THE HEAT TREAT DOCTOR

Frequently Asked Questions About Flowmeters

Everyone knows what a flowmeter is, and yet, few of us really understand them the way we should. The reality often is that once they're installed and operating on a heat treating furnace we take them for granted. This can often lead to serious errors that compound themselves over time. Let's learn why.

What is a flowmeter, really? A flowmeter is a device used for measuring the flow of gases or liquids. There are actually two different ways to measure flow: by volumetric means and by mass flow techniques. As heat treaters we are most familiar with the volumetric flow measurement of gases. The principle involves the displacement of the gas volume over time. Atmosphere furnaces, gas generators, and combustion systems typically use these types of devices.

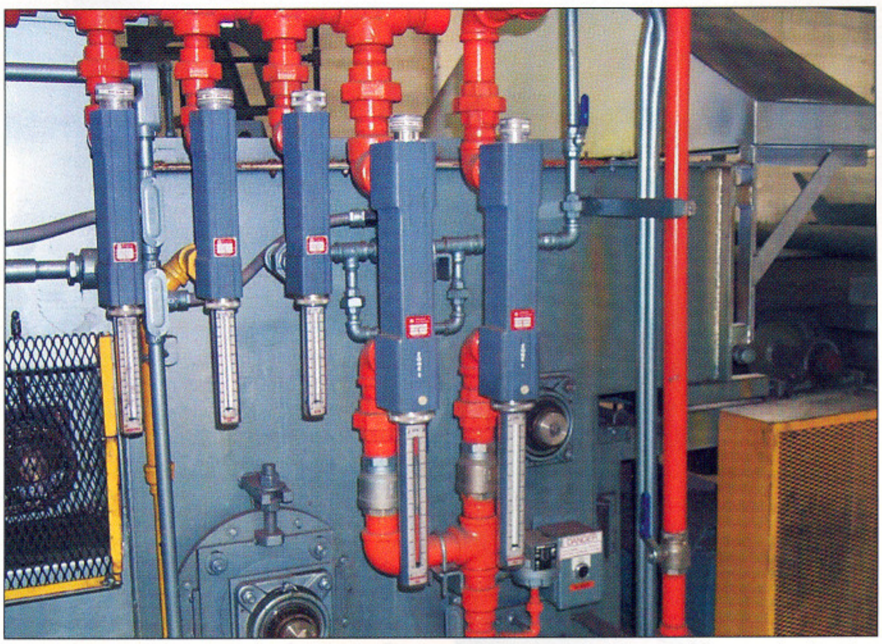
Mass flow involves measuring the weight of a gas, and these devices are commonly found on vacuum furnaces that meter in gases for partial pressure operation.

What types of flowmeters are there? As heat treaters we often focus on the measurement of gases. However, there are a number of different devices used to sense and measure the flow of both gases and liquids, and these fall under the generic term "flowmeter." For example, anyone who has seen a nitrogen-methanol system is aware that liquid methanol must be metered into the furnace.

Some of the many devices that fall under the flowmeter heading are flowscopes, mass flowmeters, orifices, rotameters, positive displacement meters, electromagnetic meters, ultrasonic (Doppler effect) devices, wedge flow devices, impact meters, and turbine meters, to name a few.

Is it easier to control a gas or a liquid? Interestingly, liquids, because of their low compressibility, are easier to measure and control than gases. For most volumetric flow applications, the incoming pressure in liquid systems does not need to be closely controlled. Liquids, by their very nature, can be captured easily and measured to a high degree of accuracy. On the other hand, gases, because of their high compressibility, require more complex sensing and control methods.

What is the accuracy range of a gas flowmeter? When measuring gas flows in heat treating applications there is an important distinction between the operating range of a flowmeter and the design range when purchasing a new meter. Plan to operate a flowmeter in a range not below 25% and not above 90% of its scale capacity. In other words, if your flowmeter is rated for 0 to 2000 ft^3/h or cfh (0 to 57 m^3/h), it can be read accurately only when the flow is between 500 and 1800 cfh (14



Heat treating furnace gas panel has five mechanical Waukee Flo-Meters with manual adjusting valves. Courtesy Waukee Engineering Co. Inc., Milwaukee, Wis. (www.waukeemeters.com).

About the columnist . . .

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Dan Herring has spent more than 25 years working for furnace equipment manufacturers in a variety of roles, including senior management and new business development. Now an independent entrepreneur, Dan lectures, writes, teaches, and consults. A frequent speaker at local, national, and international conferences, he is dedicated to advancing the state of the art in thermal processing. He has published more than 75 technical papers, written three books, and contributes to Heat Treating Progress *and other industry publications.*

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Generic and practical information presented here is not intended to replace or supplement federal, state, and local codes, government standards, insurance requirements, company policies and procedures, or common sense. In addition, all equipment manufacturers' instructions and operating and maintenance manuals should always be thoroughly read and followed. Further, personnel training should be provided unequivocally to everyone who will be associated with operating such equipment.

How to calculate the specific gravity of a gas

The following procedure can be used to calculate the specific gravity of a gas relative to that of air (1.00 at standard temperature and pressure). The example used is for natural gas of a fixed composition.*

Molecular weight of air

To find the molecular weight of air, make the following assumptions and calculations:

79% nitrogen (molecular weight = 28): 0.79 x 28 = 22.1
21% oxygen (molecular weight = 32): 0.21 x 32 = 6.7

Therefore, the molecular weight of air, MW_1, is 22.1 + 6.7 = 28.8.

Molecular weight of natural gas

To find the molecular weight of natural gas, make the following assumptions and calculations:

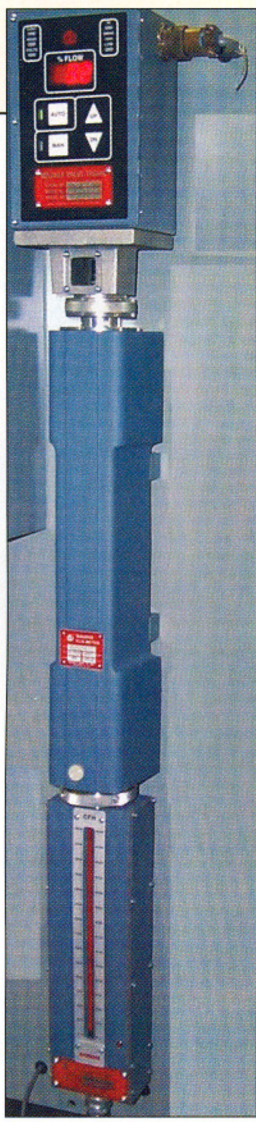
90% methane (molecular weight = 16): 0.90 x 16 = 14.4
5% ethane (molecular weight = 30): 0.05 x 30 = 1.5
5% nitrogen (molecular weight = 28): 0.05 x 28 = 1.4

Therefore, the molecular weight of natural gas, MW_2, is 14.4 + 1.5 + 1.4 = 17.3.

Specific gravity of natural gas

The specific gravity of natural gas compared with that of air is thus MW_2/MW_1 = 17.3/28.8 = 0.60.

* *Note: Published values of the specific gravity of natural gas range from about 0.60 to about 0.67. Variation in natural gas composition by location accounts for the different values.*



A Waukee Engineering electronic volumetric flowmeter, left, has three main components (top to bottom): Valve-Tronic microprocessor-based motorized valve for controlling gas flow; Flo-Meter for indicating rates of flow of air and industrial gases; and Waukee-Tronic electronic package that provides visual flow indication plus a 4 to 20 mA output that is linearly proportional to flow rate. Photo above shows a member of the Mass-Flo family of mass-flow meters and controllers. According to MKS Instruments Inc., Andover, Mass. (www.mksinst.com), the devices couple configuration flexibility with high performance to provide cost-effective, precise flow control.

and 51 m^3/h). Flows outside these limits are erratic.

A good rule of thumb for sizing a flowmeter is to purchase your meter "in the middle third"; that is, size the flowmeter so that the actual flow will be no less than 33% and no higher than 67% of the scale you select. This gives you the ability during actual operation to compensate for unexpected changes in flow requirements that may occur. Over the life of a heat treating furnace, process requirements and operating conditions often change, sometimes dramatically, and you want your gas measurement to remain accurate.

What affects my gas measurements? If knowing the proper flow rate is important to you, it is important to be aware that a change in temperature, pressure, or specific gravity of the gas from that for which the meter was calibrated will cause a serious error in the indicated scale reading. It is quite common in a heat treat shop to find flowmeters operating at pressures and temperatures different from those for which they were calibrated.

Should I have my flowmeters recalibrated? If a change of operating conditions is permanent, such as the need to constantly operate at a different pressure, then recalibration of the flow measurement device is strongly recommended. As a rule, flowmeters used in heat treating applications are designed for a maximum temperature of 150°F (65°C) and operating pressures up to 50 psig (345 kPa). However, most flowmeters have maximum operating pressures well below this value.

What do I need to consider if I want to use a flowmeter for one gas but it is calibrated for another? One of the most common problems seen in heat treat shops is that operating personnel and supervisors are unaware of the consequences of flowing a gas through a flowmeter that is different from the one for which it was calibrated.

When switching gases, the difference in specific gravity of the two gases is the principle factor that must be taken into account. Specific gravity (sidebar) is the ratio of the density of a gas to the density of dry air at standard temperature and pressure, 77ºF (25ºC) and 1 atmosphere (14.7 psi or 101 kPa).

The following equation can be used

Specific gravities of gases commonly used in heat treating

Gas that meter is calibrated for (SG_1), or is used for (SG_2)	Specific gravity, SG
Air	1.00
Acetylene (C_2H_2)	0.907
Ammonia (NH_3)	0.59
Dissociated ammonia	0.295
Argon (Ar)	1.38
Butane (C_4H_{10})	2.02
Carbon dioxide (CO_2)	1.529
City gas	0.59
Endothermic, cracked	0.59
Exothermic, cracked (lean)	1.00
Exothermic, cracked (rich)	0.85
Forming gas (95% N_2-5% H_2)	0.927
Forming gas (90% N_2-10% H_2)	0.87
Helium (He)	0.138
Hydrogen (H_2)	0.695
Natural gas (CH_4)	0.65
Nitrogen (N_2)	0.96
Oxygen (O_2)	1.105
Propane (C_3H_8)	1.522

Courtesy Waukee Engineering Co. Inc., Milwaukee (www.waukeemeters.com)

to calculate the actual flow when another gas is being metered:

$$Fa = Fi \times \sqrt{\frac{SG_1}{SG_2}},$$

where Fa = actual flow, Fi = flow indicated by the scale reading on the flowmeter, SG_1 = specific gravity of the "nameplate" gas (the gas the meter is calibrated for), and SG_2 = specific gravity of the gas to be used in the flowmeter. Specific gravities of many of the gases commonly used in heat treating are listed in the table.

Do I need to maintain my flow devices? All flowmeters eventually require maintenance. It is a sad truth that some units require more maintenance than others, so this factor should be considered when a unit is selected. However, in most heat treating operations, the equipment manufacturer has already made that choice for you, so understanding what maintenance is required and when it should be performed is of paramount importance.

Flowmeters have moving parts and require internal inspection, especially if the fluid is dirty or viscous. For example, in furnaces using endothermic gas, flowmeters often become contaminated with carbon (soot) and must be cleaned. The flowmeter must be disassembled, all internal moving parts cleaned, and dirty fluid in the flowmeter tube replaced. *Caution:* This involves isolating the flowmeter, or waiting until the unit is shut down. Note that maintenance must be performed in a safe manner, as many of the gases involved are asphyxiants as well as being flammable, toxic, and life threatening.

Remember, too, that all flow measurement devices that use secondary instruments such as pressure sensors to actuate a control valve or send a signal to a remote source must be periodically inspected, calibrated, repaired, and/or replaced. Improper location of the flowmeter itself, the secondary sensor, or readout devices can result in measurement errors and hidden costs.

Do I really need to learn about my flowmeters to be in control, stay in control, operate safely, and keep the cost of my operation as low as possible? Simply stated, "Yes." Hopefully, this discussion has helped reinforce this idea. Now go and check your flow devices! **HTP**

References

• *North American Combustion Handbook*, 2nd Ed.: North American Mfg. Co., Cleveland, Ohio, 1978.

• Private Correspondence: Vytas Braziunas, Automation Intelligence LLC, Milwaukee, Wis.