

FLOGAT



16 Series Mass and Volumetric Flow Meters

Precision Gas Flow Meter Operating Manual

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Wide-Range Laminar Flow Element Patent:

The wide-range laminar flow element and products using the wide-range laminar flow element are covered by U.S. Patent Number: 5,511,416. Manufacture or use of the wide-range laminar flow element in products other than products licensed under said patent will be deemed an infringement.

Table of Contents	Page
Introduction	1
Operating Principle	1
Gas Viscosity	2
Other Gases	2
Volumetric Flow vs. Mass Flow	3
Volumetric Flow and Mass Flow Conversion	3
Installation	5
Plumbing	5
Mounting	5
Application	5
Power and Signal Connections	6
V Series Volumetric Flow Meter Operations	10
Main Mode	10
Mode	10
Tare	10
Volumetric Flow Meters Under Pressure	11
Gas Select Mode	12
Identity Mode	12
M Series Mass Flow Meter Operations	13
Main Mode	13
Mode	13
Tare	13
Gas Absolute Pressure	14
Gas Temperature	14
Volumetric Flow Rate	14
Mass Flow Rate	14
Gas Select Mode	14
Identity Mode	15
RS-232 Output and Input	15
Configuring Hyperterminal®	15
Changing from Streaming to Polling Mode	15
Tare	16
Gas Select	16
Collecting Data	17
Data Format	17
Sending a Simple Script File to Hyperterminal®	18
Options	19
Totalizing Mode Screen	19
9 Volt Battery Pack	20
Troubleshooting	22
Maintenance and Recalibration	23
Warranty	23

Table of Contents continued	
Additional Information	24
Accessories	24
Gas Viscosity Table	24
Gas Density Table	25
Flow Conversion Table	25
Performance Specifications	26
Conformity / Supplemental Information	26
Dimensional Drawings	27

Table of Figures	Page
Figure 1. 8 Pin Mini-DIN Connector	6
Figure 2. Mini-DIN to DB-9 Connection for RS-232 Signals	8
Figure 3. Typical Multiple Device (Addressable) Wiring Configuration	8
Figure 4. Optional Industrial Connector	9
Figure 5. Proper set up for remote tare on meters	9
Figure 6. Main Mode Display, V Series Flow Meter	10
Figure 7. Gas Select Mode	12
Figure 8. Identity Mode	12
Figure 9. Main Mode Display, M Series Flow Meter	13
Figure 10. Back Cover Removal	21
Figure 11. Battery Pack Installation/Removal	21

Introduction

Thank you for purchasing a V or M Series Gas Flow Meter. Please take the time to find and read the pertinent information contained in this manual for your specific device. This will help to ensure that you get the best possible service life from your instrument. This manual covers the following FloCat instruments:

V Series 16 Bit Volumetric Gas Flow Meters
M Series 16 Bit Mass Gas Flow Meters

The 16 Series data presentation format utilizes a full graphic display that allows simultaneous viewing of all operating parameters. Selected parameters can be toggled to the large primary display for ease of viewing.

Operating Principle

All V or M Series Gas Flow Meters 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:

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

Where: Q = Volumetric Flow Rate
P₁ = Static pressure at the inlet
P₂ = 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:

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

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 12). 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 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 V and M Series internally compensate for this change.

Other Gases: M Series Flow Meters 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 184.332 micropoise.

At 25°C, the absolute viscosity of Argon (η_{og}) is 225.987 micropoise.

- $Q_{og} = Q_1 (\eta_1 / \eta_{og})$
- $Q_{og} = 110 \text{ SLPM } (184.332 / 225.987)$
- $Q_{og} = 89.72 \text{ SLPM}$

So, the actual flow of Argon through the meter is 89.72 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 standard 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/min)

Gas: Helium

Gas Density at 25C and 14.696 PSIA = .1636 grams/Liter

True Mass Flow = (Mass Flow Meter Reading) X (Gas Density)

True Mass Flow = (250 CC/min) X (1 Liter/ 1000 CC) X (.1636 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:

$$\text{Mass} = \text{Volume} \times \text{Density}$$

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.

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 reference 25°C and 14.695 PSIA (101.32kPa) - unless ordered otherwise. Refer to the calibration sheet to confirm the reference point.

Installation

Plumbing

All V or M Series Gas Flow Meters 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 meter. The inlet and outlet ports are equal in size and symmetric (in-line). Normally speaking, the port sizes and dimensions for differing flow ranges are as follows:

Flow Range	Height	Length	Depth	Port Size
.5 to 50 (S)CCM	3.867"	2.375"	1.05"	10-32 UNF
50+ (S)CCM to 20 (S)LPM	4.167"	2.375"	1.05"	1/8" NPT(F)
20+ to 100 (S)LPM	4.367"	4.0"	1.6"	1/4" NPT(F)
100+ to 250 (S)LPM	4.967"	4.0"	1.6"	1/2" NPT(F)
250+ to 1000 (S)LPM	4.967"	4.0"	1.6"	3/4" NPT(F)

Meters with 10-32 ports have o-ring face seals and require no further sealant or tape. On other meters, avoid the use of pipe dopes or sealants on the ports as these compounds can cause permanent damage to the meter 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 out of the threads that may come loose and enter the flow stream. In addition, it is recommended that a 20 micron filter be installed upstream of meters with full scale ranges of 1 (S)LPM or less and a 50 micron filter be installed upstream of meters with full scale ranges above 1 (S)LPM.

Mounting

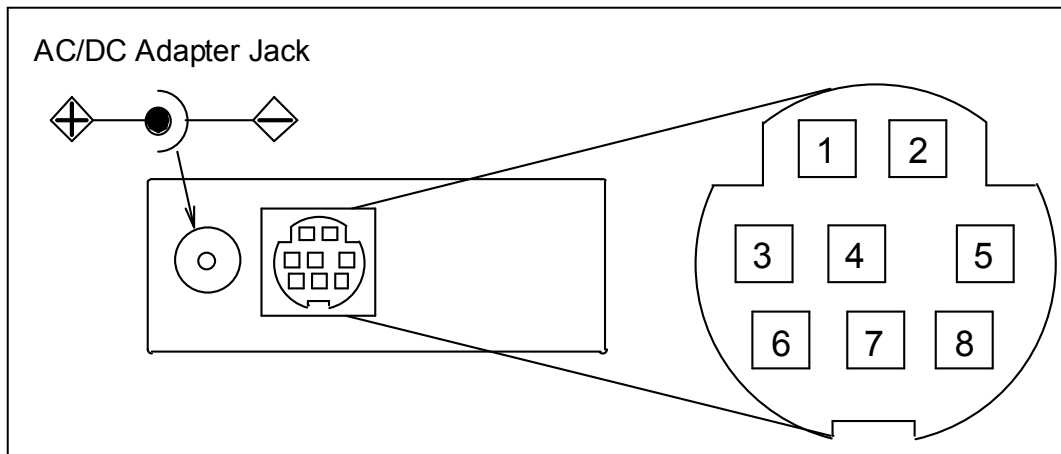
All V or M Series Gas Flow Meters have mounting holes for convenient mounting to flat panels. These meters are position insensitive and can be mounted in any orientation. The sizes and dimensions for these holes are shown on pages 27-29 of this manual.

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. Although the meter's operation is uni-directional, reversing the flow direction will inflict no damage as long as the maximum specified limits are not exceeded. The differential pressure sensor utilized in V or M Series Gas Flow Meters is a very sensitive device capable of detecting minute differences in pressure. Avoid installations (such as snap acting solenoid valves upstream) that apply instantaneous high pressure to the meter as permanent damage to the differential pressure sensor could result. This damage is not covered under warranty!

Power and Signal Connections

Power can be supplied to your V or M Series meter 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 between 9 and 30 volts is required to use the power jack. The adapter current should be at least 100mA. The power jack accepts 2.1 mm female power plugs with positive centers. *Cables and AC/DC adapters may purchased from the manufacturer (see Accessories page 24)* and are commonly available at local electronics suppliers. Alternatively, power can be supplied through the Mini-DIN connector as shown below:



Pin	Function	Mini-Din Cable Color Code
1	4-20mA Output Signal	Black
2	5.12 Vdc or Auxiliary Output	Brown
3	RS-232 Input Signal	Red
4	Remote Tare (Ground to Tare)	Orange
5	RS-232 Output Signal	Yellow
6	0-5 Vdc (or 0-10 Vdc) Output Signal	Green
7	Power In (9-30 Vdc, 100mA)	Blue
8	Ground (common)	Purple

Figure 1. 8 Pin Mini-DIN Connector

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.

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 2, 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

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 2. Adapter cables are available from the manufacturer or they can be constructed in the field with parts from a local electronic supply house. In Figure 2, 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 2. (See page 15 for details on accessing RS-232 output.)

Standard Voltage (0-5 Vdc) Output Signal

All M and V series flow meters 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 meter 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 meter 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 meter 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 meter to determine which output signals were ordered.) The current signal is 4 mA at 0 flow and 20 mA at the meter’s full scale flow. The output current is linear over the entire range. Ground for this signal is common on Pin 8. **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 meter 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 meter 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 meter could output the mass flow rate (0-5 Vdc on pin 6) and the absolute pressure (0-5 Vdc on pin 2). This ability makes these devices exceedingly versatile. **Note:** *This is a current sourcing device. Do not attempt to connect it to “loop powered “ systems.*

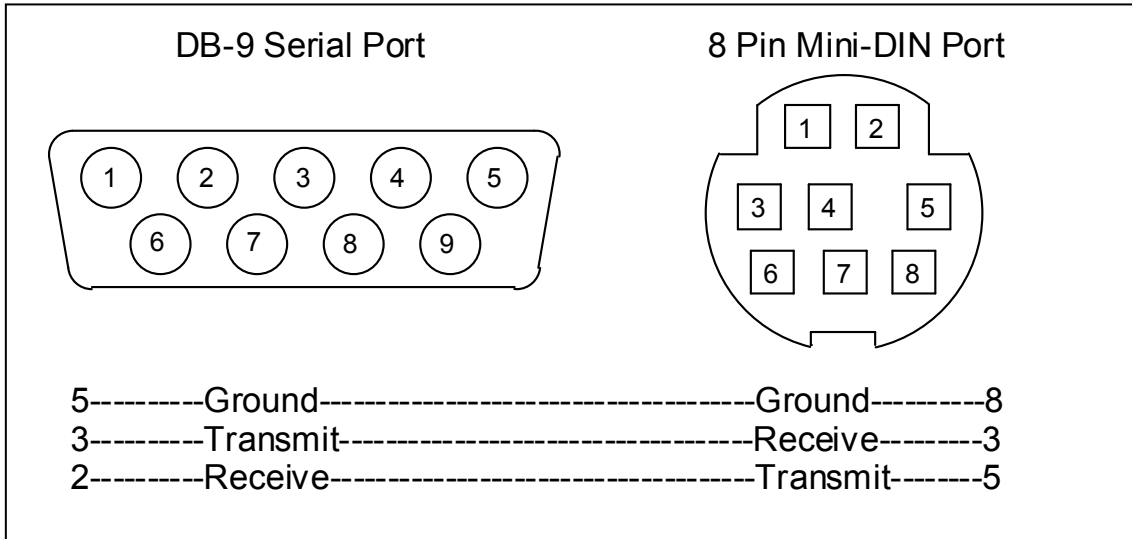


Figure 2. Mini-DIN to DB-9 Connection for RS-232 Signals

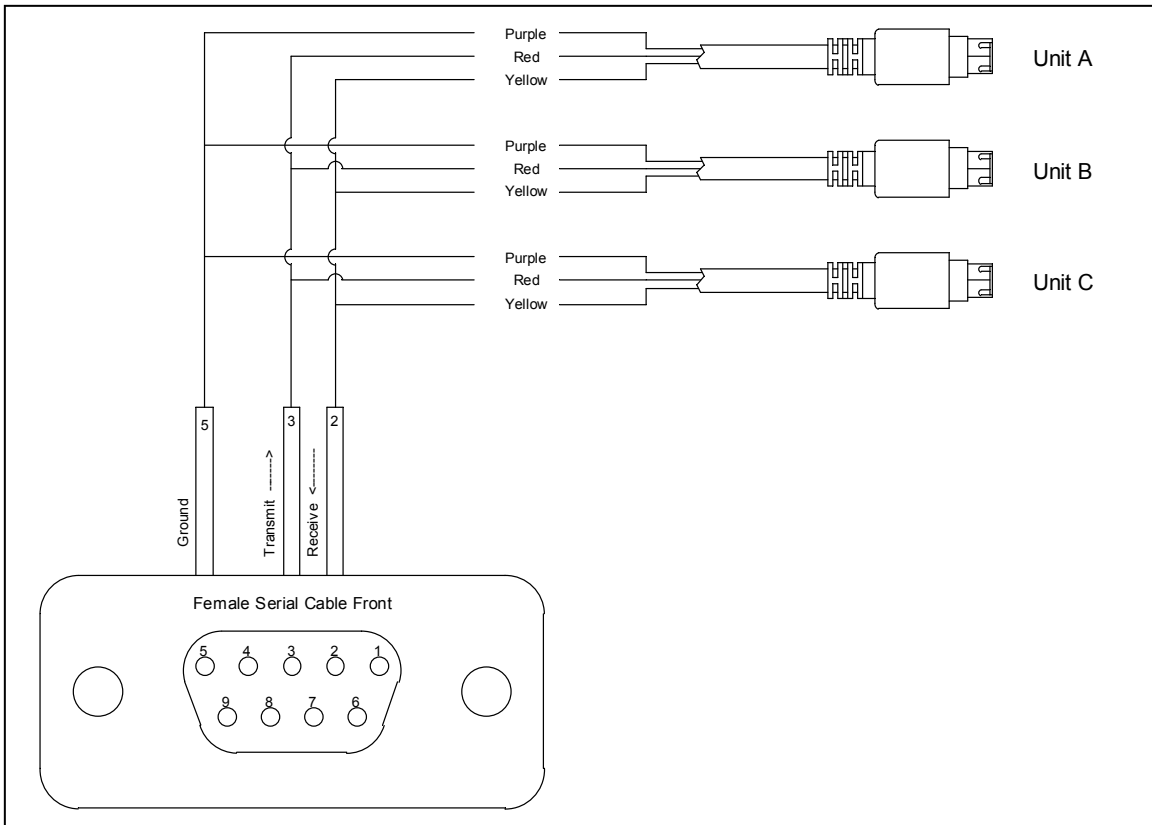


Figure 3. Typical Multiple Device (Addressable) Wiring Configuration

An optional industrial connector is also available:

Pin	Function	Cable Color Code
1	Power In	Red
2	RS-232 Output	Blue
3	RS-232 Input Signal	White
4	Remote Tare (Ground to Tare)	Green
5	Ground	Black
6	Signal Out (Voltage or Current as ordered)	Brown

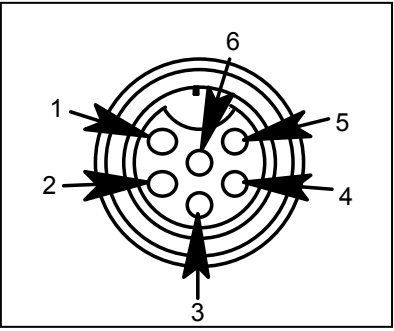


Figure 4. Optional Industrial Connector

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 meter options ordered.

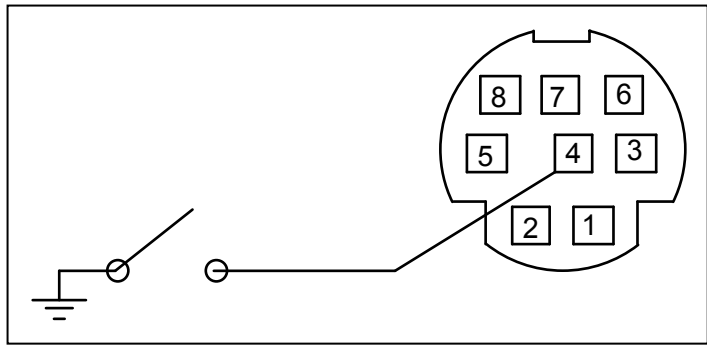


Figure 5. Proper set up for remote tare on meters (Momentarily ground Pin 4 to Tare)

V Series Volumetric Flow Meter Operation

The V Series Volumetric Flow Meter is a simple, rugged device. The membrane switch user interface and dynamically labeled graphic display combine to provide exceedingly flexible and user-friendly operation. The V Series can have several screen “modes” depending on how the device is ordered. All V Series meters have a default Main Mode, a Gas Select Mode (the Gas Select Mode is lost on meters calibrated for a single gas or blend), and an Identity Mode. Other optional modes are available and are described under “Options”. The device defaults to Main Mode as soon as power is applied to the meter. *Note that volumetric meters are intended for use in near atmospheric conditions. Please see page 11.*

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 6. The process gas that is selected is shown directly under the flow units.

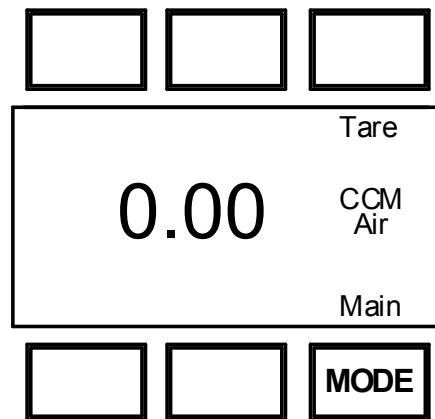


Figure 6. Main Mode Display, V Series Flow Meter

MODE – The “MODE” button in the lower right hand corner toggles the display between modes.

Tare – Pushing the dynamically labeled “Tare” button in the upper right hand corner tares the flow meter and provides it with a reference point for zero flow. *This is a simple but important step in obtaining accurate measurements.* It is good practice to “zero” the flow meter each time it is powered up and whenever a known zero flow condition exists. If the flow reading varies significantly from zero after an initial tare, give the unit a minute or so to warm up and re-zero it.

Zeroing the unit while there is any flow will directly affect the accuracy by providing a false zero point. If in doubt about whether a zero flow condition exists, remove the unit from the line and positively block both ports before pressing the “Tare” button. If the unit reads a significant negative value when removed from the line and blocked, it is a good indication that it was given a false zero. It is better to zero the unit at atmospheric pressure and a confirmed “no flow” condition than to give it a false zero under line pressure.

Note: A remote tare can be achieved by momentarily grounding pin 4 to tare as shown in Figure 5 on page 9.

Volumetric Flow Meters Under Pressure

V Series Volumetric Flow Meters 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:

$$Re = \rho V L / \mu$$

Where:

- ρ = density
- V = average velocity
- L = Constant determined by length and geometry of passage
- μ = 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 μ 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 through 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.

Gas Select Mode

The gas select mode is accessed by pressing the button labeled “MODE” until the dynamic label over the button reads “Gas” as shown in Figure 7 below.

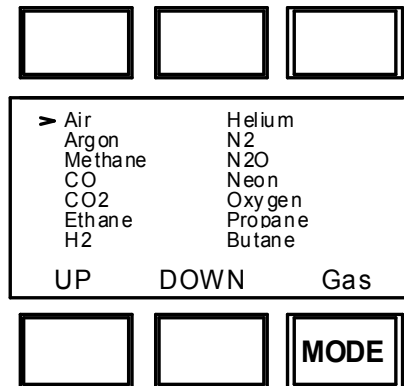


Figure 7. Gas Select Mode

The selected gas is displayed on the default main mode screen as shown in Figure 5, and is indicated by the arrow in the gas select mode screen in Figure 6. To change the selected gas, use the buttons under the dynamic labels “UP” and “DOWN” 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 is not available for units ordered for use with custom gases or blends.

Identity Mode

The Identity Mode is accessed by pressing the “MODE” button until the dynamic label over the “MODE” button reads “I.D.” as shown in Figure 8. The identity mode displays important information about your flow meter including the model number, serial number, and date of manufacture.

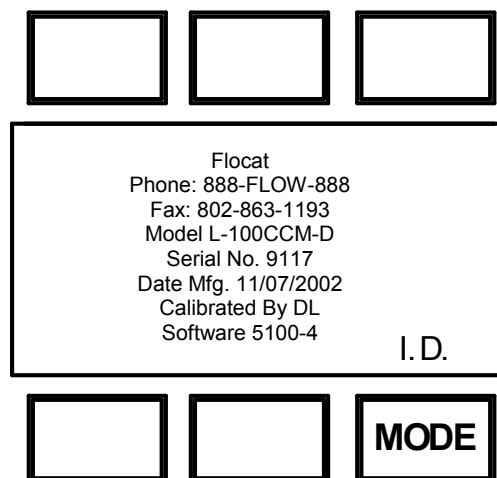


Figure 8. Identity Mode

M Series Mass Flow Meter Operation

The M Series Mass Flow Meter is designed to provide a multitude of useful flow data in one simple, rugged device. The membrane switch user interface and dynamically labeled graphic display combine to provide exceedingly flexible and user-friendly operation. The M Series can have several screen “modes” depending on how the device is ordered. All M Series meters have a default Main Mode, a Gas Select Mode, and an Identity Mode. Other optional modes are available and are described under “Options”. The device defaults to Main Mode as soon as power is applied to the meter.

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 9:

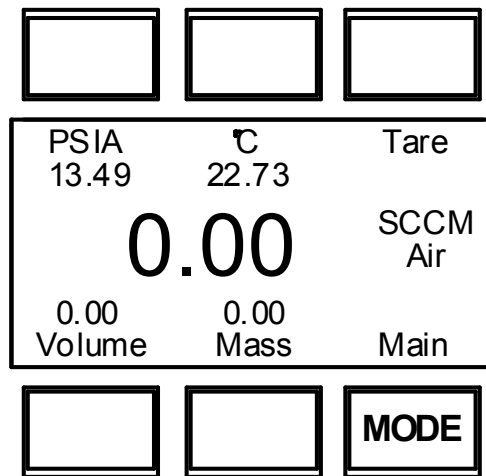


Figure 9. Main Mode Display, M Series Flow Meter

MODE – The “MODE” button in the lower right hand corner toggles the display between modes.

Tare – Pushing the dynamically labeled “Tare” button in the upper right hand corner tares the flow meter and provides it with a reference point for zero flow. *This is a simple but important step in obtaining accurate measurements.* It is good practice to “zero” the flow meter each time it is powered up. If the flow reading varies significantly from zero after an initial tare, give the unit a minute or so to warm up and re-zero it.

If possible, it is helpful to zero the unit near the expected operating pressure by positively blocking the flow downstream of the flow meter prior to pushing the “Tare” button. Zeroing the unit while there is any flow will directly affect the accuracy by providing a false zero point. If in doubt about whether a zero flow condition exists, remove the unit from the line and positively block both ports before pressing the “Tare” button. If the unit reads a significant negative value when removed from the line and blocked, it is a good indication that it was given a false zero. It is better to zero the unit at atmospheric pressure and a confirmed no flow conditions than to give it a false zero under line pressure.

Note: A remote tare can be achieved by momentarily grounding pin 4 to tare as shown in Figure 5 on page 9.

Gas Absolute Pressure: The M Series flow meters 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:

$$\text{PSIG} = \text{PSIA} - (\text{Local Atmospheric Pressure})$$

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 M Series flow meters also 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 meters 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 the dynamic label “°C”. This parameter can be moved to the primary display by pushing the button above the dynamic label (top center).

Volumetric Flow Rate: The volumetric flow rate is determined using the Flow Measurement Operating Principle described elsewhere in this manual. This parameter is located in the lower left corner of the display over the dynamic label “Volume”. This parameter can be moved to the primary display by pushing the button below the dynamic label (lower left). In order to get an accurate volumetric flow rate, the gas being measured must be selected (see *Gas Select Mode* below). 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.

Mass Flow Rate: The mass flow rate is the volumetric flow rate corrected to a standard temperature and pressure (14.696 psia and 25°C). This parameter is located in the lower middle portion of the display over the dynamic label “Mass”. This parameter can be moved to the primary display by pushing the button located below the dynamic label (bottom center). The meter 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.

Gas Select Mode

The gas select mode is accessed by pressing the button labeled “MODE” until the dynamic label over the button reads “Gas” as shown in Figure 7. The selected gas is displayed on the default main mode screen as shown in Figure 9, and is indicated by the arrow in the gas select mode screen in Figure 7. To change the selected gas, use the buttons under the dynamic labels “UP” and “DOWN” 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.

Identity Mode

The Identity Mode is accessed by pressing the “MODE” button until the dynamic label over the “MODE” button reads “I.D.” as shown in Figure 8. The identity mode displays important information about your flow meter including the model number, serial number, and date of manufacture.

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 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.
5. Click on the “ASCII Setup” button and be sure the “Send Line Ends with Line Feeds” box is not checked and the “Echo Typed Characters Locally” box and the “Append Line Feeds to Incoming Lines” boxes are checked. 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”. 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” 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.

Tare –Tareing (or zeroing) the flow meter provides it with a reference point for zero flow. *This is a simple but important step in obtaining accurate measurements.* It is good practice to “zero” the flow meter each time it is powered up. A unit may be Tared by following the instructions on page 10 or it may be Tared via RS-232 input.

To send a Tare command via RS-232, enter the following strings:

In Streaming Mode: \$\$V<Enter>

In Polling Mode: Address\$\$V<Enter> (e.g. B\$\$V<Enter>)

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 meter screen:

Number (#)	Gas
0	Air
1	Argon
2	Methane
3	Carbon Monoxide
4	Carbon Dioxide
5	Ethane
6	Hydrogen
7	Helium
8	Nitrogen
9	Nitrous Oxide
10	Neon
11	Oxygen
12	Propane
13	Butane

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 long term data capture see “Sending a Simple Script to Hyperterminal” on page 18.

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 meters, there are two columns of data representing volumetric flow rate in the units specified at time of order and the selected gas.

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

V Series Volumetric Flow Meter Data Format

For mass flow meters, there are 5 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.

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

M Series Mass Flow Meter Data Format

Sending a Simple Script File to Hyperterminal®

It is sometimes desirable to capture data from a device 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.

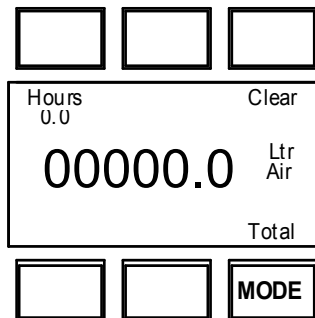
The time between each line will be set in Hyperterminal.

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'll 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'd enter 30000 into the box. If you want a line every 5 minutes, you'd enter 300000 into the box.
15. When you've entered the value you want, click on OK and OK in the Properties dialog box.
16. Go the Transfer menu and select "Send **T**ext 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.

Options

Totalizing Mode Screen: V and M Series Laminar Flow Meters and Controllers can be purchased from the factory 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 dynamic label over it reads “Total”.



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.

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:

1. No Rollover – When the counter reaches the maximum count it stops counting until the counter is cleared.
2. Rollover – When the counter reaches the maximum count it automatically rolls over to zero and continues counting until the counter is cleared.
3. 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 side 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>)

(Options continued)

9 Volt Battery Pack: An optional 9 Volt battery pack that uses a common 9 Volt battery can be purchased from the factory. It is designed to mount to the top of your 16 Series Flow Meter. Power is passed from the battery to the flow meter through the 8 pin Mini-DIN connector. Output signals from the flow meter are passed through the male connector on the bottom of the battery pack to the female connector on top of the battery pack so the signals can be accessed normally. Turn the switch on top of the battery pack off when the meter is not in use.

Normal (9V alkaline) battery life is approximately 8 hours (30-40 hours with a 9V-lithium battery), however many factors can affect this. Replace the battery as often as required. A common indicator that the battery may be approaching the end of its life is a sharp increase in the temperature indicated on the meter. This false signal can result when the voltage drops below its normally regulated level. This can affect the accuracy of the meter so it is good practice to check that the temperature is approximately correct (25°C is about room temperature) or use a fresh battery especially if the measurement is critical.

Replacing the Battery:

The battery can be replaced with the battery pack installed on the flow meter.

1. Remove the four Phillips head screws from the back cover and gently remove it as shown in Figure 9.
2. Remove the 9V battery, pulling the top of the battery out first.
3. Remove the old battery from the harness and replace it with a new battery.
4. Install the new battery bottom end first and replace the back cover so that the cushioning pad presses directly down on the battery.
5. Replace the four Phillips head screws.

Battery Pack Installation and Removal:

The battery must be removed before the battery pack can be installed or removed.

1. Remove the back cover of the battery pack and remove the battery if installed (see "Replacing the Battery").
2. Carefully place the battery pack on top of the flow meter, being especially careful that the pins in the 8 pin Mini-DIN plug are inserted properly into the 8 pin Mini-DIN socket on top of the flow meter. The two screws trapped in the bottom of the battery pack will not allow the plug to be completely inserted into the socket until they are screwed into place.
3. Slip the included hex wrench into either of the two holes on the top of the battery pack as shown in Figure 10 and start the screw into the corresponding threaded hole in the top of the meter.
4. Before the screw is tightened down all the way, move the hex wrench to the other hole and tighten the other screw gently down. Avoid over tightening the screw.
5. Return the hex wrench to the first hole and tighten the first screw gently down. Avoid over tightening the screw.
6. Install the battery and replace the back cover as described above.
7. Removal is the reverse of the installation.

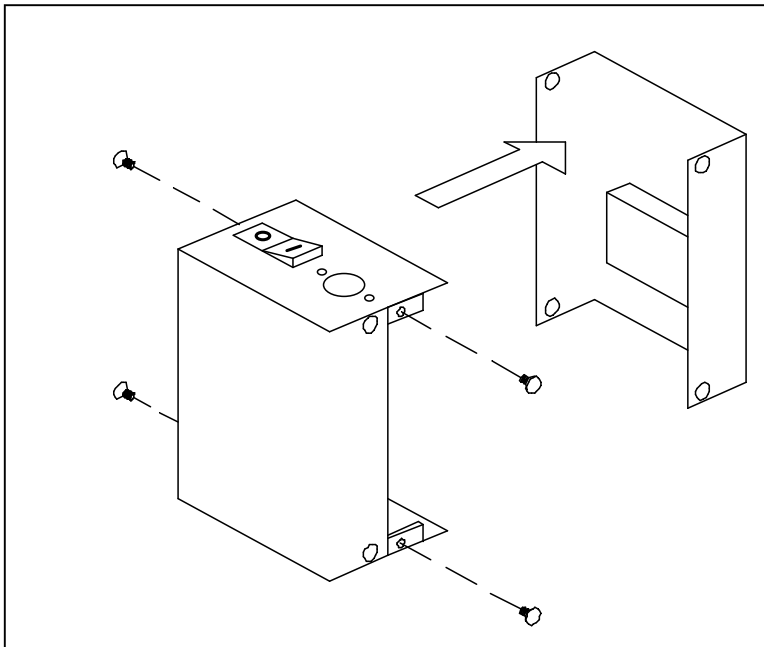


Figure 9. Back Cover Removal

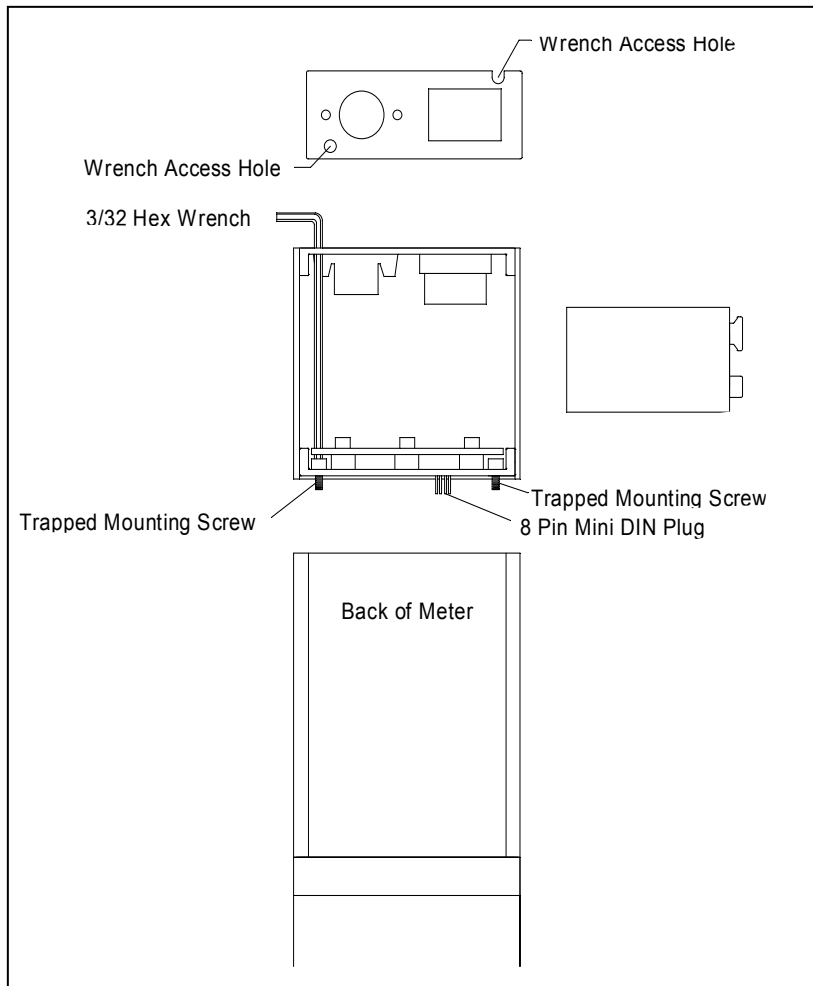


Figure 10. Battery Pack Installation/Removal

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.

Meter reads negative flow when there is a confirmed no flow condition.

This is an indication of an improper tare. If the meter is tared while there is flow, that flow is accepted as zero flow. When an actual zero flow condition exists, the meter will read a negative flow. Simply re-tare at the confirmed zero flow condition. Also note that while the meter is intended for positive flow, it will read negative flow with reasonable accuracy (it is not calibrated for bi-directional flow) and no damage will result.

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.

Flow flutters or is jumpy.

The meters are very fast and will pick up any actual flow fluctuations such as from a diaphragm pump, etc. Also, inspect the inside of the upstream connection for debris such as Teflon tape shreds. *Note:* M & V Series meters feature a programmable geometric running average (GRA) that can aid in allowing a rapidly fluctuating flow to be read.

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 meter reading is strange, inconsistent, or incorrect.

Make sure you use a volumetric flow meter only under low pressure (close to atmospheric) and with little to no back pressure for accurate readings. Mass meters should be used for higher pressure applications. See page 11.

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. Close Hyperterminal® and reopen it. Reboot your PC.

Slower response than specified.

V and M Series meters 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.

V and M Series meters 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.

Maintenance and Recalibration

General: V and M Series Flow Meters 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 meter is designed to measure CLEAN, DRY, NON-CORROSIVE gases. A 20 micron filter (50 micron for 50 LPM and up) mounted upstream of the meter 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 quite 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 Identity Mode screen.

Cleaning: V and M Series Flow Meters require no periodic cleaning. If necessary, the outside of the meter can be cleaned with a soft dry rag. Avoid excess moisture or solvents.

For repairs, re-calibrations, or recycling of this product, contact:

Flocat
P.O. Box 1073
8 Leroy Road
Williston, VT 05495

Phone: 888-FLOW-888
Fax: 802-863-1193

www.flocat.com

Warranty

This product is warranted to the original purchaser for a period of one year from the date of purchase to be free of defects in material or workmanship. Under this warranty the product will be repaired or replaced at manufacturer's option, without charge for parts or labor when the product is carried or shipped prepaid to the factory together with proof of purchase. This warranty does not apply to cosmetic items, nor to products that are damaged, defaced or otherwise misused or subjected to abnormal use. See "Application" under the Installation section. Where consistent with state law, the manufacturer shall not be liable for consequential economic, property, or personal injury damages. The manufacturer does not warrant or assume responsibility for the use of its products in life support applications or systems.

Additional Information

Accessories:

Description
Remote Digital Display
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

Gas Viscosity Table:

**Absolute viscosities of common gases at 25°C in micro poise
(1 Poise = gram / (cm)(sec))**

Butane	75.68
Propane	81.340
Hydrogen	89.230
Ethane	92.462
Methane	111.296
Nitrous Oxide	147.880
Carbon Dioxide	148.711
Carbon Monoxide	177.761
Nitrogen	177.820
Air	184.332
Helium	197.616
Oxygen	205.353
Argon	225.987
Neon	314.743

Gas Density Table:

Gas	Molecular Weight Grams/Mole	Density Grams/Liter at 0°C, 14.696 PSIA	Density Grams/Liter at 25°C, 14.696PSIA
Butane	58.124	2.5932	2.3758
Propane	44.097	1.9674	1.8024
H2	2.016	0.0899	0.0824
Ethane	30.070	1.3416	1.2291
Acetylene	26.038	1.1617	1.0643
Methane	16.043	0.7158	0.6557
Nitrous Oxide	44.013	1.9637	1.7990
CO2	44.011	1.9636	1.7989
CO	28.010	1.2497	1.1449
N2	28.013	1.2498	1.1450
Air	28.964	1.2922	1.1839
He	4.003	0.1786	0.1636
O2	31.999	1.4276	1.3079
Ar	39.948	1.7823	1.6328
Neon	20.183	0.9005	0.8250

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

Performance Specifications for 16 Series Mass and Volumetric Flow Meters

SPECIFICATION	MASS M Series	VOLUMETRIC V Series	ENGINEERING UNITS
Accuracy ¹	+/-1% (0.5%opt)	+/-1% (0.5%opt)	Full Scale
Repeatability	+/-0.5%	+/-0.5%	Full Scale
Turndown Ratio	100:1	100:1	Full Scale
Response Time (adjustable) ²	10	10	Milliseconds
Pressure Drop ³ ≤ 20 SLPM	0.4	0.4	PSI
20 to 50 SLPM	0.8	0.8	PSI
50 to 500 SLPM	.50—1.64	.50—1.64	PSI
1000 SLPM	3.0	3.0	PSI
Operating Temperature	-10 to +50	-10 to +50	°C
Zero Shift	0.02%	0.02%	Full Scale / °C / ATM
Span Shift	0.02%	0.02%	Full Scale / °C / ATM
Humidity Range	0-100%	0-100%	Non-Condensing
Common Mode Pressure (max)	125	125 ⁴	PSIG
Supply Current (typical) ⁵	30	30	Milliamp
Supply Voltage	7 - 30	7 - 30	Volts DC
Electrical Connections (Standard)	8 pin	8 pin	Circ. Mini DIN/Multi Pin
Electrical Connections (Optional)	6 pin	6 pin	Industrial
Mechanical Connections	10-32 for .5 to 50 (S)CCM	10-32 for .5 to 50 (S)CCM	UNF
	1/8" for 50+ (S)CCM to 20 (S)LPM	1/8" for 50+ (S)CCM to 20 (S)LPM	NPT (female)
	1/4" for 20+ to 100 (S)LPM	1/4" for 20+ to 100 (S)LPM	
	1/2" for 100+ to 250 (S)LPM	1/2" for 100+ to 250 (S)LPM	
	3/4" for 250+ to 1500 (S)LPM	3/4" for 250+ to 1500 (S)LPM	

1. The 0.5% Option is not available on 0.5 (S)CCM or 100+ (S)LPM flow ranges
2. 10 ms represents a typical default response time for 63.2% of a step change. A variable register allows response time to be field adjustable to certain extent via RS-232 communication. The primary trade off for response time is signal noise. Response time may be longer for very low flow ranges.
3. Meters with flow ranges of 50 (S)LPM or greater can exhibit considerably higher pressure drops.
4. While V Series meters can withstand 125PSIG, their maximum exit pressure is 15PSIG.
5. 30 mA represents typical current draw, with 0-5 or 0-10v output add 20mA for each 4-20 mA output, a 100 mA available supply is recommended.

Conformity / Supplemental Information:

The product complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC (including 93/68/EEC) and carries the CE Marking accordingly. Contact the manufacturer for more information.

