Basic Flowmeter Principles

How They Work

Flowmeters are used in fluid systems (liquid and gas) to indicate the rate of flow of the fluid. They can also control the rate of flow if they are equipped with a flow control valve.

Rotameters are a particular kind of flowmeter, based on the variable area principle. They provide a simple, precise and economical means of indicating flow rates in fluid systems.

This variable area principle consists of three basic elements: A uniformly tapered flow tube, a float, and a measurement scale. A control valve may be added if flow control is also desired.

In operation, the rotameter is positioned vertically in the fluid system with the smallest diameter end of the tapered flow tube at the bottom. This is the fluid inlet. The float, typically spherical, is located inside the flow tube, and is engineered so that its diameter is nearly identical to the flow tube's inlet diameter.

When fluid — gas or liquid — is introduced into the tube, the float is lifted from its initial position at the inlet, allowing the fluid to pass between it and the tube wall. As the float rises, more and more fluid flows by the float because the tapered tube's diameter is increasing. Ultimately, a point is reached where the flow area is large enough to allow the entire volume of the fluid to flow past the float. This flow area is called the annular passage. The float is now stationary at that level within the tube, as its weight is being supported by the fluid forces which caused it to rise. This position corresponds to a point on the tube's measurement scale and provides an indication of the fluid's flow rate.

One way to change the capacity, or flow range, of a rotameter is to change the float material, and thus its density, while keeping the flow tube and float size constant. Floats which are made from less dense materials will rise higher in the tube and therefore will yield lower flow capacities for the same diameter flow tube.

Floats made from more dense materials will rise less thereby yielding higher flow capacities. Relative flow capacities for some common float materials are shown in Figure 1.

Another way to change the capacity is to change the diameter of the flow tube and the size of the float.

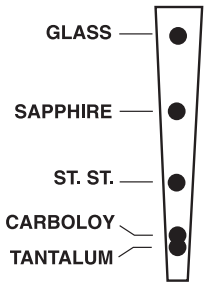

Figure I

Selecting The Right Flowmeter Size

There are certain factors which affect the measurement of a fluid's flow rate with a rotameter. The fluid's temperature, pressure and specific gravity all impact gas flow measurements.

Flow capacities (ranges) for the flowmeters described in this catalog are given for air at standard conditions — 14.7 psia (101.3 KPa Abs) and 70°F (21°C). Sizing a meter for a gas other than air, or for your specific application pressure and/or temperature, requires that you first determine the equivalent flow capacity in air at standard conditions. Once determined, the flow capacity tables in this catalog can be applied directly. Reference Scale tables can be requested for each flowmeter ordered which will provide conversion to your desired fluid or conditions.

Note that for flowmeters calibrated at standard conditions with a valve on the inlet, readings on the tube are correct provided that the outlet pressure is close to atmospheric. When the valve is on the outlet, readings are correct if the inlet gas pressure is equal to the pressure for which the tube was calibrated.

For your convenience, **Table 1** provides correction factors for gases other than air at standard conditions. Call a customer service representative if you require further assistance in sizing a rotameter for your particular application.

Basic Flowmeter Principles *(continued)*

Table 1: Flow Rate Factors for Gases other than Air

Gas	Factor	Gas	Factor	Gas	Factor
Acetylene	0.95	Halocarbon-11	2.18	Hydrogen Chloride	1.13
Air	1.00	Halocarbon-12	2.05	Hydrogen Sulfide	1.08
Ammonia	0.77	Halocarbon-13	1.90	Isobutane	1.42
Argon	1.18	Halocarbon-13B	2.27	Isobutylene	1.39
1-3 Butadiene	1.37	Halocarbon-14	1.74	Methane (Natural Gas)	0.75
Butane	1.42	Halocarbon-21	1.89	Methyl Fluoride	1.09
1-Butene	1.39	Halocarbon-22	1.73	Monomethylamine	1.04
Carbon Dioxide	1.23	Halocarbon-23	1.56	Neon	0.83
Carbon Monoxide	0.98	Halocarbon-113	2.54	Nitrogen	0.98
Chlorine	1.57	Halocarbon-114	2.43	Nitrogen Dioxide	1.60
Cracked Ammonia	0.54	Halocarbon-116	2.18	Nitrous Oxide	1.23
Cyclopropane	1.21	Halocarbon-115	2.31	Oxygen	1.05
Difluoroethane	1.51	Halocarbon-142B	1.86	Propane	1.23
Dimethyl Ether	1.26	Halocarbon-152A	1.51	Propylene	1.21
Ethane	1.02	Helium	0.37	Sulfur Dioxide	1.50
Ethylene	0.98	Hydrogen	0.26	Sulfur Hexafluoride	2.25

For other gases or for non-standard temperatures and pressures, call a customer service representative.

Note that for flowmeters calibrated at standard conditions with a valve on the inlet, readings on the tube are correct provided that the outlet pressure is close to atmospheric. When the valve is on the outlet, readings are correct if the inlet gas pressure is equal to the pressure for which the tube was calibrated.

To estimate which flow tube should be purchased when measuring the flow of a gas other than air, multiply the flow rate desired by its factor above to find the air flow equivalent. The flow tube whose range (capacity) covers this flow rate should be the one purchased. Be sure to keep units consistent. Air Equivalent= Gas Flow Rate Desired x Factor. These factors assume standard operating conditions. Temperature 70°F/21°C; pressure 14.7 psia (101.3 K Pa Abs).

Flowmeter Measurement Scales

Depending upon the model, the flowmeter's measurement scale can be either direct reading or in reference scale units.

Direct reading tubes are straightforward. The measurement scale on each of these tubes reads actual flow at standard conditions in a choice of English or Metric units.

Reference scale tubes, on the other hand, provide a uniformly calibrated scale in arbitrary millimeter (mm) units. Obtaining actual flow rates with these tubes requires the use of a reference scale flow correlation table (available from Matheson) which relates the mm scale reading to an actual flow rate. Reference scale tubes are useful when measuring flow rates for gases other than air, for non-standard conditions, or when conditions or the gas may frequently change.

Variable area flowmeters are often defined by their measurement scale length, that is, the distance between the zero and full scale marking. Scale length is typically indicated in millimeter (mm) units. The FM-1050, for example, uses a 150mm tube and the FM-1000 uses a 65mm tube. *Note that this scale length has no relationship at all with whether the flowmeter is a direct reading or a reference scale tube.*

Basic Flowmeter Principles *(continued)*

Flowmeter Calibration and Services

There are many formulas available, which calculate the flow of a fluid through a variable area flowmeter for which it is not calibrated. Moreover, these equations are used to generate correction factors for correlating other fluid flows to some known calibration, as shown in Table 1.

Matheson has conducted extensive experiments to determine the accuracy of these mathematical formulas. At best, calculated values estimate flow rates to about ±5% accuracy. If you require greater accuracy, it will be necessary to calibrate the flowmeter with the actual gas, or at the particular conditions (temperature/pressure), in question.

Matheson has a fully equipped laboratory and has developed many special procedures for calibrating flowmeters to different gases and/or conditions.

Over the years, we have built an extensive library of flow correlation tables and curves for dozens of gases at numerous conditions. Utilizing these flow correlation tables with a Matheson flowmeter will yield the accuracy specification listed for each flowmeter model in this catalog. (Ex. ±5% for FM-1050 or FM-1000). Request the tables when you order your flowmeter.

For accuracies better than standard, Matheson can directly calibrate your flowmeter(s) at a cost below what most laboratories would incur to do it themselves. To request a price quotation for your specific flowmeter application, please specify the gas, operating pressure and temperature, and flow rate or flowmeter model number. For more information call a customer service representative.

Overview Of Flowmeter Models

Matheson offers a complete line of variable area flowmeters to meet your application requirements.

Model Series	Scale Length	Scale Type[1]	Comments	Page No.
Tube-Cube®	—	—	—	355
FM-1050	150mm	Reference	High accuracy	356
FM-1000	65mm	Direct	High accuracy	358
FM-1100	70mm	Direct	High flow capacity	360
FM-1127	127mm	Direct	High flow capacity	360
Mixers	150mm	Reference	2, 3, and 4-tube mixers	362
Replacement Parts	—	—	—	364
PG-1000	50mm	Direct	Economical Acrylic body with glass tube	365
PM-1000	37mm	Direct	Economical Acrylic block and tube	367

[1] *Note: Direct Reading scales are available in both English and Metric units.*
Reference scales come with a flow correlation table for air at standard conditions.
Request a correlation table for the gas(es) or liquid(s) you will be measuring.

Basic Flowmeter Principles *(continued)*

General Ordering Information

Model Series	Number of Metering Tubes		End Blocks/ Seal Material	Valve Types	Connections	Accessories	Connection Orientation		Flow Tube (Capacities)			
☐	☐	—	☐	☐	☐	☐	☐	—	☐	☐	☐	☐

The Model Number Generator Tables (see above example) provided in each Model Series section enable you to build your own custom flowmeter by allowing you to specify the exact model number you wish to purchase. While the Model Number provides all the necessary information in coded form, to ensure that you receive the correct model for your application, it is recommended that you also specify on your order:

- Model Number, per Model Number Generator Table
- Gas to be measured
- Specific gravity of gas if other than air
- Operating, maximum and minimum flow rates
- Operating and maximum temperatures and pressures
- Scale type: Direct reading or mm reference If direct reading, English or Metric units. If mm reference, flow correlation table(s) needed
- Number of metering tubes
- End blocks and seal materials
- Valve type, if any: utility, high accuracy or none
- Connection type, size, orientation
- Accessories: bezel, baseplate, higher accuracy calibrations, clean for oxygen service, etc.
- Shipping and billing information