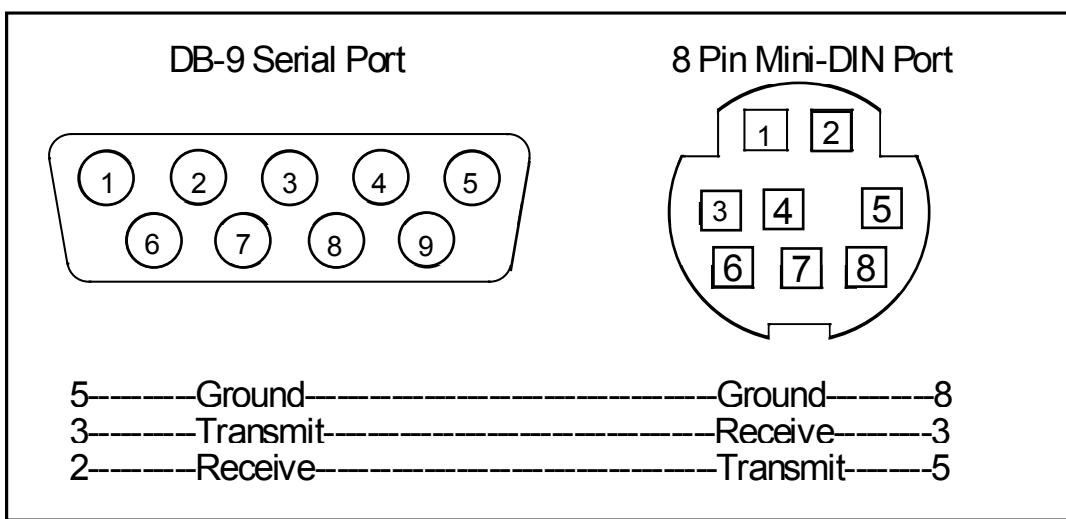
Figure 3. Mini-DIN to DB-9 Connection for RS-232 Signals
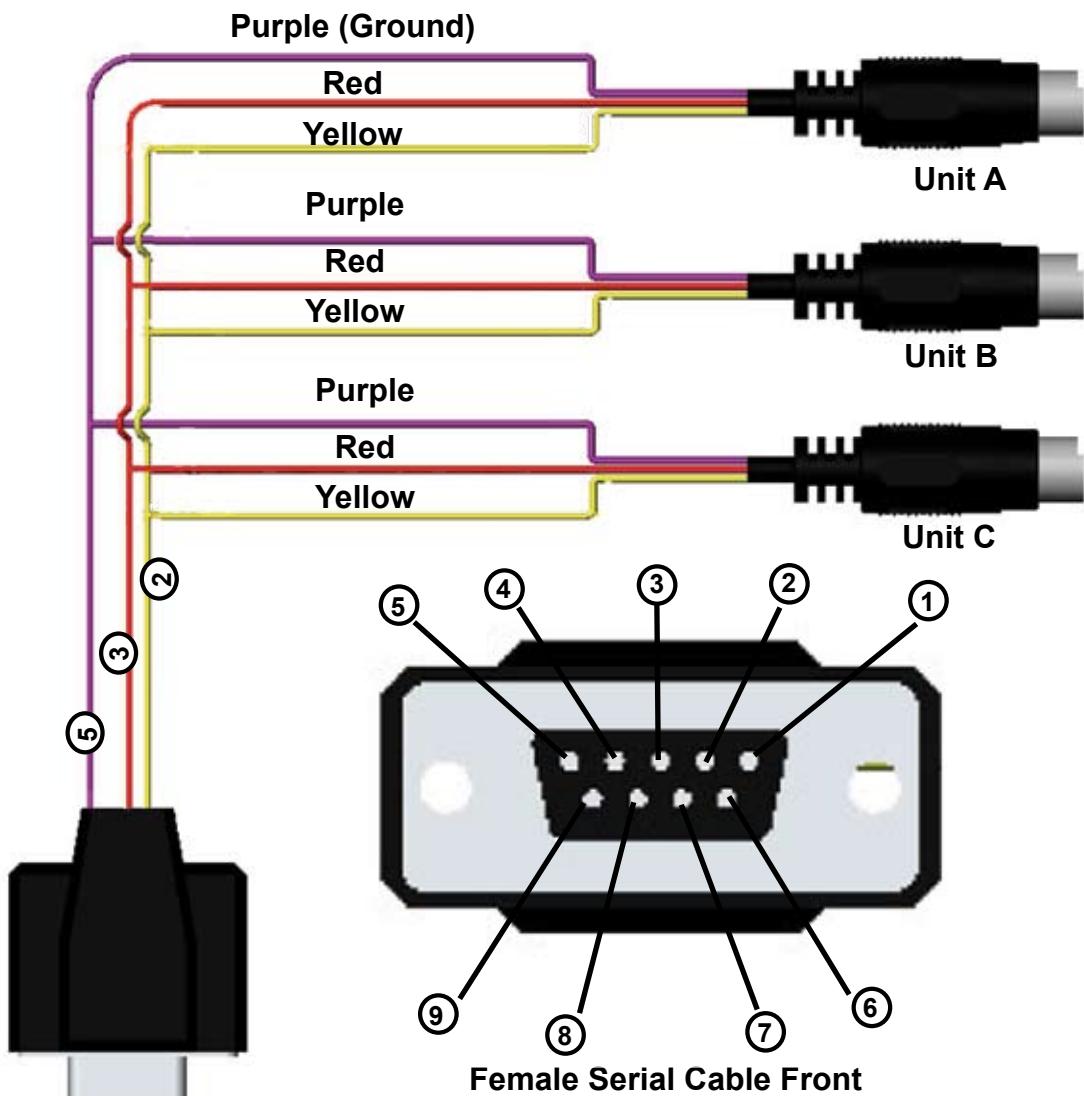
Figure 4. Typical Multiple Device (Addressable) Wiring Configuration

An optional industrial connector is also available:

Pin	Function	Cable Color
1	Power In (+)	Red
2	RS-232 Output	Blue
3	RS-232 Input Signal	White
4	Analog Input Signal	Green
5	Ground (commom for power, communications and signals)	Black
6	Signal Out (Voltage or Current as ordered)	Brown
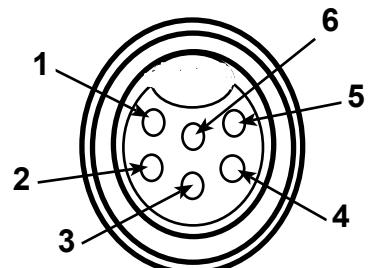
Figure 5. Optional Industrial Connector

Note: The above pin-out is applicable to all the flow meters and controllers ordered with the industrial connector. The availability of different output signals depends on the flow controller options ordered.

MC Series Mass Flow Controller Operation

The MC Series Mass Flow Controller provides a multitude of useful flow data in one simple, rugged device. The MC Series can have several screen "modes" depending on how the device is ordered. All MC Series controllers have a default Main Mode, Select Menu Mode, Control Set Up Mode, Gas Select Mode (the Gas Select Mode may not be available on controllers calibrated for a custom gas or blend), Communication Select Mode and Manufacturer Data Mode. (In addition, your device may have been ordered with a Totaliizing Mode, page 41.) The device defaults to Main Mode as soon as power is applied to the controller.

Main Mode

The main mode screen defaults on power up with the mass flow on the primary display. The following parameters are displayed in the main mode as shown in Figure 6.
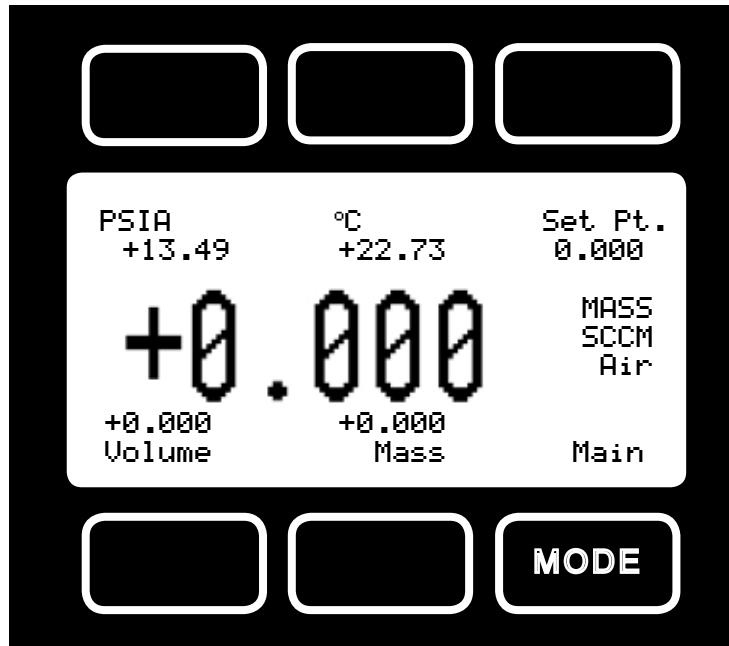
Figure 6. Main Mode Display, MC Series Flow Controller

 The "MODE" button in the lower right hand corner toggles the display between modes.

Set Pt. – The set-point is shown in the upper right corner of the display. The set-point cannot be adjusted from the main mode screen. For information on changing the set-point, see "***Set"***, page 13.

Gas Absolute Pressure: The MC Series flow controllers utilize an absolute pressure sensor to measure the line pressure of the gas flow being monitored. This sensor references hard vacuum and accurately reads line pressure both above and below local atmospheric pressure. This parameter is located in the upper left corner of the display under the dynamic label "PSIA". This parameter can be moved to the primary display by pushing the button just above the dynamic label (top left). The engineering unit associated with absolute pressure is pounds per square inch absolute (PSIA). This can be converted to gage pressure (PSIG = the reading obtained by a pressure gauge that reads zero at atmospheric pressure) by simply subtracting local atmospheric pressure from the absolute pressure reading:

$$PSIG = PSIA - (Local\ Atmospheric\ Pressure)$$

The flow meters use the absolute pressure of the gas in the calculation of the mass flow rate. For working in metric units, note that 1 PSI = 6.89 kPa.

Gas Temperature: The MC Series flow controllers utilize a temperature sensor to measure the line temperature of the gas flow being monitored. The temperature is displayed in engineering units of degrees Celsius (°C). The flow controllers use the temperature of the gas in the calculation of the mass flow rate. This parameter is located in the upper middle portion of the display under "°C". This parameter can be moved to the primary display by pushing the top center button above "°C".

Volumetric Flow Rate: The volumetric flow rate is determined using the Flow Measurement Operating Principle described on page 26. This parameter is located in the lower left corner of the display over "Volume". This parameter can be moved to the primary display by pushing the "Volume" button (lower left). In order to get an accurate volumetric flow rate, the gas being measured must be selected (see Gas Select Mode). This is important because the device calculates the flow rate based on the viscosity of the gas at the measured temperature. If the gas being measured is not what is selected, an incorrect value for the viscosity of the gas will be used in the calculation of flow, and the resulting output will be inaccurate in direct proportion to the ratio between the two gases viscosities.

Mass Flow Rate: The mass flow rate is the volumetric flow rate corrected to a standard temperature and pressure (typically 14.696 psia and 25°C). This parameter is located in the lower middle portion of the display over "Mass". This parameter can be moved to the primary display by pushing the button located below "Mass" (bottom center). The controllers uses the measured temperature and the measured absolute pressure to calculate what the flow rate would be if the gas pressure was at 1 atmosphere and the gas temperature was 25°C. This allows a solid reference point for comparing one flow to another.

Flashing Error Message: Our flow meters and controllers display an error message (MOV = mass overrange, VOV = volumetric overrange, POV = pressure overrange, TOV = temperature overrange) when a measured parameter exceeds the range of the sensors in the device. When any item flashes on the display, neither the flashing parameter nor the mass flow measurement is accurate. Reducing the value of the flashing parameter to within specified limits will return the unit to normal operation and accuracy.

Select Menu Mode

Pushing "Mode" once will bring up the "Select Menu" display. Push the button nearest your selection to go to the corresponding screen. Push "Mode" again to return to the Main Mode display. (**Note:** *If your controller was ordered with Totalizing Mode option (page 41), pushing the "Mode" button once will bring up the "Totalizing Mode" display. Pushing "Mode" a second time will bring up the "Select Menu" display.)*
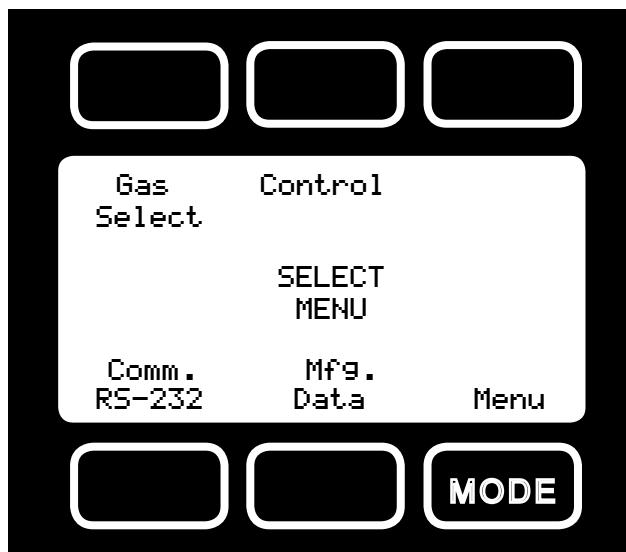
Figure 7. Select Menu Display

Control Setup Mode

The Control Setup Mode is accessed by pressing the center button above "Control" on the Select Menu display (Fig.7) This mode allows the user to set up most parameters commonly associated with PID control. MC Series flow controllers allow the user to select how the set-point is to be conveyed to the controller, what that set-point is if control is local, and what the Proportional and Differential terms of the PID control loop will be. The UP and DOWN buttons for adjusting variables can be held down for higher speed adjustment or pressed repeatedly for fine adjustment.

Input – MC Series Flow Controllers normally ship defaulted to analog control as indicated in Figure 8. To change how the set-point will be conveyed to the controller push the button in the upper right hand corner just above the dynamic label "Input" until the arrow is directly in front of the desired option. The controller will ignore any set-point except that of the selected input and it will remember which input is selected even if the power is disconnected.

Analog refers to a remote analog set-point applied to Pin 4 of the Mini-DIN connector as described in the installation section of this manual. To determine what type of analog set-point your controller was ordered with, refer to the Calibration Data Sheet that was included with your controller. 0-5 Vdc is standard unless ordered otherwise. Note that if nothing is connected to Pin 4, and the controller is set for analog control, the set-point will float. **CAUTION!** NEVER LEAVE A CONTROLLER WITH ANY NON-ZERO SET-POINT IF NO PRESSURE IS AVAILABLE TO MAKE FLOW. THE CONTROLLER WILL APPLY FULL POWER TO THE VALVE IN AN ATTEMPT TO REACH THE SET-POINT. WHEN THERE IS NO FLOW, THIS CAN MAKE THE VALVE VERY **HOT!**

Serial refers to a remote digital RS-232 set-point applied via a serial connection to a computer or PLC as described in the Installation and RS-232 sections of this manual. **CAUTION!** NEVER LEAVE A CONTROLLER WITH ANY NON-ZERO SET-POINT IF NO PRESSURE IS AVAILABLE TO MAKE FLOW. THE CONTROLLER WILL APPLY FULL POWER TO THE VALVE IN AN ATTEMPT TO REACH THE SET-POINT. WHEN THERE IS NO FLOW, THIS CAN MAKE THE VALVE VERY **HOT!**

Local refers to a set-point applied directly at the controller. For more information on changing the set-point locally refer to the heading "Select" below. Local input must be selected prior to attempting to change the set-point locally. **CAUTION!** NEVER LEAVE A CONTROLLER WITH ANY NON-ZERO SET-POINT IF NO PRESSURE IS AVAILABLE TO MAKE FLOW. THE CONTROLLER WILL APPLY FULL POWER TO THE VALVE IN AN ATTEMPT TO REACH THE SET-POINT. WHEN THERE IS NO FLOW, THIS CAN MAKE THE VALVE VERY **HOT!**

Figure 8. MC Series Control Setup Display

Loop—The selection of what variable to close the loop on is a feature unique to these mass flow controllers. When the mass flow controller is supplied with the control valve upstream of the electronics portion of the system, the unit can be set to control on outlet pressure (absolute pressures only) or volumetric flow rate, instead of mass flow rate. Repeatedly pressing the button adjacent to the word "Loop" on the control setup screen will change what variable is controlled. The change from mass to volume can usually be accomplished without much, if any, change in the P and D settings. When you change from controlling flow to controlling pressure, sometimes fairly radical changes must be made to these variables. **Note**: Full scale pressure is normally 160PSIA. *Consult the factory if you are having difficulties with this procedure.*

Select – To avoid accidental changing of the PID loop parameters or the set-point, the Control Setup mode defaults with the selector on a null position. To change the set-point or the P and D PID loop parameters, push the button in the upper left corner just above the dynamic label "Select" until the selection arrow is pointing to the parameter you wish to change. When the parameter you wish to change is selected, it may be adjusted up or down with the buttons under the display below the dynamic labels "Up" and "Down". Press the buttons repeatedly to make slow adjustments or hold them down to make fast adjustments.

P refers to the Proportional term of the PID loop. Before changing this parameter, it is good practice to write down the initial value so that it can be returned to the factory settings if necessary.

D refers to the Differential term of the PID loop. Before changing this parameter, it is good practice to write down the initial value so that it can be returned to the factory settings if necessary.

AUT0on / AUT0off refers to the standard auto-tare or "auto-zero" feature. It is recommended that the controller be left in the default auto-tare ON mode unless your specific application requires that it be turned off. The auto-tare feature automatically tares (takes the detected signal as zero) the unit when it receives a zero set-point for more than two seconds. A zero set-point results in the closing of the valve and a known "no flow" condition. This feature helps to make the device more accurate by periodically removing any cumulative errors associated with drift.

Set refers to the Set-Point. This parameter may only be changed if "Local" is selected as the Input. See above for information on selecting the input. Using the UP and DOWN buttons, the set-point may be adjusted between zero and the full-scale range of the controller. **CAUTION!** *Never leave a Controller with any non-zero set-point if no pressure is available to make flow. The controller will apply full power to the valve in an attempt to reach the set-point. When there is no flow, this can make the valve very* **HOT!**

Gas Select Mode

The gas select mode is accessed by pressing the button above "Gas Select" on the Select Menu display. The screen will appear as shown in Figure 9.

```
PgUP      PgDWN        Main
  H2  Hydrogen
  He  Helium
 >N2  Nitrogen
  N2O  Nitrous Oxide
  Ne  Neon
  O2  Oxygen
  UP        DOWN        Gas

              MODE
```

Figure 9. Gas Select Mode

The selected gas is displayed on the default main mode screen as shown in Figure 6, and is indicated by the arrow in the Gas Select Mode screen in Figure 9. To change the selected gas, use the buttons under "UP" and "DOWN" or above "PgUP" and "PgDWN" to position the arrow in front of the desired gas. When the mode is cycled back to the Main Mode, the selected gas will be displayed on the main screen. (**Note:** *Gas Select Mode may not be available for units ordered for use with a custom gas or blend.)*

Communication Select Mode

The Communication Select mode is accessed by pressing the button below "Comm. RS-232" on the Select Menu display. The screen will appear as shown in Figure 10.
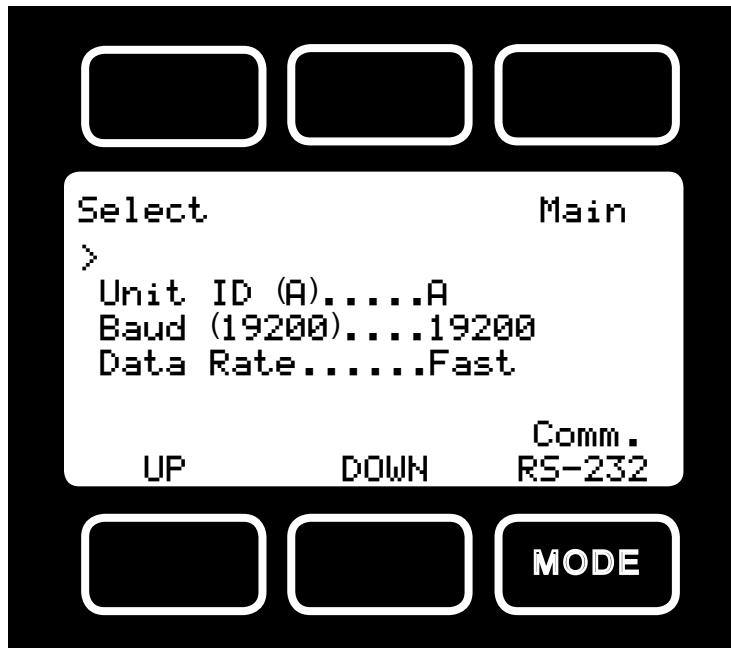
Figure 10. Communication Select Display

Unit ID – Valid unit identifiers are letters A-Z and @ (see **Note** below). This identifier allows the user to assign a unique address to each device so that multiple units can be connected to a single RS-232 port on a computer. The Communication Select Mode allows you to view and/or change a unit's unique address. To change the unit ID address, press the "Select" button in the upper left corner of the display until the cursor arrow is in front of the word "Unit ID". Then, using the UP and DOWN buttons at the bottom of the display, change the unit ID to the desired letter. ***Any ID change will take effect when the Communication Select Screen is exited by pushing the MODE button.***

Note: When the symbol @ is selected as the unit ID, the device will go into streaming mode when the Communication Select Mode is exited by pushing the MODE button. See RS-232 Communications (page 18) for information about the streaming mode.

Baud – The baud rate (bits per second) determines the rate at which data is passed back and forth between the instrument and the computer. Both devices must send/receive at the same baud rate in order for the devices to communicate via RS-232. The default baud rate for these devices is 19200 baud, sometimes referred to as 19.2K baud. To change the baud rate in the Communication Select Mode, press the "Select" button in the upper left corner of the display until the cursor arrow is in front of the word "Baud". Then, using the UP and DOWN buttons at the bottom of the display, select the required baud rate to match your computer or PLC. The choices are 38400, 19200, 9600, or 2400 baud. ***Any baud rate change will not take effect until power to the unit is cycled.***

Data Rate – Changing the Data Rate affects the rate at which the instrument dumps its data in the streaming mode. Slow is ½ the Fast rate. The speed of the Fast rate is determined by the selected baud rate. It is sometimes desirable to reduce the data rate if the communication speed bogs down the computer's processor (as is not uncommon in older laptops), or to reduce the size of data files collected in the streaming mode. To change the data rate in the Communication Select Mode, press the "Select" button in the upper left corner of the display until the cursor arrow is in front of the word "Data Rate". Then, using the UP and DOWN buttons at the bottom of the display, select either Fast or Slow. ***Any data rate change will be effective immediately upon changing the value between Fast and Slow.***

Manufacturer Data Mode

"Manufacturer Data" is accessed by pressing the "Mfg. Data" button on the Select Menu display (Figure 11). The "Mfg 1" display shows the name and telephone number of the manufacturer. The "Mfg 2" display shows important information about your flow meter including the model number, serial number, and date of manufacture.
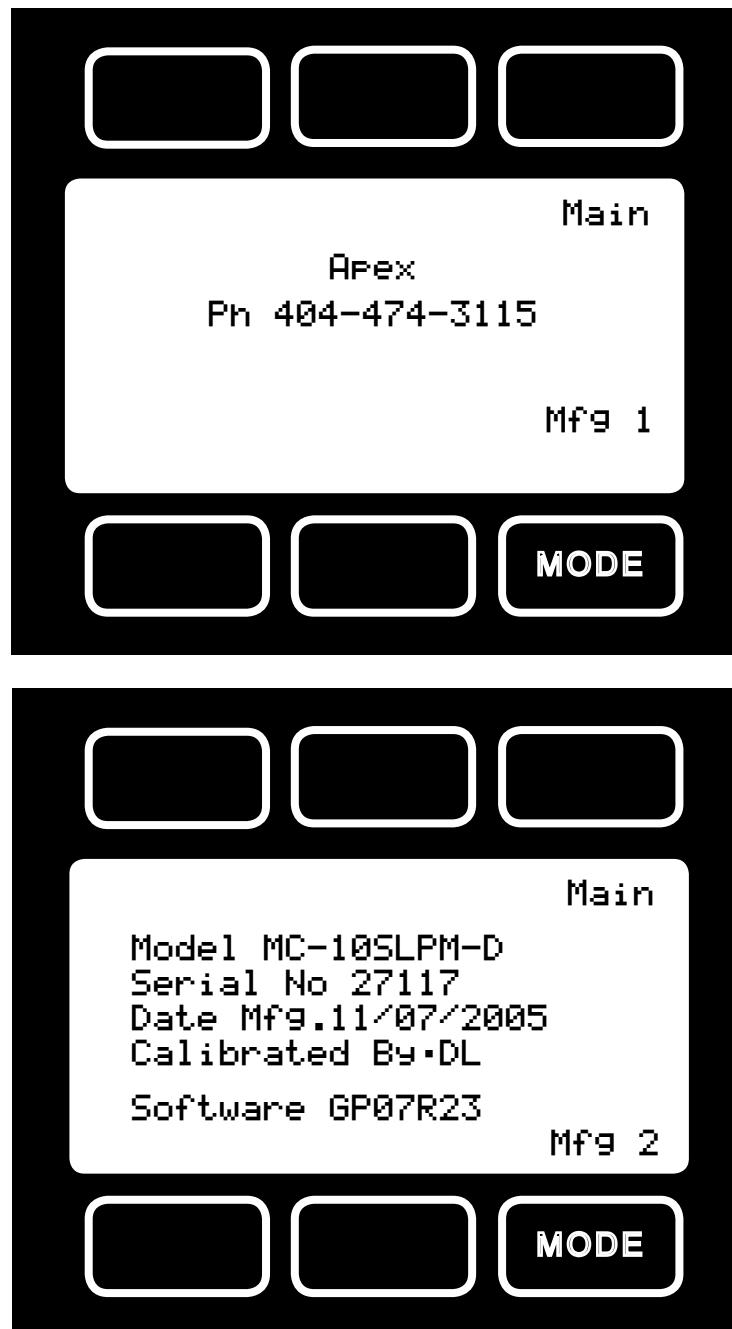
Figure 11. Manufacturer Data Displays

VC Series Volumetric Flow Controller Operation

The VC Series can have several screen "modes" depending on how the device is ordered. All VC Series controllers have a default Main Mode, Select Menu Mode, Control Setup Mode, Gas Select Mode (the Gas Select Mode may not be available on meters calibrated for a custom gas or blend), Communication Select Mode and Manufacturer Data Mode. (In addition, your device may have been ordered with a Totaliizing Mode, page 41.) The device defaults to Main Mode as soon as power is applied to the controller. Note that volumetric controllers are intended for use in near atmospheric conditions (Please see page 31).

Main Mode

The main mode screen shows the volumetric flow in the units specified at time of order. In the flow mode, only two buttons are active as shown in Figure 12. The process gas that is selected is shown directly under the flow units.
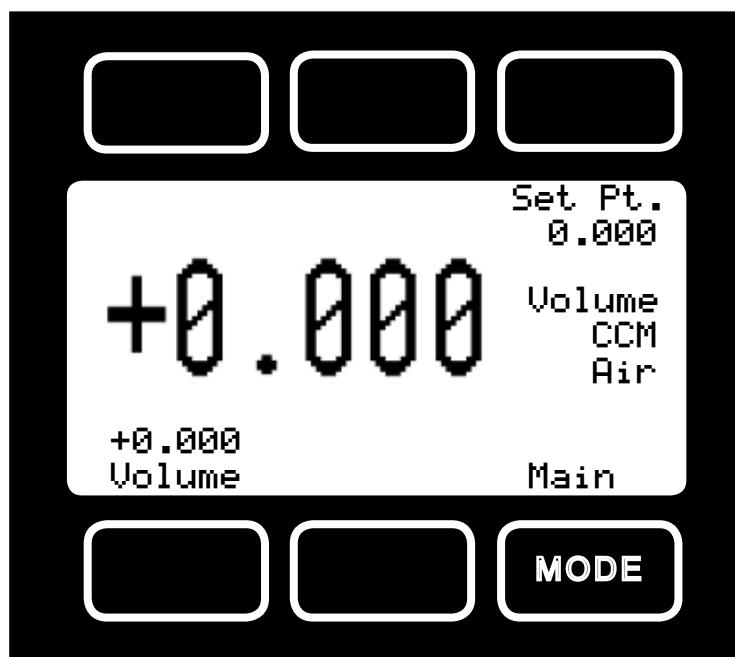
Figure 12. Main Mode Display, VC Series Flow Controller

The "MODE" button in the lower right hand corner toggles the display between the Main Display and the Menu Display.

Volume – The volume flow rate is defaulted on the primary display. If the set-point has been toggled to the primary screen as described below, the volume flow rate can be toggled back to the primary display by pushing the button (lower left corner) directly beneath the dynamic label "Volume".

Set Pt – The set-point is shown in the upper right corner of the display. The set-point cannot be adjusted from the main mode screen. For information on changing the set-point, see "Control Setup Mode".

Flashing Error Message: Our volumetric flow meters and controllers display an error message (VOV = volumetric overrange) when a measured parameter exceeds the range of the sensors in the device. When any item flashes on the display, the flashing parameter is not accurate. Reducing the value of the flashing parameter to within specified limits will return the unit to normal operation and accuracy.

Select Menu Mode

Pushing "Mode" once will bring up the "Select Menu" display (Figure 7, page 11). Push the button nearest your selection to go to the corresponding screen. Push "Mode" again to return to the Main Mode display. (**Note:** *If your controller was ordered with Totalizing Mode option (page 41), pushing the "Mode" button once will bring up the "Totalizing Mode" display. Pushing "Mode" a second time will bring up the "Select Menu" display.)*

Control Setup Mode

The Control Setup Mode is accessed by pressing the center button above "Control" on the Select Menu Display (Fig.7 page 11) This mode allows the user to set up most parameters commonly associated with PID control. VC Series flow controllers allow the user to select how the set-point is to be conveyed to the controller, what that set-point is if control is local, and what the Proportional and Differential terms of the PID control loop will be. The UP and DOWN buttons for adjusting variables can be held down for higher speed adjustment or pressed repeatedly for fine adjustment
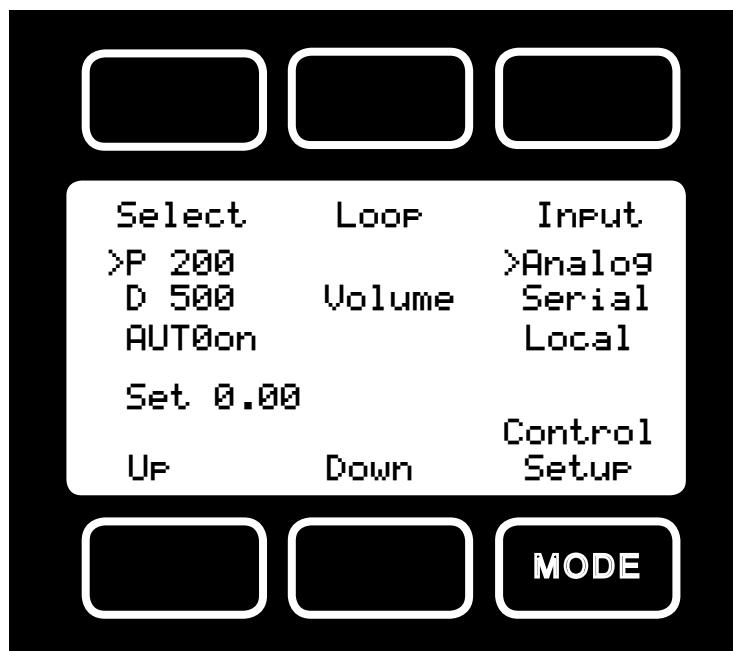
Figure 13. VC Series Control Setup Display

Input – VC Series Flow Controllers normally ship defaulted to analog control as indicated in Figure 13 above. To change how the set-point will be conveyed to the controller push the button in the upper right hand corner just above the dynamic label "Input" until the arrow is directly in front of the desired option. The controller will ignore any set-point except that of the selected input and it will remember which input is selected even if the power is disconnected.

Analog refers to a remote analog set-point applied to Pin 4 of the Mini-DIN connector as described in the installation section of this manual. To determine what type of analog set-point your controller was ordered with, refer to the Calibration Data Sheet that was included with your controller. 0-5 Vdc is standard unless ordered otherwise. Note that if nothing is connected to Pin 4, and the controller is set for analog control, the set-point will float. **CAUTION!** *Never leave a Controller with any non-zero set-point if no pressure is available to make flow. The controller will apply full power to the valve in an attempt to reach the set-point. When there is no flow, this can make the valve very* **HOT!**

Serial refers to a remote digital RS-232 set-point applied via a serial connection to a computer or PLC as described in the Installation and RS-232 sections of this manual. **CAUTION!** *Never leave a Controller with any non-zero set-point if no pressure is available to make flow. The controller will apply full power to the valve in an attempt to reach the set-point. When there is no flow, this can make the valve very* **HOT!**

Local refers to a set-point applied directly at the controller. For more information on changing the set-point locally refer to the heading "Select" below. Local input must be selected prior to attempting to change the set-point locally. **CAUTION!** *Never leave a Controller with any non-zero set-point if no pressure is available to make flow. The controller will apply full power to the valve in an attempt to reach the set-point. When there is no flow, this can make the valve very* **HOT!**

Select – To avoid accidental changing of the PID loop parameters or the set-point, the Control Setup mode defaults with the selector on a null position. To change the set-point or the P and D PID loop parameters, push the button in the upper left corner just above the dynamic label "Select" until the selection arrow is pointing to the parameter you wish to change. When the parameter you wish to change is selected, it may be adjusted up or down with the buttons under the display below the dynamic labels "UP" and "DOWN". Press the buttons repeatedly to make slow adjustments or hold them down to make fast adjustments.

P refers to the Proportional term of the PID loop. Before changing this parameter, it is good practice to write down the initial value so that it can be returned to the factory settings if necessary.

D refers to the Differential term of the PID loop. Before changing this parameter, it is good practice to write down the initial value so that it can be returned to the factory settings if necessary.

AUT0on / AUT0off refers to the standard auto-tare or "auto-zero" feature. It is recommended that the controller be left in the default auto-tare ON mode unless your specific application requires that it be turned off. The auto-tare feature automatically tares (takes the detected signal as zero) the unit when it receives a zero set-point for more than two seconds. A zero set-point results in the closing of the valve and a known "no flow" condition. This feature helps to make the device more accurate by periodically removing any cumulative errors associated with drift.

Set refers to the Set-point. This parameter may only be changed if "Local" is selected as the Input. See above for information on selecting the input. Using the UP and DOWN buttons, the set-point may be adjusted between zero and the full-scale range of the controller. **CAUTION!** *Never leave a Controller with any non-zero set-point if no pressure is available to make flow. The controller will apply full power to the valve in an attempt to reach the set-point. When there is no flow, this can make the valve very* **HOT!**

Gas Select Mode

The Gas Select Mode is accessed by pressing the button above "Gas Select" on the Select Menu display. The screen will appear as shown in Figure 9 (page 13). The selected gas is displayed on the default main mode screen as shown in Figure 11, and is indicated by the arrow in the gas select mode screen in Figure 9. To change the selected gas, use the buttons under "UP" and "DOWN" or those above "PgUP" and "PgDWN" to position the arrow in front of the desired gas. When the mode is cycled back to the main mode, the selected gas will be displayed on the main screen.

Note: *Gas Select Mode may not be available for units ordered for use with a custom gas or blend.*

Communication Select Mode

The Communication Select mode is accessed by pressing the button below "Comm. RS-232" on the Select Menu display. Please see page 14 for Communication Select mode instructions.

Manufacturer Data Mode

"Manufacturuer Data" is accessed by pressing the "Mfg. Data" button on the Select Menu display (Figure 7, page 11). The "Mfg 1" display shows the name and telephone number of the manufacturer. The"Mfg 2" display shows important information about your flow controller including the model number, serial number, and date of manufacture (Figure 10, page 14).

RS-232 Output and Input

Configuring HyperTerminal®:

1. Open your HyperTerminal® RS-232 terminal program (installed under the "Accessories" menu on all Microsoft Windows operating systems).
2. Select "Properties" from the file menu.
3. Click on the "Configure" button under the "Connect To" tab. Be sure the program is set for: 19,200 baud (or matches the baud rate selected in the RS-232 communications menu on the controller) and an 8-N-1-None (8 Data Bits, No Parity, 1 Stop Bit, and no Flow Control) protocol.
4. Under the "Settings" tab, make sure the Terminal Emulation is set to ANSI or Auto Detect.
5. Click on the "ASCII Setup" button and be sure the "Send Line Ends with Line Feeds" box <u>is not checked</u> and the "Echo Typed Characters Locally" box and the "Append Line Feeds to Incoming Lines" boxes <u>are checked</u>. Those settings not mentioned here are normally okay in the default position.
6. Save the settings, close HyperTerminal® and reopen it.

In Polling Mode, the screen should be blank except the blinking cursor. In order to get the data streaming to the screen, hit the "Enter" key several times to clear any extraneous information. Type "*@=@" followed by "Enter" (or using the RS-232 communcation select menu, select @ as identifier and exit the screen). If data still does not appear, check all the connections and com port assignments.

Changing From Streaming to Polling Mode:
When the meter is in the Streaming Mode, the screen is updated approximately 10-60 times per second (depending on the amount of data on each line) so that the user sees the data essentially in real time. It is sometimes desirable, and necessary when using more than one unit on a single RS-232 line, to be able to poll the unit.

In Polling Mode the unit measures the flow normally, but only sends a line of data when it is "polled". Each unit can be given its own unique identifier or address. Unless otherwise specified each unit is shipped with a default address of capital A. Other valid addresses are B thru Z.

Once you have established communication with the unit and have a stream of information filling your screen:

1. Type *@=A followed by "Enter" (or using the RS-232 communcation select menu, select A as identifier and exit the screen) to stop the streaming mode of information. Note that the flow of information will not stop while you are typing and you will not be able to read what you have typed. Also, the unit does not accept a backspace or delete in the line so it must be typed correctly. If in doubt, simply hit enter and start again. If the unit does not get exactly what it is expecting, it will ignore it. If the line has been typed correctly, the data will stop.

2. You may now poll the unit by typing A followed by "Enter". This does an instantaneous poll of unit A and returns the values once. You may type A "Enter" as many times as you like. Alternately you could resume streaming mode by typing *@=@ followed by "Enter". Repeat step 1 to remove the unit from the streaming mode.

3. To assign the unit a new address, type *@=New Address, e.g. *@=B. Care should be taken not to assign an address to a unit if more than one unit is on the RS232 line as all of the addresses will be reassigned. Instead, each should be individually attached to the RS-232 line, given an address, and taken off. After each unit has been given a unique address, they can all be put back on the same line and polled individually.

Sending a Set-point via RS-232: To send a set-point via RS-232, "Serial" must be selected under the "Input" list in the control set up mode. To give controllers a set-point, or change an existing point, simply type in a number between 0 and 65535 (2% over range), where 64000 denotes full-scale flow rate, and hit "Enter". The set-point column and flow rates should change accordingly. If they do not, try hitting "Enter" a couple of times and repeating your command. The formula for performing a linear interpolation is as follows:

Value = (Desired Set-point X 64000) / Full Scale Flow Range

For example, if your device is a 100 SLPM full-scale unit and you wish to apply a set-point of 35 SLPM you would enter the following value:

22400 = (35 SLPM X 64000) / 100 SLPM

If the controller is in polling mode as described in *Changing from Streaming Mode to Polling Mode*, the set-point must be preceded by the address of the controller. For example, if your controller has been given an address of D, the set-point above would be sent by typing:

D22400 followed by "Enter"

To adjust the Proportional and Differential (P&D) terms via RS-232:

Type *@=A followed by "Enter" to stop the streaming mode of information.

To adjust the "P" or proportional term of the PID controller, type *R21 followed by "Enter".

The computer will respond by reading the current value for register 21 between 0-65535. <u>It is good practice to write this value down so you can return to the factory settings if necessary</u>. Enter the value you wish to try by writing the new value to register 21. For example, if you wished to try a "P" term of 220, you would type *W21=**220** followed by "Enter" where the bold number denotes the new value.

The computer will respond to the new value by confirming that 21=220. To see the effect of the change you may now poll the unit by typing A followed by "Enter". This does an instantaneous poll and returns the values once. You may type A "Enter" as many times as you like. Alternately you could resume streaming mode by typing *@=@ followed by "Enter". Repeat step 3 to remove the unit from the streaming mode.

To adjust the "D" or proportional term of the PID controller, type *R22 followed by "Enter".

The computer will respond by reading the current value for register 22 between 0-65535. <u>It is good practice to write this value down so you can return to the factory settings if necessary</u>. Enter the value you wish to try by writing the new value to register 22. For example, if you wished to try a "D" term of 25, you would type *W22=**25** followed by "Enter" where the bold number denotes the new value.

The computer will respond to the new value by confirming that 22=25. To see the effect of the change you may now poll the unit by typing A followed by "Enter". This does an instantaneous poll and returns the values once. You may type A "Enter" as many times as you like. Alternately you could resume streaming mode by typing *@=@ followed by "Enter". Repeat.

You may test your settings for a step change by changing the set-point. To do this type A32000 (A is the default single unit address, if you have multiple addressed units on your RS-232 line the letter preceding the value would change accordingly.) followed by "Enter" to give the unit a ½ full scale setpoint. Monitor the unit's response to the step change to ensure it is satisfactory for your needs. Recall that the "P" term controls how quickly the unit goes from one setpoint to the next, and the "D" term controls how quickly the signal begins to "decelerate" as it approaches the new set-point (controls the overshoot).

Gas Select – The selected gas can be changed via RS-232 input. To change the selected gas, enter the following commands:

      In Streaming Mode: $$#<Enter>
      In Polling Mode: Address$$#<Enter>   (e.g. B$$#<Enter>)

Where # is the number of the gas selected from the table below. Note that this also corresponds to the gas select menu on the flow controller screen:

#	GAS	
0	Air	Air
1	Argon	Ar
2	Methane	CH4
3	Carbon Monoxide	CO
4	Carbon Dioxide	CO2
5	Ethane	C2H6
6	Hydrogen	H2
7	Helium	He
8	Nitrogen	N2
9	Nitrous Oxide	N2O
10	Neon	Ne
11	Oxygen	O2
12	Propane	C3H8
13	normal-Butane	n-C4H10
14	Acetylene	C2H2
15	Ethylene	C2H4
16	iso-Butane	i-C2H10
17	Krypton	Kr
18	Xenon	Xe
19	Sulfur Hexafluoride	SF6
20	75% Argon / 25% CO2	C-25
21	90% Argon / 10% CO2	C-10
22	92% Argon / 8% CO2	C-8
23	98% Argon / 2% CO2	C-2
24	75% CO2 / 25% Argon	C-75
25	75% Argon / 25% Helium	A-75
26	75% Helium / 25% Argon	A-25
27	90% Helium / 7.5% Argon / 2.5% CO2 (Praxair - Helistar® A1025)	A1025
28	90% Argon / 8% CO2 / 2% Oxygen (Praxair - Stargon® CS)	Star29
29	95% Argon / 5% Methane	P-5

For example, to select Propane, enter: $$12<Enter>

Collecting Data:

The RS-232 output updates to the screen many times per second. Very short-term events can be captured simply by disconnecting (there are two telephone symbol icons at the top of the HyperTerminal® screen for disconnecting and connecting) immediately after the event in question. The scroll bar can be driven up to the event and all of the data associated with the event can be selected, copied, and pasted into Microsoft® Excel® or other spreadsheet program as described below.

For longer term data, it is useful to capture the data in a text file. With the desired data streaming to the screen, select "Capture Text" from the Transfer Menu. Type in the path and file name you wish to use. Push the start button. When the data collection period is complete, simply select "Capture Text" from the Transfer Menu and select "Stop" from the sub-menu that appears.

Data that is selected and copied, either directly from HyperTerminal® or from a text file can be pasted directly into Excel®. When the data is pasted it will all be in the selected column. Select "Text to Columns..." under the Data menu in Excel® and a Text to Columns Wizard (dialog box) will appear. Make sure that "Fixed Width" is selected under Original Data Type in the first dialog box and click "Next". In the second dialog box, set the column widths as desired, but the default is usually acceptable. Click on "Next" again. In the third dialog box, make sure the column data format is set to "General", and click "Finish". This separates the data into columns for manipulation and removes symbols such as the plus signs from the numbers. Once the data is in this format, it can be graphed or manipulated as desired. ***For extended term data capture see:*** "Sending a Simple Script to HyperTerminal®" on page 25.

Data Format:

The data stream on the screen represents the flow parameters of the main mode in the units shown on the display. For volumetric flow controllers, there are three columns of data representing volumetric flow rate in the units specified at time of order, set point and the selected gas.

<div align="center">

+4.123 4.125 Air
+4.123 4.125 Air
+4.123 4.125 Air
+4.123 4.125 Air
+4.124 4.125 Air
+4.125 4.125 Air

</div>

<div align="center">VC Series Volumetric Flow Controller Data Format</div>

For mass flow controllers, there are 6 columns of data representing pressure, temperature, volumetric flow, mass flow and the selected gas. The first column is absolute pressure (normally in PSIA), the second column is temperature (normally in °C), the third column is volumetric flow rate (in the units specified at time of order and shown on the display), and the fourth column is mass flow (also in the units specified at time of order and shown on the display). For instance, if the meter was ordered in units of SCFM, the display on the meter would read 2.004 SCFM and the last two columns of the output below would represent volumetric flow and mass flow in CFM and SCFM respectively.

<div align="center">

+014.70 +025.00 +02.004 +02.004 2.004 Air
+014.70 +025.00 +02.004 +02.004 2.004 Air
+014.70 +025.00 +02.004 +02.004 2.004 Air
+014.70 +025.00 +02.004 +02.004 2.004 Air
+014.70 +025.00 +02.004 +02.004 2.004 Air
+014.70 +025.00 +02.004 +02.004 2.004 Air

</div>

<div align="center">MC Series Mass Flow Controller Data Format</div>

Sending a Simple Script File to HyperTerminal®

It is sometimes desirable to capture data for an extended period of time. Standard streaming mode information is useful for short term events, however, when capturing data for an extended period of time, the amount of data and thus the file size can become too large very quickly. Without any special programming skills, the user can use HyperTerminal and a text editing program such as Microsoft Word to capture text at user defined intervals.

1. Open your text editing program, MS Word for example.
2. Set the cap lock on so that you are typing in capital letters.
3. Beginning at the top of the page, type A<Enter> repeatedly. If you're using MS Word, you can tell how many lines you have by the line count at the bottom of the screen. The number of lines will correspond to the total number of times the flow device will be polled, and thus the total number of lines of data it will produce.

For example: A
    A
    A
    A
    A
    A

  will get a total of six lines of data from the flow meter, but you can enter as many as you like.

The time between each line will be set in HyperTerminal.

4. When you have as many lines as you wish, go to the File menu and select save. In the save dialog box, enter a path and file name as desired and in the "Save as Type" box, select the plain text (.txt) option. It is important that it be saved as a generic text file for HyperTerminal to work with it.
5. Click Save.
6. A file conversion box will appear. In the "End Lines With" drop down box, select CR Only. Everything else can be left as default.
7. Click O.K.
8. You have now created a "script" file to send to HyperTerminal. Close the file and exit the text editing program.
9. Open HyperTerminal and establish communication with your flow device as outlined in the manual.
10. Set the flow device to Polling Mode as described in the manual. Each time you type A<Enter>, the meter should return one line of data to the screen.
11. Go to the File menu in HyperTerminal and select "Properties".
12. Select the "Settings" tab.
13. Click on the "ASCII Setup" button.
14. The "Line Delay" box is defaulted to 0 milliseconds. This is where you will tell the program how often to read a line from the script file you've created. 1000 milliseconds is one second, so if you want a line of data every 30 seconds, you would enter 30000 into the box. If you want a line every 5 minutes, you would enter 300000 into the box.
15. When you have entered the value you want, click on OK and OK in the Properties dialog box.
16. Go the Transfer menu and select "Send **Text** File…" (NOT Send File…).
17. Browse and select the text "script" file you created.
18. Click Open.
19. The program will begin "executing" your script file, reading one line at a time with the line delay you specified and the flow device will respond by sending one line of data for each poll it receives, when it receives it.

You can also capture the data to another file as described in the manual under "Collecting Data". You will be simultaneously sending it a script file and capturing the output to a separate file for analysis.

Operating Principle

All M and V Series Gas Flow Meters (and MC and VC Series Gas Flow Controllers) are based on the accurate measurement of volumetric flow. The volumetric flow rate is determined by creating a pressure drop across a unique internal restriction, known as a Laminar Flow Element (LFE), and measuring differential pressure across it. The restriction is designed so that the gas molecules are forced to move in parallel paths along the entire length of the passage; hence laminar (streamline) flow is established for the entire range of operation of the device. Unlike other flow measuring devices, in laminar flow meters the relationship between pressure drop and flow is linear. The underlying principle of operation of the 16 Series flow meters is known as the Poiseuille Equation:

$$Q = (P_1 - P_2)\pi r^4 / 8\eta L \qquad \text{(Equation 1)}$$

Where:
- Q = Volumetric Flow Rate
- P_1 = Static pressure at the inlet
- P_2 = Static pressure at the outlet
- r = Radius of the restriction
- η = (eta) absolute viscosity of the fluid
- L = Length of the restriction

Since π, r and L are constant; Equation 1 can be rewritten as:

$$Q = K (\Delta P / \eta) \qquad \text{(Equation 2)}$$

Where K is a constant factor determined by the geometry of the restriction. Equation 2 shows the linear relationship between volumetric flow rate (Q) differential pressure (ΔP) and absolute viscosity (η) in a simpler form.

Gas Viscosity: In order to get an accurate volumetric flow rate, the gas being measured must be selected (see Gas Select Mode, page 14). This is important because the device calculates the flow rate based on the viscosity of the gas at the measured temperature. If the gas being measured is not what is selected, an incorrect value for the viscosity of the gas will be used in the calculation of flow, and the resulting output will be inaccurate in direct proportion to the difference in the two gases viscosities.

Gas viscosity, and thus gas composition, can be very important to the accuracy of the meter. Anything that has an effect on the gas viscosity (e.g. water vapor, odorant additives, etc.) will have a direct proportional effect on the accuracy. Selecting methane and measuring natural gas for instance, will result in a fairly decent reading, but it is not highly accurate (errors are typically < 0.6%) because natural gas contains small and varying amounts of other gases such as butane and propane that result in a viscosity that is somewhat different than pure methane.

Absolute viscosity changes very little with pressure (within the operating ranges of these meters) therefore a true volumetric reading does not require a correction for pressure. Changes in gas temperature do affect viscosity. For this reason, the M and V Series internally compensate for this change.

Other Gases: M Series Flow Meters/Controllers can easily be used to measure the flow rate of gases other than those listed as long as "non-corrosive" gas compatibility is observed. For example, a flow meter that has been set for air can be used to measure the flow of argon.

The conversion factor needed for measuring the flow of different gases is linear and is simply determined by the ratio of the absolute viscosity of the gases. This factor can be calculated as follows:

$$Q_{og} = Q_1 [\eta_1 / \eta_{og}]$$

Where:

Q_1	=	Flow rate indicated by the flow meter
η_1	=	Viscosity of the calibrated gas at the measured temp.
Q_{og}	=	Flow rate of the alternate gas
η_{og}	=	Viscosity of the alternate gas at the measured temp.

Say we have a meter set for air and we want to flow argon through it. With argon flowing through the meter, the display reads 110 SLPM. For ease of calculation, let us say the gas temperature is 25°C. What is the actual flow of argon?

Q_{og}	=	Actual Argon Flow Rate
Q_1	=	Flow rate indicated by meter (110 SLPM)
η_1	=	Viscosity of gas selected or calibrated for by the meter at the measured temp.
η_{og}	=	Viscosity of gas flowing through the meter at the measured temp.

At 25°C, the absolute viscosity of Air (η_1) is 184.918 micropoise.
At 25°C, the absolute viscosity of Argon (η_{og}) is 225.593 micropoise.

Q_{og}	=	Q1 (η 1 / η_{og})
Q_{og}	=	110 SLPM (184.918 / 225.593)
Q_{og}	=	90.17 SLPM

So, the actual flow of Argon through the meter is 90.17 SLPM. As you can see, because the Argon gas is more viscous than the Air the meter is set for, the meter indicates a higher flow than the actual flow.

A good rule of thumb is: "At a given flow rate, the higher the viscosity, the higher the indicated flow."

Volume Flow vs. Mass Flow: At room temperature and low pressures the volumetric and mass flow rate will be nearly identical, however, these rates can vary drastically with changes in temperature and/or pressure because the temperature and pressure of the gas directly affects the volume. For example, assume a volumetric flow reading was used to fill balloons with 250 mL of helium, but the incoming line ran near a furnace that cycled on and off, intermittently heating the incoming helium. Because the volumetric meter simply measures the volume of gas flow, all of the balloons would initially be the same size. However, if all the balloons are placed in a room and allowed to come to an equilibrium temperature, they would generally all come out to be different sizes. If, on the other hand, a mass flow reading were used to fill the balloons with 250 <u>standard</u> mL of helium, the resulting balloons would initially be different sizes, but when allowed to come to an equilibrium temperature, they would all turn out to be the same size.

This parameter is called corrected mass flow because the resulting reading has been compensated for temperature and pressure and can therefore be tied to the mass of the gas. Without knowing the temperature and pressure of the gas and thus the density, the mass of the gas cannot be determined.

Once the corrected mass flow rate at standard conditions has been determined and the density at standard conditions is known (see the density table at the back of this manual), a true mass flow can be calculated as detailed in the following example:

Mass Flow Meter Reading = 250 SCCM (Standard Cubic Centimeters/Minute)
Gas: Helium
Gas Density at 25C and 14.696 PSIA = .16353 grams/Liter
True Mass Flow = (Mass Flow Meter Reading) X (Gas Density)
True Mass Flow = (250 CC/min) X (1 Liter / 1000 CC) X (.16353 grams/Liter)
True Mass Flow = 0.0409 grams/min of Helium

Volumetric and Mass Flow Conversion: In order to convert volume to mass, the density of the gas must be known. The relationship between volume and mass is as follows:

$$Mass = Volume \times Density$$

The density of the gas changes with temperature and pressure and therefore the conversion of volumetric flow rate to mass flow rate requires knowledge of density change. Using ideal gas laws, the effect of temperature on density is:

$$\rho_a / \rho_s = T_s / T_a$$

Where:
- ρ_a = density @ flow condition
- T_a = absolute temp @ flow condition in °Kelvin
- ρ_s = density @ standard (reference) condition
- T_s = absolute temp @ standard (reference) condition in °Kelvin
- °K = °C + 273.15   Note: °K=°Kelvin

The change in density with pressure can also be described as:

$$\rho_a / \rho_s = P_a / P_s$$

Where:
- ρ_a = density @ flow condition
- P_a = flow absolute pressure
- ρ_s = density @ standard (reference) condition
- P_s = Absolute pressure @ standard (reference) condition

Therefore, in order to determine mass flow rate, two correction factors must be applied to volumetric rate: temperature effect on density and pressure effect on density.

Compressibility: Heretofore, we have discussed the gasses as if they were "Ideal" in their characteristics. The ideal gas law is formulated as:

$PV=nRT$ where: P = Absolute Pressure
V = Volume (or Volumetric Flow Rate)
n = number moles (or Molar Flow Rate)
R = Gas Constant (related to molecular weight)
T = Absolute Temperature

Most gasses behave in a nearly ideal manner when measured within the temperature and pressure limitations of our products. However, some gasses (such as propane and butane) can behave in a less than ideal manner within these constraints. The non-ideal gas law is formulated as:

$PV=ZnRT$

Where: "Z" is the compressibility factor. This can be seen in an increasingly blatant manner as gasses approach conditions where they condense to liquid. As the compressibility factor goes down (Z=1 is the ideal gas condition), the gas takes up less volume than what one would expect from the ideal gas calculation.

This reduces to: $P_a V_a / Z_a T_a = P_s V_s / Z_s T_s$, eliminating R and n.

M Series mass flow meters/controllers model gas flows based upon the non-ideal gas characteristics of the calibrated gas. The flow corrections are normally made to 25 C and 14.696 PSIA and the compressibility factor of the gas under those conditions. This allows the user to multiply the mass flow rate by the density of the real gas at those standard conditions to get the mass flow rate in grams per minute.

Because we incorporate the compressibility factor into our 'full gas model'; attempts to manually compute mass flows from only the P, V, and T values shown on the display will sometimes result in modest errors.

Note: Although the correct units for mass are expressed in grams, kilograms, etc. it has become standard that mass flow rate is specified in SLPM (standard liters / minute), SCCM (standard cubic centimeters / minute) or SmL/M (standard milliliters / minute).

This means that mass flow rate is calculated by normalizing the volumetric flow rate to some standard temperature and pressure (STP). By knowing the density at that STP, one can determine the mass flow rate in grams per minute, kilograms per hour, etc.

STP is usually specified as the sea level conditions; however, no single standard exists for this convention. Examples of common reference conditions include:

0°C	and	14.696 PSIA
25°C	and	14.696 PSIA
0°C	and	760 torr (mmHG)
70°F	and	14.696 PSIA
68°F	and	29.92 inHG
20°C	and	760 torr (mmHG)

M Series Flow Meters/Controllers reference 25ºC and14.696 PSIA (101.32kPa) - unless ordered otherwise and specified in the notes field of the calibration sheet.

Standard Gas Data Tables: We have incorporated the latest data sets from NIST (including their REFPROP 7 data) in our products' built-in gas property models. Be aware that calibrators that you may be spot checking against may be using older data sets such as the widely distributed Air Liquide data. This may generate apparent calibration discrepancies of up to 0.6% of reading on well behaved gases and as much as 3% of reading on some gases such as propane and butane, unless the standard was directly calibrated on the gas in question. As the older standards are phased out of the industry, this difference in readings will cease to be a problem. If you see a difference between the meter and your in-house standard, in addition to calling Apex, call the manufacturer of your standard for clarification as to which data set they used in their calibration. This comparison will in all likelihood resolve the problem.

Gas Number	Short Form	Long Form	Viscosity* 25 deg C 14.696 PSIA	Density** 25 deg C 14.696 PSIA	Compressibility 25 deg C 14.696 PSIA
0	Air	Air	184.918	1.1840	0.9997
1	Ar	Argon	225.593	1.6339	0.9994
2	CH4	Methane	111.852	0.6569	0.9982
3	CO	Carbon Monoxide	176.473	1.1453	0.9997
4	CO2	Carbon Dioxide	149.332	1.8080	0.9949
5	C2H6	Ethane	93.540	1.2385	0.9924
6	H2	Hydrogen	89.153	0.08235	1.0006
7	He	Helium	198.457	0.16353	1.0005
8	N2	Nitrogen	178.120	1.1453	0.9998
9	N2O	Nitrous Oxide	148.456	1.8088	0.9946
10	Ne	Neon	311.149	0.8246	1.0005
11	O2	Oxygen	204.591	1.3088	0.9994
12	C3H8	Propane	81.458	1.8316	0.9841
13	n-C4H10	normal-Butane	74.052	2.4494	0.9699
14	C2H2	Acetylene	104.448	1.0720	0.9928
15	C2H4	Ethylene	103.177	1.1533	0.9943
16	i-C4H10	iso-Butane	74.988	2.4403	0.9728
17	Kr	Krypton	251.342	3.4274	0.9994
18	Xe	Xenon	229.785	5.3954	0.9947
19	SF6	Sulfur Hexafluoride	153.532	6.0380	0.9887
20	C-25	75% Argon / 25% CO2	205.615	1.6766	0.9987
21	C-10	90% Argon / 10% CO2	217.529	1.6509	0.9991
22	C-8	92% Argon / 8% CO2	219.134	1.6475	0.9992
23	C-2	98% Argon / 2% CO2	223.973	1.6373	0.9993
24	C-75	75% CO2 / 25% Argon	167.451	1.7634	0.9966
25	A-75	75% Argon / 25% Helium	230.998	1.2660	0.9997
26	A-25	75% Helium / 25% Argon	234.306	0.5306	1.0002
27	A1025	90% Helium / 7.5% Argon / 2.5% CO2 (Praxair - Helistar® A1025)	214.840	0.3146	1.0003
28	Star29	90% Argon / 8% CO2 / 2% Oxygen (Praxair - Stargon® CS)	218.817	1.6410	0.9992
29	P-5	95% Argon / 5% Methane	223.483	1.5850	0.9993
*in micropoise (1 Poise = gram / (cm) (sec))		** Grams/Liter		(NIST REFPROP 7 database)	

Gas Viscosities, Densities and Compressibilities at 25º C

Gas Number	Short Form	Long Form	Viscosity* 0 deg C 14.696 PSIA	Density** 0 deg C 14.696 PSIA	Compressibility 0 deg C 14.696 PSIA
0	Air	Air	172.588	1.2927	0.9994
1	Ar	Argon	209.566	1.7840	0.9991
2	CH4	Methane	103.657	0.7175	0.9976
3	CO	Carbon Monoxide	165.130	1.2505	0.9994
4	CO2	Carbon Dioxide	137.129	1.9768	0.9933
5	C2H6	Ethane	86.127	1.3551	0.9900
6	H2	Hydrogen	83.970	0.08988	1.0007
7	He	Helium	186.945	0.17849	1.0005
8	N2	Nitrogen	166.371	1.2504	0.9995
9	N2O	Nitrous Oxide	136.350	1.9778	0.9928
10	Ne	Neon	293.825	0.8999	1.0005
11	O2	Oxygen	190.555	1.4290	0.9990
12	C3H8	Propane	74.687	2.0101	0.9787
13	n-C4H10	normal-Butane	67.691	2.7048	0.9587
14	C2H2	Acetylene	97.374	1.1728	0.9905
15	C2H4	Ethylene	94.690	1.2611	0.9925
16	i-C4H10	iso-Butane	68.759	2.6893	0.9627
17	Kr	Krypton	232.175	3.7422	0.9991
18	Xe	Xenon	212.085	5.8988	0.9931
19	SF6	Sulfur Hexafluoride	140.890	6.6154	0.9850
20	C-25	75% Argon / 25% CO2	190.579	1.8309	0.9982
21	C-10	90% Argon / 10% CO2	201.897	1.8027	0.9987
22	C-8	92% Argon / 8% CO2	203.423	1.7989	0.9988
23	C-2	98% Argon / 2% CO2	208.022	1.7877	0.9990
24	C-75	75% CO2 / 25% Argon	154.328	1.9270	0.9954
25	A-75	75% Argon / 25% Helium	214.808	1.3821	0.9995
26	A-25	75% Helium / 25% Argon	218.962	0.5794	1.0002
27	A1025	90% Helium / 7.5% Argon / 2.5% CO2 (Praxair - Helistar® A1025)	201.284	0.3434	1.0002
28	Star29	90% Argon / 8% CO2 / 2% Oxygen (Praxair - Stargon® CS)	203.139	1.7918	0.9988
29	P-5	95% Argon / 5% Methane	207.633	1.7307	0.9990
*in micropoise (1 Poise = gram / (cm) (sec)) ** Grams/Liter (NIST REFPROP 7 database)					

Gas Viscosities, Densities and Compressibilities at 0° C

Volumetric Flow Meters Under Pressure

16 Series Volumetric Gas Flow Meters and Flow Controllers are intended for use in low pressure applications. This is because an accurate measurement of the volumetric flow rate by means of differential pressure requires the flow at the differential pressure sensor to be in a laminar state. The state of the flow is quantified by what is known as the Reynolds Number. If the Reynolds Number gets above a certain point, generally accepted as approximately 2000, the flow will become non-laminar. The Reynolds Number for a given Newtonian fluid flow is defined as:

$$Re = \rho VL/\eta$$

Where: ρ =   density
                    V =   average velocity
                    L =   Constant determined by length and geometry of passage
                    η =   absolute viscosity

From this relationship we see that increasing the gas density or velocity increases the Reynolds Number, and increasing the gas viscosity decreases the Reynolds number. For a given gas in a given meter at a given temperature, L and η are roughly fixed constants.

For the purpose of illustration, let us put two 100 (S)LPM flow meters, identical in every way except that one is a volumetric flow meter and one is a mass flow meter, in series with one another in a pipeline. Now let us pass a small constant air flow through the meters, thus fixing the velocity V though both meters. With the flow fixed, let us begin increasing the pressure, and thus the density ρ. The mass flow meter, which is measuring the absolute pressure and compensating for the density change registers this pressure increase as an increase in mass flow rate because the number of molecules of gas keeps going up in the fixed volume of flow. In addition, the Reynolds number has increased proportionately with the pressure increase because the density goes up with the pressure. If you increase the pressure high enough, the mass flow meter will max out at 100 SLPM, the Reynolds number has increased fairly dramatically, and the volumetric meter still registers your small fixed flow rate.

Now if we maintain the higher pressure and try to take the volumetric meter up to its published full scale flow of 100 LPM, our density ρ AND our velocity V will be high, which often results in a high Reynolds number and non-laminar flow. When the flow is non-laminar, the Poiseuille Equation upon which we base our volumetric flow measurement is no longer valid and the meter reading is therefore no longer valid.

Gas properties also need to be taken into account in deciding whether you can use a volumetric flow meter at a particular line pressure. Helium, which has a relatively low density and a relatively high viscosity at standard conditions, can generally get away with higher pressures in a volumetric flow meter. Propane, on the other hand, has a relatively high density and relatively low viscosity making it a considerably more difficult gas to measure at higher pressures in a volumetric flow meter. In air, most volumetric meters make valid full scale measurements up to 10-15 PSIG line pressure.

TROUBLESHOOTING

Display does not come on or is weak.
Check power and ground connections.

Flow reading is approximately fixed either near zero or near full scale regardless of actual line flow.
Differential pressure sensor may be damaged. Avoid installations that can subject sensor to pressure drops in excess of 10 PSID. A common cause of this problem is instantaneous application of high-pressure gas as from a snap acting solenoid valve upstream of the meter. Damage due to excessive pressure differential is not covered by warranty.

Displayed mass flow, volumetric flow, pressure or temperature is flashing and message MOV, VOV, POV or TOV is displayed:
Our flow meters and controllers display an error message (MOV = mass overrange, VOV = volumetric overrange, POV = pressure overrange, TOV = temperature overrange) when a measured parameter exceeds the range of the sensors in the device. When any item flashes on the display, neither the flashing parameter nor the mass flow measurement is accurate. Reducing the value of the flashing parameter to within specified limits will return the unit to normal operation and accuracy.

After installation, there is no flow.
Apex MC and VC controllers incorporate normally closed valves and require a set-point to operate. Check that your set-point signal is present and supplied to the correct pin and that the correct input is selected under the Input list in the control set up mode screen. Also check that the unit is properly grounded.

The flow lags below the set-point.
Be sure there is enough pressure available to make the desired flow rate. If either the set-point signal line and/or the output signal line is relatively long, it may be necessary to provide heavier wires (especially ground wiring) to negate voltage drops due to line wire length. An inappropriate PID tuning can also cause this symptom if the D term is too large relative to the P term.

Meter does not agree with another meter I have in line.
Volumetric meters will often not agree with one another when put in series because they are affected by pressure drops. Volumetric flow meters should not be compared to mass flow meters. Mass flow meters can be compared against one another provided there are no leaks between the two meters and they are set to the same standard temperature and pressure. Both meters must also be calibrated (or set) for the gas being measured. M Series mass flow meters are normally set to Standard Temperature and Pressure conditions of 25° C and 14.696 PSIA. Note: it is possible to special order meters with a customer specified set of standard conditions. The calibration sheet provided with each meter lists its standard conditions.

Controller is slow to react to a set-point change or imparts an oscillation to the flow.
An inappropriate PID tuning can cause these symptoms. Use at conditions considerably different than those at which the device was originally set up can necessitate a re-tuning of the PID loop.

The output signal is lower than the reading at the display.
This can occur if the output signal is measured some distance from the meter as voltage drops in the wires increase with distance. Using heavier gauge wires, especially in the ground wire, can reduce this effect.

My volumetric controller reading is strange, inconsistent, or incorrect.
Make sure you use a volumetric flow controller only under low pressure (close to atmospheric) and with little to no back pressure for accurate readings. Mass controllers should be used for higher pressure applications. See "Volumetric Flow Meters Under Pressure" page 30.

RS-232 Serial Communications is not responding.

Check that your meter is powered and connected properly. Be sure that the port on the computer to which the meter is connected is active. Confirm that the port settings are correct per the RS-232 instructions in this manual (Check the RS-232 communications select screen for current meter readings). Close Hyperterminal® and reopen it. Reboot your PC.

Slower response than specified.

MC and VC Series controllers feature an RS-232 programmable Geometric Running Average (GRA). Depending on the full scale range of the meter, it may have the GRA set to enhance the stability/readability of the display, which would result in slower perceived response time. If you require the fastest possible response time, please consult the factory for written instructions on adjusting the GRA.

Jumps to zero at low flow.

MC and VC Series controllers feature an RS-232 programmable zero deadband. The factory setting is usually 0.5% of full scale. This can be adjusted via RS-232 programming between NONE and 6.375% of full scale. Contact the factory for more information.

Discrepancies between old and new units.

Please see "Standard Gas Data Tables" explanation on page 29.

Maintenance and Recalibration

General: MC and VC Series Flow Controllers require minimal maintenance. They have no moving parts. The single most important thing that affects the life and accuracy of these devices is the quality of the gas being measured. The controller is designed to measure CLEAN, DRY, NON-CORROSIVE gases. A 20 micron filter (50 micron for 50LPM and up) mounted upstream of the controller is highly recommended. Moisture, oil, and other contaminants can affect the laminar flow elements and/or reduce the area that is used to calculate the flow rate. This directly affects the accuracy.

Recalibration: The recommended period for recalibration is once every year. Providing that the CLEAN, DRY, and NON-CORROSIVE mantra is observed, this periodic recalibration is sufficient. A label located on the back of the meter lists the recalibration due date. The meter should be returned to the factory for recalibration near the listed due date. Before calling to schedule a recalibration, please note the serial number on the back of the meter. The Serial Number, Model Number, and Date of Manufacture are also available on the Manufacture Data 2 screen (page 16).

Cleaning: MC and VC Series Flow Controllers require no periodic cleaning. If necessary, the outside of the controller can be cleaned with a soft dry rag. Avoid excess moisture or solvents.

For repairs, recalibrations, or recycling of this product contact:

Apex Vacuum
222 Riverstone Drive
Canton, GA 30114
USA
Ph. 404-474-3115

Website: www.apexvacuum.com

Technical Data for Micro Flow Mass & Volumetric Flow Controllers
0-0.5SCCM Full Scale up to 0-50SCCM Full Scale

Specification	Mass Controller	Volumetric Controller	Description
Accuracy	± 0.8% of Reading ±0.2% of Full Scale		At calibration conditions after tare
High Accuracy Option	± 0.4% of Reading ±0.2% of Full Scale		At calibration conditions after tare
Repeatability	± 0.2%		Full Scale
Operating Range	1% to 100% Full Scale		Measure
Typical Response Time	100		Milliseconds (Adjustable)
Standard Conditions (STP)	25ºC & 14.696PSIA	Not Applicable	Mass Reference Conditions
Operating Temperature	−10 to +50		ºCelsius
Zero Shift	0.02%		Full Scale / ºCelsius / Atm
Span Shift	0.02%		Full Scale / ºCelsius / Atm
Humidity Range	0 to 100%		Non–Condensing
Controllable Flow Rate	102.4%		Full Scale
Maximum Pressure	125	125[1]	PSIG
Input /Output Signal Digital	Mass, Volume, Pressure & Temperature	Volumetric Flow	RS-232 Serial
Input / Output Signal Analog	Mass Flow	Volumetric Flow	0-5Vdc
Optional Input / Output Signal Secondary Analog	Mass, Volume, Pressure or Temperature	Volumetric Flow	0-5 Vdc or 0-10Vdc or 4-20mA
Electrical Connections	8 Pin		Mini-DIN
Supply Voltage	12 to 18 Vdc (15-30Vdc for 4-20mA outputs)[2]		
Supply Current	0.250		
Mounting Attitude Sensitivity	0%		
Warm-up Time	< 1		Second
Wetted Materials	303 & 302 Stainless Steel, Viton®, Silicon, RTV, Glass Reinforced Nylon, Aluminum, Brass, 410 Stainless Steel, Buna-N.		

1. Volumetric meters only: Operating pressure limitations determined by Reynolds number thresholds. For operating pressures >10PSIG, please contact the manufacturer for more details.
2. 24 volt applications should specify 24 volt coils.

Mechanical Specifications

Full Scale Flow Mass Controller	Full Scale Flow Volumetric Controller	Mechanical Dimensions	Process Connections[1]	Pressure Drop[2] (PSID)
0.5SCCM up to 1SCCM	0.5CCM up to 1CCM	3.9"H x 3.5"W x 1.1"D	**10-32 Female Thread***	0.5
2SCCM up to 50SCCM	2CCM up to 50CCM			1.0

* Units ≤50SCCM F.S. are shipped with 10-32 Male Buna-N O-ring face seal to 1/8" Female NPT fittings. These adaptor fittings were selected for customer convenience in process connection. It should be noted that the 1/8" Female NPT introduces additional dead volume. To minimize dead volume, please see Accessories for the 10-32 Male to 1/8"OD compression fitting.
1. Compatible with Beswick®, Swagelok® tube, Parker®, face seal, push connect and compression adapter fittings.
2. Lower Pressure Drops Available, please contact the manufacturer.

Dimensional Drawings: page 38

Technical Data for Low Flow Mass & Volumetric Flow Controllers
>50SCCM Full Scale up to 0-20SLPM Full Scale

Specification	Mass Controller	Volumetric Controller	Description
Accuracy	± 0.8% of Reading	±0.2% of Full Scale	At calibration conditions after tare
High Accuracy Option	± 0.4% of Reading	±0.2% of Full Scale	At calibration conditions after tare
Repeatability	± 0.2%		Full Scale
Operating Range	1% to 100% Full Scale		Measure
Typical Response Time	100		Milliseconds (Adjustable)
Standard Conditions (STP)	25ºC & 14.696PSIA	Not Applicable	Mass Reference Conditions
Operating Temperature	−10 to +50		ºCelsius
Zero Shift	0.02%		Full Scale / ºCelsius / Atm
Span Shift	0.02%		Full Scale / ºCelsius / Atm
Humidity Range	0 to 100%		Non–Condensing
Controllable Flow Rate	102.4%		Full Scale
Maximum Pressure	125	125[1]	PSIG
Input /Output Signal Digital	Mass, Volume, Pressure & Temperature	Volumetric Flow	RS-232 Serial
Input / Output Signal Analog	Mass Flow	Volumetric Flow	0-5Vdc
Optional Input / Output Signal Secondary Analog	Mass, Volume, Pressure or Temperature	Volumetric Flow	0-5 Vdc or 0-10Vdc or 4-20mA
Electrical Connections	8 Pin		Mini-DIN
Supply Voltage	12 to 18 Vdc (15-30Vdc for 4-20mA outputs)[2]		
Supply Current	0.250 Amp		
Mounting Attitude Sensitivity	0%		Tare after installation
Warm-up Time	< 1		Second
Wetted Materials	303 & 302 Stainless Steel, Viton®, Silicon, RTV, Glass Reinforced Nylon, Aluminum.		

1. Volumetric meters only: Operating pressure limitations determined by Reynolds number thresholds. For operating pressures >10PSIG, please contact the manufacturer for more details.
2. 24 volt applications should specify 24 volt coils.

Mechanical Specifications

Full Scale Flow Mass Controller	Full Scale Flow Volumetric Controller	Mechanical Dimensions	Process Connections[1]	Pressure Drop[2] (PSID)
>50SCCM to 500SCCM	>50CCM to 500CCM	4.1"H x 3.6"W x 1.1"D	1/8" NPT Female	1.0
1SLPM	1LPM			1.5
5SLPM	5LPM			2.0
10SLPM	10LPM			5.0
20SLPM	20LPM	4.2"H x 2.4"W x 1.1"D		20.0

1. Compatible with Beswick®, Swagelok® tube, Parker®, face seal, push connect and compression adapter fittings.
2. Lower Pressure Drops Available, please contact the manufacturer.

Dimensional Drawings: page 38, 39

Technical Data for Moderate Flow Mass & Volumetric Flow Controllers
>20SLPM Full Scale up to 0-250SLPM Full Scale

Specification	Mass Controller	Volumetric Controller	Description
Accuracy	± 0.8% of Reading ±0.2% of Full Scale		At calibration conditions after tare
High Accuracy Option	± 0.4% of Reading ±0.2% of Full Scale		At calibration conditions after tare
Repeatability	± 0.2%		Full Scale
Operating Range	1% to 100% Full Scale		Measure
Typical Response Time	100		Milliseconds (Adjustable)
Standard Conditions (STP)	25ºC & 14.696PSIA	Not Applicable	Mass Reference Conditions
Operating Temperature	−10 to +50		ºCelsius
Zero Shift	0.02%		Full Scale / ºCelsius / Atm
Span Shift	0.02%		Full Scale / ºCelsius / Atm
Humidity Range	0 to 100%		Non–Condensing
Controllable Flow Rate	102.4%		Full Scale
Maximum Pressure	125	125[1]	PSIG
Input /Output Signal Digital	Mass, Volume, Pressure & Temperature	Volumetric Flow	RS-232 Serial
Input / Output Signal Analog	Mass Flow	Volumetric Flow	0-5Vdc
Optional Input / Output Signal Secondary Analog	Mass, Volume, Pressure or Temperature	Volumetric Flow	0-5 Vdc or 0-10Vdc or 4-20mA
Electrical Connections	8 Pin		Mini-DIN
Supply Voltage	24-30Vdc		
Supply Current	1.0 Amp maximum		
Mounting Attitude Sensitivity	0%		Tare after installation
Warm-up Time	< 1		Second
Wetted Materials	303 & 302 Stainless Steel, Viton®, Silicon, RTV, Glass Reinforced Nylon, Aluminum, 410 & 416 Stainless Steel, Nickel.		
1. Volumetric meters only: Operating pressure limitations determined by Reynolds number thresholds. For operating pressures >10PSIG, please contact the manufacturer for more details.			

Mechanical Specifications

Full Scale Flow Mass Controller	Full Scale Flow Volumetric Controller	Mechanical Dimensions	Process Connections[1]	Pressure Drop[2] (PSID)
>20SLPM	>20LPM	4.7"H x 6.9"W x 2.3"D	1/4" NPT Female	2.5
100SLPM	100LPM	4.7"H x 7.4"W x 2.3"D		5.0
250SLPM	250LPM	5.0"H x 6.9"W x 2.3"D	1/2" NPT Female	10.0
1. Compatible with Beswick®, Swagelok® tube, Parker®, face seal, push connect and compression adapter fittings.				
2. Lower Pressure Drops Available, please contact the manufacturer.				

Dimensional Drawings: page 39, 40

# Technical Data for High Flow Mass & Volumetric Flow Controllers
>250 SLPM Full Scale up to 0-1500 SLPM Full Scale

Specification	Mass Controller	Volumetric Controller	Description
Accuracy	± 0.8% of Reading	±0.2% of Full Scale	At calibration conditions after tare
High Accuracy Option	± 0.4% of Reading	±0.2% of Full Scale	At calibration conditions after tare
Repeatability	± 0.2%		Full Scale
Operating Range	1% to 100% Full Scale		Measure
Typical Response Time	100		Milliseconds (Adjustable)
Standard Conditions (STP)	25ºC & 14.696PSIA	Not Applicable	Mass Reference Conditions
Operating Temperature	−10 to +50		ºCelsius
Zero Shift	0.02%		Full Scale / ºCelsius / Atm
Span Shift	0.02%		Full Scale / ºCelsius / Atm
Humidity Range	0 to 100%		Non–Condensing
Controllable Flow Rate	102.4%		Full Scale
Maximum Pressure	125	125*	PSIG
Input /Output Signal Digital	Mass, Volume, Pressure & Temperature	Volumetric Flow	RS-232 Serial
Input / Output Signal Analog	Mass Flow	Volumetric Flow	0-5Vdc
Optional Input / Output Signal Secondary Analog	Mass, Volume, Pressure or Temperature	Volumetric Flow	0-5 Vdc or 0-10Vdc or 4-20mA
Electrical Connections	8 Pin		Mini-DIN
Supply Voltage	24 to 30 Vdc		
Supply Current	1.0Amp maximum		
Mounting Attitude Sensitivity	0%		
Warm-up Time	< 1		Second
Wetted Materials	303 & 302 Stainless Steel, Viton®, Silicon, RTV, Glass Reinforced Nylon, Aluminum, 410 & 416 Stainless Steel, Nickel.		

* Volumetric meters only: Operating pressure limitations determined by Reynolds number thresholds. For operating pressures >10PSIG, please contact the manufacturer for more details.

Mechanical Specifications

Full Scale Flow Mass Controller	Full Scale Flow Volumetric Controller	Mechanical Dimensions	Process Connections[1]	Pressure Drop[2] (PSID)
>250SLPM	>250LPM			4.1
1000SLPM	1000LPM	5.0"H x 7.4"W x 2.3"D	3/4" NPT Female	12.3
1500SLPM	1500LPM			23.3

1. Compatible with Beswick®, Swagelok® tube, Parker®, face seal, push connect and compression adapter fittings.
2. Lower Pressure Drops Available, Please contact the manufacturer.
Controllers ≥ 500 (S)LPM utilize a low drop valve that seals off only in the positive flow direction. If the downstream pressure exceeds the inlet pressure, reverse flow will occur.

Dimensional Drawings: page 40

MC & VC Series:
0 - 0.5SCCM
0 - 1SCCM
0 - 2SCCM
0 - 5SCCM
0 - 10SCCM
0 - 20SCCM
0 - 50SCCM

.478

.525

10-32 Thread both sides

3.867

3.527

Flow →

.336

.525

1.050

2.225

.150

.125

.925

8-32 X .350 ⤓ 2PL

MC & VC Series:
0 - 100SCCM
0 - 200SCCM
0 - 500SCCM
0 - 1SLPM
0 - 2SLPM
0 - 3SLPM
0 - 5SLPM
0 - 10SLPM

Ø .332 ⤓ .438
1/8 NPT

.358

.525

4.082

Flow →

3.588

.358

.525

1.050

.125

.925

2.225

.150

2X Ø .136 ⤓ .446
8-32 UNC - 2B ⤓ .350

MC & VC Series:
0 - 20SLPM

PSIA 13.49   C +22.73   Sol Pt 0.00
+0.000   SLPM
+0.000 +0.000   Air
Volume Mass   Main

Flow →

4.167

3.588

.358
.525
1/8" NPT Both Ends

2.225   .150   .125
.925

8-32 x .350 ▽ 2 PL

.358
.525
1.050

MC & VC Series:
0 - 50SLPM
0 - 100SLPM

4.667

.800
1.125
1/4 NPT

+0.000
Flow →

Approx 7.4320

1/4 NPT
.800
1.125
2.250

2.280   3.250
.375   .280   .750   .500
1.875   1.750

2X 8-32 UNC - 2B ▽ .500
4X 8-32 UNC - 2B ▽ .375

MC & VC Series:
0 - 250SLPM

.800

1.125

1/2 NPT Thread
Both sides

4.967

6.935

.800

1.125

2.250

2.280   3.250   .750   .500

.375   .280

1.875   1.750

8-32 X 350 ▽ 6PL
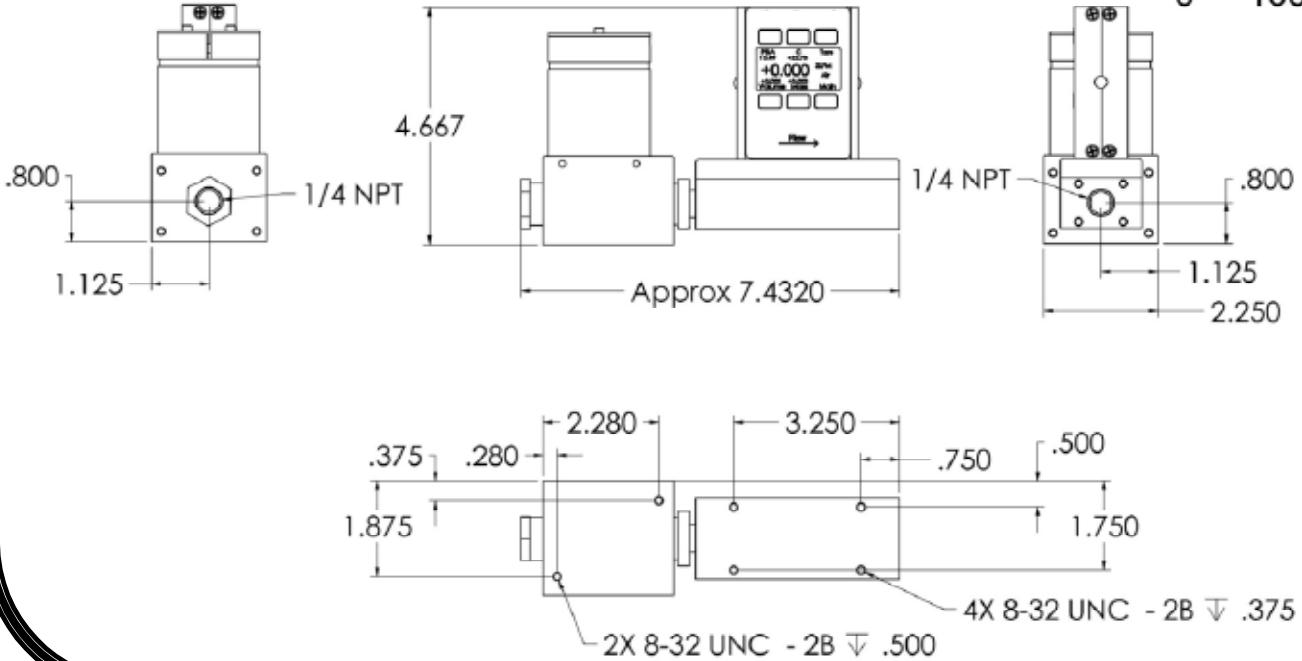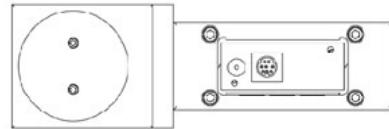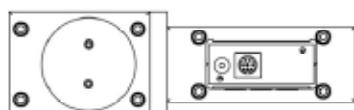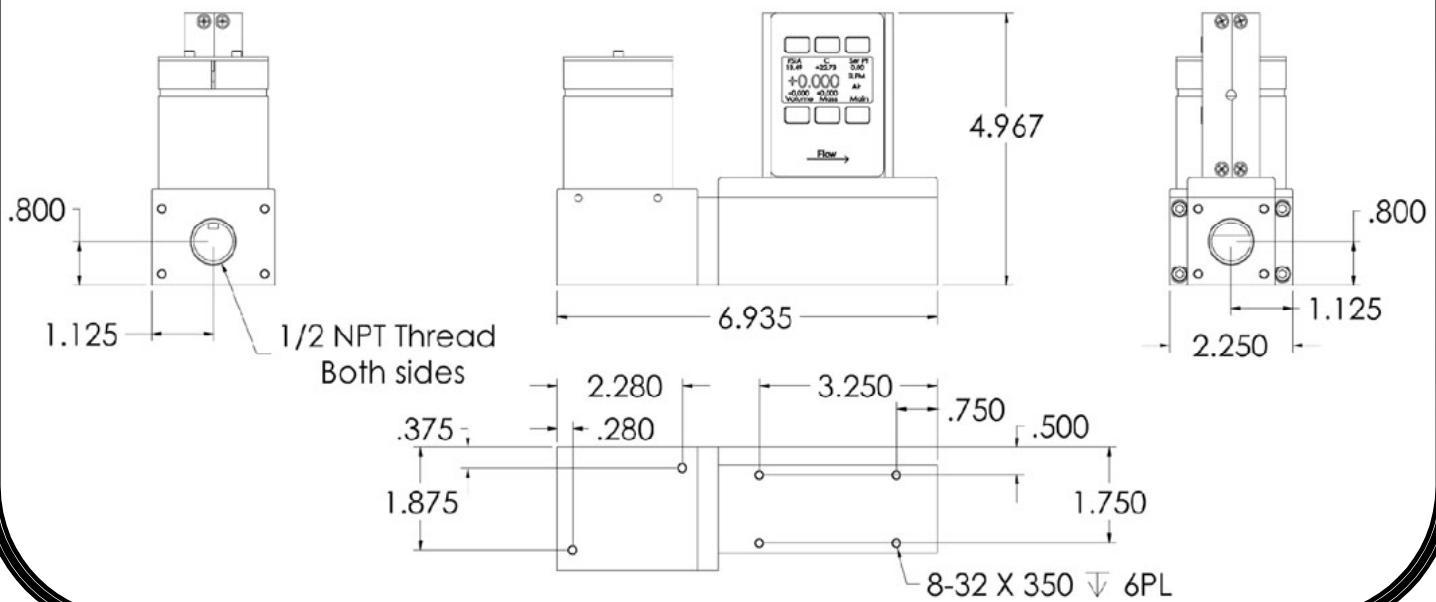
MCR & VCR Series:
0 - 500SLPM
0 - 1000SLPM
0 - 1500SLPM

3/4 NPT Thread
Both sides

1.187

1.125

5.587

7.375

.800

1.125

2.250

2.750   3.250   .750   .500

.375   .250

1.875   1.750

4X ⌀ .136 ▽ .500
8-32 UNC - 2B ▽ .328

4X ⌀ .136 ▽ .531
8-32 UNC - 2B ▽ .375
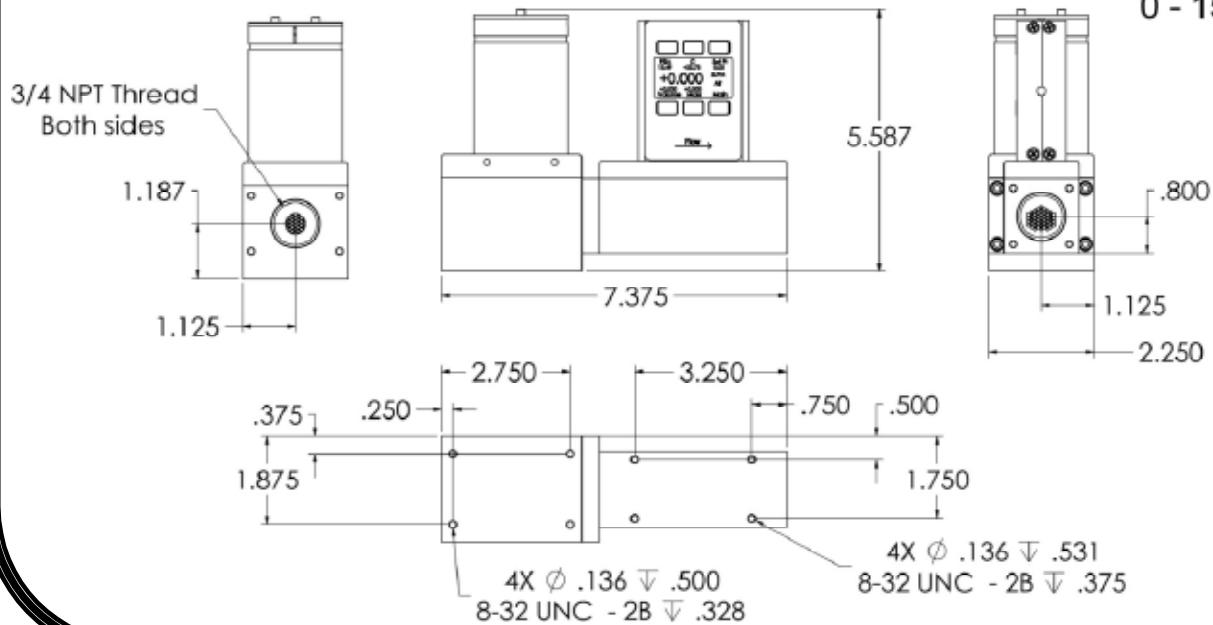
Option: Totalizing Mode

16 Series Flow Meters and Controllers can be purchased with the Totalizing Mode option. This option adds an additional mode screen that displays the total flow (normally in the units of the main flow screen) that has passed through the meter or controller since the last time the totalizer was cleared. The Totalizing Mode screen shown below is accessed by pushing the "MODE" button until the label over it reads "Total". *If your meter or controller is ordered with Totalizing Mode option, pushing the "Mode" button once will bring up the "Totalizing Mode" display. Pushing "Mode" a second time will bring up the "Select Menu" display. Pushing it a third time will return you to the Main Mode Sreen.*
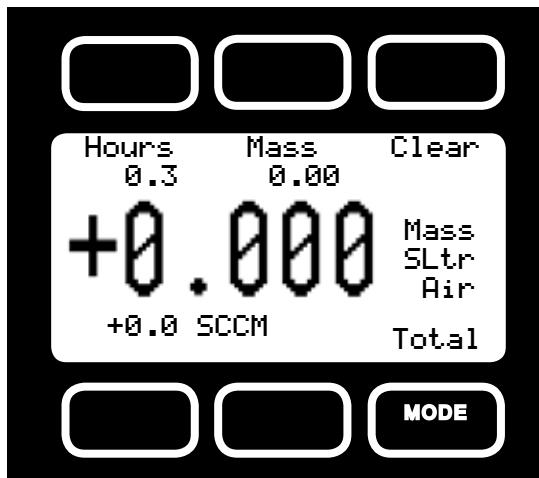
Counter – The counter can have as many as six digits. At the time of order, the customer must specify the resolution of the count. This directly affects the maximum count. For instance, if a resolution of 1/100ths of a liter is specified on a meter which is totalizing in liters, the maximum count would be 9999.99 liters. If the same unit were specified with a 1 liter resolution, the maximum count would be 999999 liters.

Rollover – The customer can also specify at the time of order what the totalizer is to do when the maximum count is reached. The following options may be specified:

No Rollover – When the counter reaches the maximum count it stops counting until the counter is cleared.
Rollover – When the counter reaches the maximum count it automatically rolls over to zero and continues counting until the counter is cleared.
Rollover with Notification – When the counter reaches the maximum count it automatically rolls over to zero, displays an overflow error, and continues counting until the counter is cleared.

Hours.–.The display will show elapsed time since the last reset in 0.1 hour increments. The maximum measurable elapsed time is 6553.5 hours (about nine months). The hours count resets when the "clear" button is pushed, an RS-232 clear is executed or on loss of power

Clear – The counter can be reset to zero at any time by pushing the dynamically labeled "Clear" button located above the upper right corner of the display. To clear the counter via RS-232, establish serial communication with the meter or controller as described in the RS-232 section of the manual. To reset the counter, enter the following commands:

In Streaming Mode: $$T <Enter>

In Polling (addressable) Mode: Address$$T <Enter>   (e.g. B$$T <Enter>)

Option: Local Set-Point Module

The Local Set-Point Module (**LSPM**) is designed to provide the user with a simple "turn of the dial" method of changing a flow or pressure controller set-point.
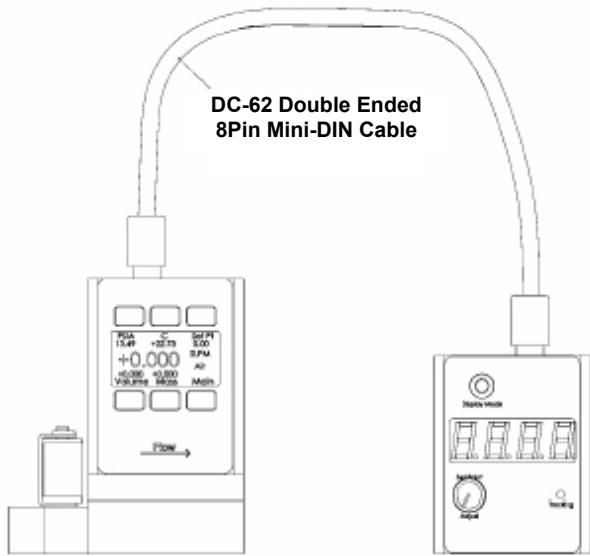
The LSPM features a set-point control dial, a digital LED display which can be set to show either the set-point or the actual process measurement, and a tracking alarm LED which glows red whenever the actual process measurement deviates from the set-point by more than 2% of full scale. This device is handy as a remote control/display device where the controller is out of convenient reach or view. It is supplied with a 6' double ended cable to run between the controller and the LSPM. There is an additional 8 pin Mini-DIN port on the LSPM that allows access to normal signal/power functions of the controller's Mini-DIN port.

- 8 Pin Mini-DIN connector connects to controller or to external device for power or output signal recording
- LCD Display can display either the set-point or the process measurement.
- Set-point Adjustment Knob provides simple "dial it in" process changes.
- Display button switches display between actual set-point and measured flow parameter.
- LED indicator switches from green to red when the measured parameter deviates from the set-point by more than 2% of full scale.

Operation Notes: The LSPM requires a double ended DC-62 8 Pin Mini-DIN cable connected between either the top or bottom connector socket of the LSPM to the connector socket on top of the controller. The two connector sockets on the LSPM are "pass through" connected so that the unused socket can be connected to a DC-61 single ended cable for connection of output signals and/or power. Appropriate power can be connected to either the LSPM or the controller, whichever is more convenient. Unless specially ordered otherwise, the LSPM utilizes the 5.12 Vdc output pin on the controller (pin 2) as a source. The 5.12 volts is connected through the potentiometer and returned to the controller on the set-point pin (pin 4) as a 0 though 5.12 Vdc input signal depending on the position of the adjustment knob.
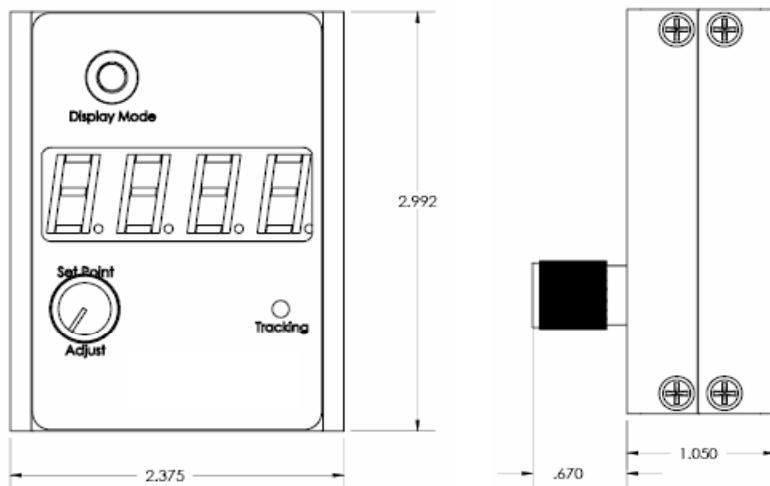
Accessories
Local Set-Point Module
Multi-Drop Box
8 Pin Male Mini-DIN connector cable, single ended, 6 foot length
8 Pin Male Mini-DIN connector cable, double ended, 6 foot length
8 Pin Male Mini-DIN connector cable, single ended, 25 foot length
8 Pin Male Right Angle Mini-Din Cable, single ended, 6 foot length
8 Pin Male Mini-DIN to DB9 Female Adaptor 6 foot length
AC to DC 12 Volt Power Supply Adapter
AC to DC 24 Volt Power Supply Adapter
AC to DC 12 Volt European Power Supply Adapter
AC to DC 24 Volt European Power Supply Adapter
Industrial cable, 6 Pin, single ended, 10 foot length

Flow Conversion Table:

	CCM	CCH	LPM	LPH	CFM	CFH
CFH	0.0021	0.00003	2.1189	0.035	60.0	1.0
CFM	0.000035	0.0000005	0.035	0.00059	1.0	0.0166
LPH	0.06	0.001	60.0	1.0	1699.0	28.316
LPM	0.001	0.000017	1.0	0.0166	28.316	0.4719
CCH	60.0	1.0	60000.0	1000.0	1699011.0	28317.0
CCM	1.0	0.0167	1000.0	16.667	28317.0	471.947

Serial Number: _____

Model Number: _____

Calibration Certificate

(Store device calibration certificate in the pocket below.)