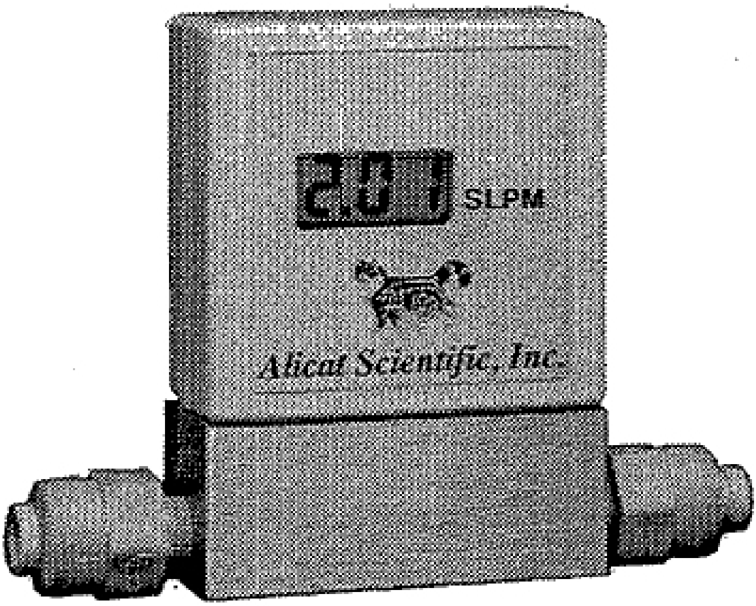


# PRECISION
# GAS FLOWMETERS

## Operation Manual

# Notice:

Alicat Scientific reserves the right to make any changes and improvements to the product described in this manual at any time and without notice.



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Although we provide assistance on Alicat products both personally and through our literature, it is still the total responsibility of the customers to determine the suitability of any product to their application.

# Table of Contents

# Introduction

Alicat's PV series flowmeters are designed to accurately measure the volumetric flow rate of most gases. The flow rate is determined by creating a pressure drop across a unique internal restriction, known as a Laminar Flow Element, and measuring differential pressure across it. The restriction is designed such that the gas molecules are forced to move in parallel paths along the entire length of the passage, and hence Laminar (or streamline) flow is established for the entire range of operation of the device.

Our flowmeters have two basic modes of measurement. Either the meter is design to measure Volumetric flow, or it is designed to measure Mass flow. The Model number on the back of the unit will indicate the type. For Example:

PVM = Mass
PVH = Volumetric
PVMC = Mass flow Controller
PVHC = Volumetric flow Controller

Unlike other pressure measuring devices, the relationship between pressure drop and flow is linear in laminar flowmeters. The underlying principle of operation of PV series flowmeters is known as the Poiseuille Equation, given below:

$$Q = \frac{(P_1 - P_2)\pi r^4}{8 \, \text{[illegible]} \, \eta L} \qquad \text{(Equation 1)}$$

Where:

$Q$ = Volumetric Flow rate
$P_1$ = static pressure at the inlet
$P_2$ = static pressure at the outlet
$r^2$ = radius of the restriction
$\eta$ = (eta) viscosity of the fluid
$L$ = length of the restriction

Since $\pi$, 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 ($\Delta P$) and viscosity ($\eta$) in a simpler form.

# Installation

Figure 1 shows the overall dimensions of PV series flowmeters.

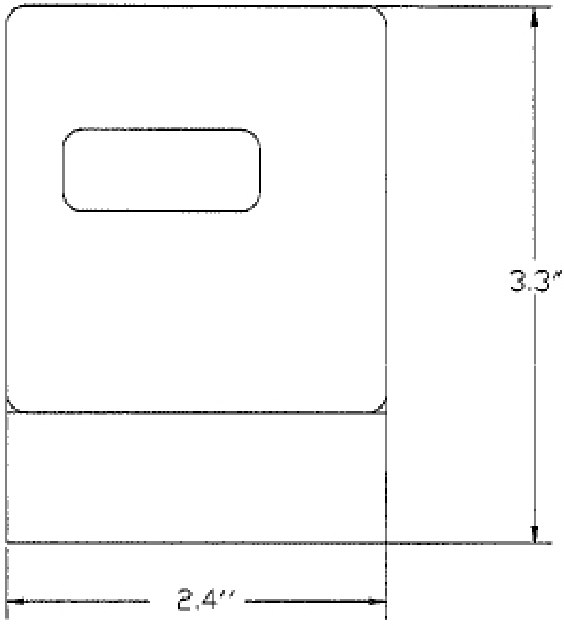



Figure 1

Two 8-32 mounting holes are provided at the bottom of the flowmeters. These blind holes are typically ½" deep

Note: A filter at the inlet of the flowmeter is recommended to prevent clogging of the internal structure.

Standard 1/8" female NPT threads are provided for tubing connection to the flowmeter. Maximum operating line pressure is 100 PSIG. **Exceeding the maximum specified line pressure may cause permanent damage to the solid-state pressure transducer.** If line pressure is higher than 100 PSIG, a pressure regulator must be used upwind from the flowmeter to reduce the pressure to 100 PSIG or less, as shown in Figure 3 below.

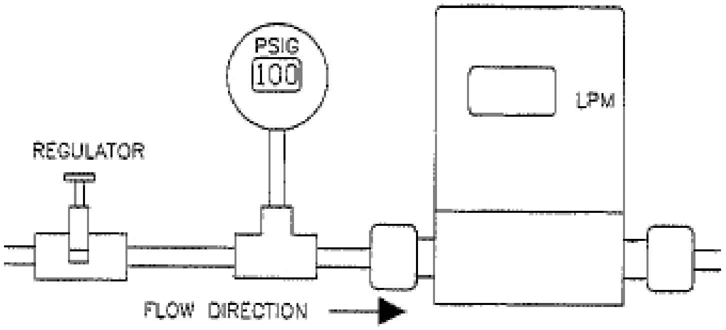


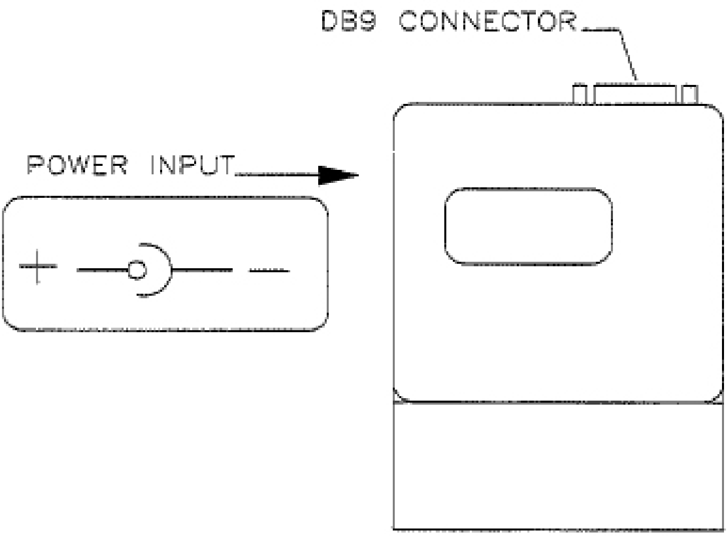

Figure 3. Maximum Line Pressure

Although the PV series operation is uni-directional, no damage will be inflicted by reversing the flow direction, as long as the maximum specified limits are not exceeded.

Note: External pressure does not effect volumetric flowmeters. Measurements are independent of line pressure.

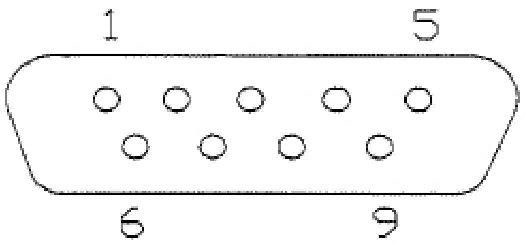
# Power and Signal Connection

For flowmeter with the side power jack, power can be applied to the unit with the polarity shown below. Any AC-DC adapter with minimum 7 volts output (max 28 volts) will work as long as the above polarity is observed. The AC adapters can be obtained from local electronic suppliers, or can be purchased from Alicat Scientific, Inc. (Part No. PVPS).




**Note: Do not connect power to signal output pins.**

An alternative method for supplying power is through the male DB9 connector as shown




| Pin | Function |
|---|---|
| 1 | Power In |
| 2 | Serial output (units with RS232 option) |
| 3 | Pressure Signal (Optional) |
| 4 | Set Point Voltage in 0-5 Vdc (Optional) |
| 5 | Power and signal ground |
| 6 | +5V output (generated internally by the flowmeter, used for powering remote LCD displays) |
| 7 | Temperature (Optional) |
| 8 | Signal voltage output (for units with voltage output option) |
| 9 | Volumetric flow signal (Optional) |

Note: The above pin-out is applicable to all the flowmeters with the DB9 connector. The availability of different output signals depends on the flowmeter options.

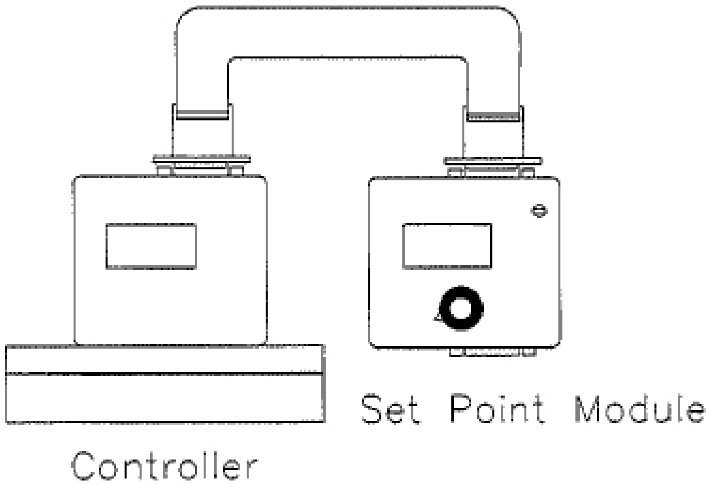
# Voltage Output

Flowmeters with the optional voltage output option provide a 5.0 Vdc output span. 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 and is available through the DB9 connector.

# Control Models

The PVMC and PVHC meters employ a proportional control valve. As much as 15 psi pressure differential may be necessary to obtain the full rated flow through the control valve. The control valve requires substantially more power than the flow measuring portion of the device. For this reason, the power requirements are 12-26 volts DC and 150 miliamps. Sufficiently heavy wiring must be used to prevent significant voltage drop in the ground return line. Failure to do so may result in voltage output offsets. The set point for the device is input through pin 4 of the DB-9 connector. This is input as a 0-5 volt DC signal. This signal may originate from a Alicat local set point module (LSPM) or other external source. 0 volts always corresponds to 0 flow and 5.00 volts always corresponds to full scale flow.

The Set Point Module allows the user to set a specific flow rate, by means of the Controller. The Set Point Module is powered by the Controller.




The pin functions for the Control setup are as follows.

| Pin | Function |
|---|---|
| 1 | Power in 7 - 30 dc |
| 2 | Serial out (Optional) |
| 3 | Pressure sgnal (Oponal) |
| 4 | Set Point voltage 0 -5 Vdc |
| 5 | Ground |
| 6 | +5 Vdc out (Pwr for LSPM) |
| 7 | Temperature signal (Optional) |
| 8 | Main Flow (Mass on PVM or Volumetric on PVH) |
| 9 | Signal Ground |

# Zero Adjustment

Figure 4 shows the location of the potentiometer for zero adjustment. This potentiometer typically provides 25% of the adjustment around the calibrated value. True zero is attained at zero flow by adjusting the zero potentiometer until the display **does not** read a negative sign. Units with voltage output option operate true zero between 10 and 15 mV on a 5V scale.

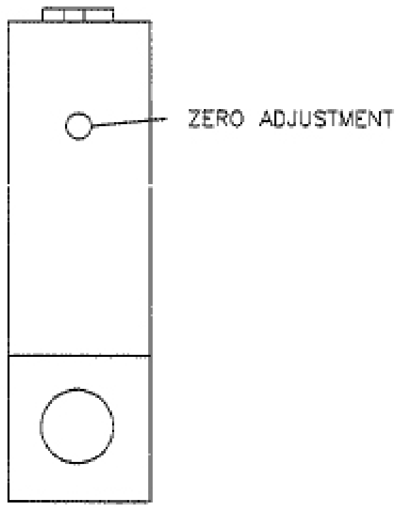



Figure 4.

# Pressure and Temperature Effects

Absolute viscosity changes very little with pressure and hence for true volumetric reading, no correction due to pressure is needed.
Change in gas temperature affect the viscosity; however, PV series flowmeters are internally compensated for this change and no temperature correction is needed for volumetric measurement.

# RS232 Serial Output

Flowmeters with the optional RS232 communication transmit the output signal at 9600 baud, 1 start bit, 8 data bits, 1 stop bit, no parity. No handshaking is required for data reception. Flow units are defined by the flowmeter model, e.g. if "+1.00" is transmitted by 1 LPM flowmeters, it simply indicates that the current flow rate is 1.00 liter per minute. Each data string is terminated by the carriage return character (0D hex).

The simple BASIC program shown below is all that is needed to receive and decode the serial data from the flowmeter. In this example the flowmeter output is connected to the serial port (COM1) of an IBM PC (or compatible computer).

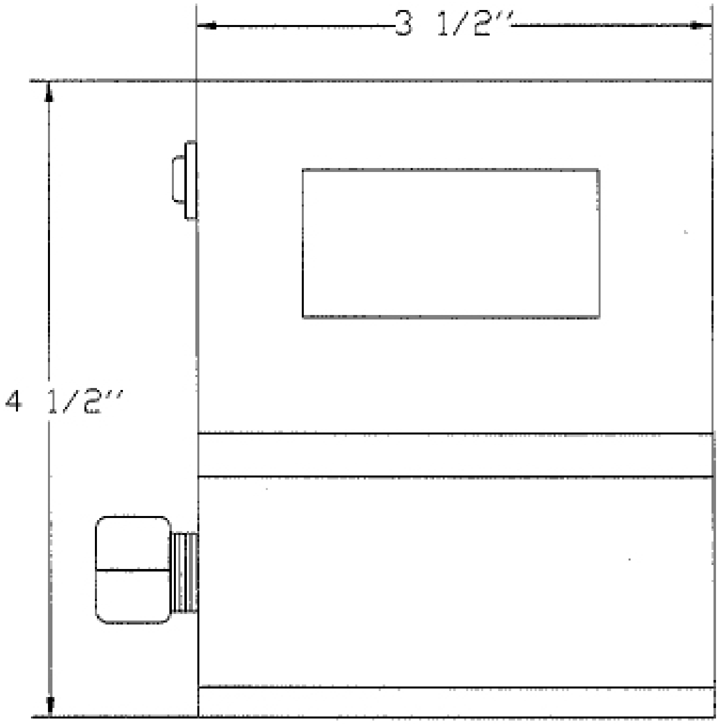
```
10 ON ERROR GOTO 99
20 CLS
30 OPEN "COM1:9600,N,8,1,CS,DS,CD" FOR
   INPUT AS #1
40 INPUT #1, A$
50 PRINT A$
60 GOTO 40
99 RESUME
```

This program interprets the received data as string characters. To convert string characters to their numeric values, simply change line 50 to:

```
50 PRINT VAL(A$)
```

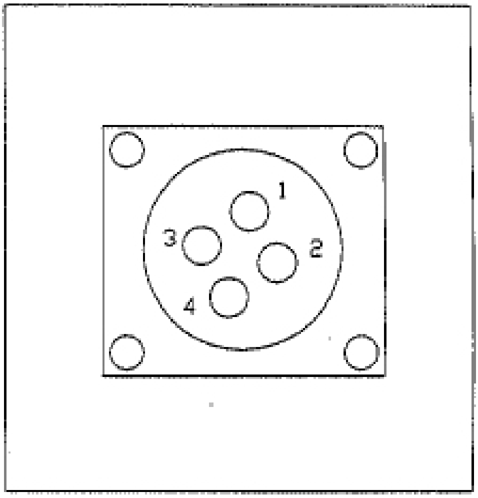
Note: Alicat flowmeters with the RS232 output option are not automatically powered by the computer. Units with RS232 require either an AC-DC adapter as specified in the manual, or power applied directly to the power and ground pins of the DB-9. **Make sure that the computer does not send voltage to any of the signal output lines.**

# High Flow Models




The high flow models are equipped with a ½" NPT Brass fitting on the flow side of the unit. This fitting is modified to employ flow straightening apparatus. This allows the user to directly connect the unit to the line. The maximum operating pressure for the high flow models is 100 psi. **Exceeding the Maximum specified line pressure may cause permanent damage to the solid-state pressure transducer.** If line pressure is higher than 100 PSIG, a pressure regulator must be used upwind from the meter. Although the PV series operation is uni-directional, no damage will be inflicted by reversing the flow direction, as long as the maximum specified limits are not exceeded. The high flow models have a power requirement of 12 - 30 Volts dc. The high flow models also have a 4 - 20 milliamp currents output.

The power connection utilized by the High flow models have a four pin connection jack. The pin out is as follows:




Pin out:

1 - Black - Ground
2 - Green - 4 - 20 milliamps output
3 - White - Voltage out
4 - Red - Power in. 12 - 30 Vdc

Note: The Zero adjustment control for the High flow models is located atop the unit.

# Using the Flowmeter with Other Gases

PV flowmeters can easily be used to measure the flow rate of gases other than the one specified by the model number, as long as the "non-corrosive" gas compatibility is observed. For instance, a flowmeter that is factory-calibrated for air can be used to measure the flow of Oxygen.

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

$$Q_{og} = Q_1 \left[\eta_{og}/\eta_1\right] \qquad \text{(Equation 3)}$$

Where:

$Q_1$ = flow rate indicated by the flowmeter

$\eta_1$ = viscosity of the calibrated gas

$Q_{og}$ = flow rate of other gas

$\eta_{og}$ = viscosity of other gas

Models specified with the switch selectable gas calibration option may be field adjusted to many different gases. (See Appendix D).

# Volumetric to Mass flow Conversion

In order to convert volume to mass, density of the gas has to be known. The relationship between volume and mass is as follows:

Mass = Volume x Density

Density of gases changes with temperature and pressure; therefore, 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:

$$\frac{\rho_a}{\rho_s} = \frac{T_s}{T_a}$$

Where:

$\rho_a$ = density at ambient condition
$T_a$ = absolute temperature at ambient condition in degrees Kelvin
$\rho_s$ = density at standard (reference) condition
$T_s$ = absolute temperature at standard (reference) condition in degrees Kelvin

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

$$\frac{\rho_a}{\rho_s} = \frac{P_s}{P_a}$$

Where:

$\rho_a$ = density at ambient condition
$P_a$ = ambient pressure
$\rho_s$ = density at standard (reference) condition
$P_s$ = pressure at 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 somewhat standard that mass flow rate is specified in SLPM (standard liters per minute) or SCCM (standard cc per minute).

This means that the 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 14.7 psia
25°C and 14.7 psia
0°C and 760 torr (mmHg)
70°C and 14.7 psia
68°F and 29.92 in.Hg
20°C and 760 mmHg
etc.

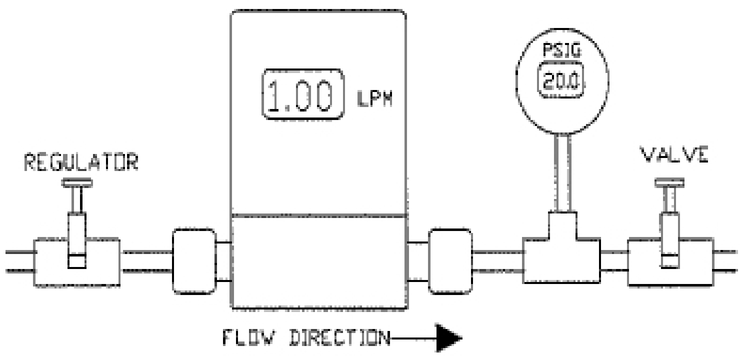
# Application Examples

Example 1: A PV flowmeter is installed in the system shown below. The volumetric flow rate indicated by the flowmeter is 1.00 LPM. Atmospheric pressure when the experiment is conducted is 14.7 psia and ambient temperature is 25°C. What is the mass flow rate at 14.7 psia and 25°C?

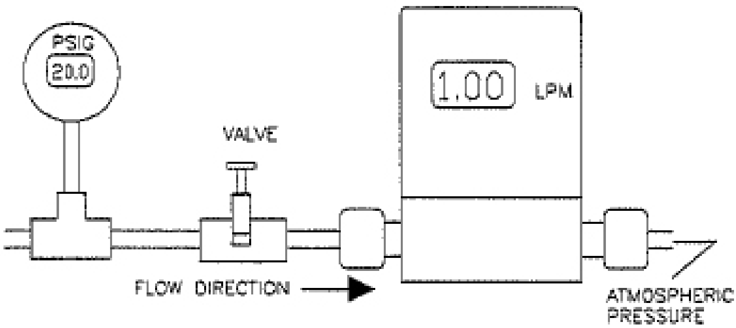
Answer: The conversion factor for the effect of line pressure on density is:

$$\frac{P_a}{P_s} = \frac{14.7\ \text{psia} + 20.0\ \text{psig}}{14.7\ \text{psia}}$$

Mass flow rate = 1.00 LPM x 2.36
= 2.36 SLPM



Example 2: A PV flowmeter is installed in the system shown below. The volumetric flow rate indicated by the flowmeter is 1.00 LPM. Atmospheric pressure in 13.5 psia and ambient temperature is 35°C. What is the mass flow rate corrected to 14.7 psia and 25°C?




Answer: Since the valve is located upstream of from the flowmeter, the line pressure indicated by the pressure gauge has no effect on density, Therefore, the conversion factors are:

$$\frac{(273 + 25)\ °K}{(273 + 35)\ °K}$$

Atmospheric pressure effect on density:

$$\frac{13.5\ \text{psia}}{14.7\ \text{psia}}$$

Mass flow rate = 1.00 x 0.968 x 0.918 = .889 SLPM
(at 14.7 psia and 25°C)

Example 3: A PV flowmeter is calibrated for air as purchased. An experiment requires the use of Oxygen. What is the conversion factor to be applied to the indicated output?

Answer: From Appendix A, the ratio of viscosity of Oxygen to Air is:

$$\eta_{Oxygen}/\eta_{Air} = 202.39/183.71 = 1.102$$

From Equation 3, the flow rate of Oxygen is determined by:

$$Q_{oxygen} = Q_{air} \times 1.102$$

This means that in order to set the flow rate of Oxygen to 1.00 LPM, the flowmeter output($Q_{air}$) should be showing 0.907 LPM.

Note: In this example the viscosity ratio is determined by using viscosity values at 0°C. The table in appendix A shows the viscosity's for common gases at 20°C and 25°C. The flow meters compensate for the change in gas viscosity with temperature at a fixed rate per °C. This rate is correct for most gases over a broad temperature range.

Example 4: The output voltage from a 500CCM PV flowmeter is 1.20 volts. What is the volumetric flow rate through the flowmeter?

Answer: The zero flow output is typically 0.01 volts and the full scale span is 5.0 volts. Therefore, the flow rate is:

((1.20V - 0.010V)/5.00V)x 500 cc/min) = 119 cc/min

# Accessories

| Item | Description |
| --- | --- |
| PVPS | Power Supply (AC to DC) |
| RDD | Remote Digital Display |
| EC 61 | Singlle ended 6' extension cable |
| EC 62 | Double ended 6' extension cable |

Please contact Factory for details and pricing.

# Appendix A. Viscosity of Common Gases

| GAS | 20 C | 25 C |
|---|---|---|
| Hydrogen | 87.549 | 88.568 |
| Ethane | 90.948 | 92.462 |
| Methane | 108.700 | 110.225 |
| Nitrous Oxide | 145.460 | 147.880 |
| Carbon Dioxide | 148.000 | 150.400 |
| Carbon Monoxide | 174.533 | 176.788 |
| Nitrogen | 174.921 | 177.069 |
| Air | 183.711 | 186.239 |
| Helium | 194.100 | 196.175 |
| Oxygen | 202.329 | 205.271 |
| Argon | 221.700 | 224.706 |
| Propane | 283.897 | 288.497 |
| Neon | 311.100 | 314.497 |

# Appendix B Flow Conversion Table

| | CC/Min | CC/Hr | LPM | LPH |
|---|---|---|---|---|
| CC/Min | 1 | 60 | 0.001 | 0.06 |
| CC/Hr | 0.0167 | 1 | 0.000017 | 0.001 |
| LPM | 1000 | 60000 | 1 | 60 |
| LPH | 16.667 | 1000 | 0.0166 | 1 |
| CuFt./Min | 28317 | 1699011 | 28.316 | 1699 |
| CuFt./HR | 471.947 | 28317 | 0.4719 | 28.316 |
| Gal/Min | 3785.412 | 227125 | 3.785 | 227.118 |
| Gal/Hr | 63.069 | 3785 | 0.063 | 3.785 |

| | CuFt/Min | CuFt/Hr | Gal/Min | Gal/Hr |
|---|---|---|---|---|
| CC/Min | 0.000035 | 0.0021 | 0.00026 | 0.0159 |
| CC/Hr | 0.0000005 | 0.00003 | 0.000004 | 0.00026 |
| LPM | 0.035 | 2.1189 | 0.264 | 15.851 |
| LPH | 0.00059 | 0.035 | 0.004 | 0.264 |
| CuFt./Min | 1 | 60 | 7.481 | 448.831 |
| CuFt./HR | 0.0166 | 1 | 0.1247 | 7.481 |
| Gal/Min | 0.1337 | 8.021 | 1 | 60 |
| Gal/Hr | 0.002 | 0.1337 | 0.0167 | 1 |

Note: PVM units measure mass flows by correcting the flow to standard conditions. Standard conditions are 25°C(77° F) and 1 atmosphere (14.695 psia)

# Appendix C.

## Warranty

Alicat Scientific, Inc. warrants that its products shall be free from defects in workmanship and materials, and shall conform to Alicat's published specifications, or other specifications accepted by Alicat in writing for a period of one (1) year from the date of Alicat's shipment.

This warranty does not apply to any products which have been subject to misuse, neglect, accident, or modification. Alicat's sole obligation under its warranty shall be repair or replace the product or issue credit.

## Limitation of Application Liability

Alicat Scientific, Inc. does not warrant or assume responsibility for the use of its products in life support applications or systems.

# Appendix D  Dip Switch Settings

1. **Dip Switch Setting:** The Alicat flow meters are capable of being set to any non-corrosive gas or blend of gasses. Removal of the rear cover of the flow meter will reveal a bank of dip switches. The accompanying table shows the appropriate settings for the most commonly used gasses. The switches are numbered 1-10 left to right. Each switch whose associated column has an "x" in it should have it's slider in the down position, all others should be in the up position. Consult the factory for custom blend settings.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gas | | | | | | | | | | |
| Hydrogen | X | | X | X | | X | X | X | X | X |
| Ethane | | X | | | X | X | | X | X | X |
| Methane | | X | | X | X | | X | X | | X |
| Nitrous Oxide | X | | X | X | X | X | | X | X | |
| Carbon Dioxide | X | X | X | X | | X | | X | X | |
| Carbon Monoxide | X | X | | | X | X | | | X | |
| Nitrogen | | X | | | X | X | | | X | |
| Air | | | | | X | | | | X | |
| Helium | X | X | X | X | | X | X | X | | |
| Oxygen | X | X | X | | | | | | | X |
| Argon | | X | X | X | X | | | X | | X |
| Propane | | | X | | | X | | | | |
| Neon | | | | | | | | | | |