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DHI DH Instruments
A Fluke Company

Mass flow versus volume flow in gas flow measurement

Application Note

Mass flow

Mass flow is the movement of a quantity of material through a conveyance per quantity of time. SI units of measure for this parameter are kg/sec. Conversions of kg/sec to a variety of other mass flow units are possible, such as g/s and mole/s. Other very common mass flow units used in gas flow measurement are the volumetrically based type such as sccm, slm, scfm, etc. Volumetrically based mass flow units should not be confused with volume or actual flow units. Volumetrically based mass flow units define mass in terms of the quantity of gas that occupies a volume under ***standard*** conditions of pressure and temperature.

When a gas flow system is in steady state, mass flow is the same at all locations in the system and it is independent of the gas pressure and temperature conditions. Therefore, the measurement of mass flow made by the molbloc/molbox system represents the mass flow at all other points at the same time in a flow system that is in steady state. This characteristic represents the strong value of mass flow measurement over volumetric flow measurement in a gas flow system.

Flow devices that are fundamentally based on the measurement of mass, or have the internal capability to measure gas conditions and calculate mass flow from volume, can be directly compared to the molbloc/molbox system in mass flow units.

Volume flow

Volume flow is the measurement of the volume of gas through a conveyance per quantity of time. SI units of measure for this parameter are m^3/s. Other units used for volume flow are lpm, cfm, ccm. Volume flow is sometimes referred to as actual flow, and units of acfm, alm are common.

In a gas flow system under steady state conditions, volume flow is likely to be different throughout the system and it is highly dependent upon the gas pressure and temperature at the point where it is measured. This means that the volume flow will not be the same at all points within a system due to changes in pressure and temperature that naturally occur as the gas moves through the restrictions caused by plumbing, valves, regulators, filters, etc., even though the mass flow rate is the same.

Volume flow devices are quite common in industry because of their relative low cost. Devices based upon volumetric flow principles are typically very simple and therefore do not include the sensors to measure gas pressure and temperature which are required to calculate mass flow. These devices can have output indication in either mass flow or volume flow units.

Using the molbloc™/ molbox™ system

Calibration of Volume Flow Devices that Indicate in Volume Flow Units

When the molbloc/molbox system is used to measure the volume flow rate of a device under test (DUT) the gas conditions where that DUT is located must be known. Since the mass flow through the system is known at the molbloc element and throughout the system, the volume flow rate can be readily calculated by utilizing the actual gas pressure and temperature conditions at the DUT. These conditions are not likely to be the same as the molbloc conditions, so exercise caution when selecting these values for the volume flow determination.

Tech Tip:

To accurately calculate volume flow at the DUT, you must enter the gas pressure and temperature at the DUT into the molbox, or COMPASS software. This may not be the same as the molbloc values for pressure and temperature.

Calibration of Volume Flow Devices that Indicate in Mass Flow Units

Many very common flow devices are based upon volume flow measurement principles and are calibrated for, or indicate in, volumetrically based mass flow units. Examples of volumetric flow devices include variable-area flow meters (rotameters), orifice plates, venturis, turbine meters, soap-film meters, among others. Examples of volumetrically based mass flow units are sccm, slm, scfm, etc.

The output or flowrate indication of this type of DUT is based upon a specific gas at specific operating conditions – these are known as its normal operating conditions. Since the actual laboratory conditions during calibration are not typically the same as the normal operating conditions for which the meter output or indication is based, it will not indicate the correct flowrate unless accounting for these differences.

Therefore calibrations that are performed at conditions OTHER THAN the normal operating conditions of the DUT, or in a gas OTHER THAN its normal operating gas, a correction is necessary to properly correlate the DUT output/indication flowrate to the molbox reference flow.

Using the molbloc/molbox system with COMPASS Gas Density Corrections

With Compass for molbox software, the user can select between two available gas density correction types. These are called “Proportional” and “Square Root”. COMPASS applies this calculated correction to the molbox reference flow and stores it to the “Ref Flow DUT Cond” data field. This data field will then be used by COMPASS for all DUT error calculations. The user should be sure to include this field when creating data reports. It is this data field that provides the reference flow that is corrected to allow correlation to the DUT indicated flow when the DUT is not being calibrated at its normal operating conditions.

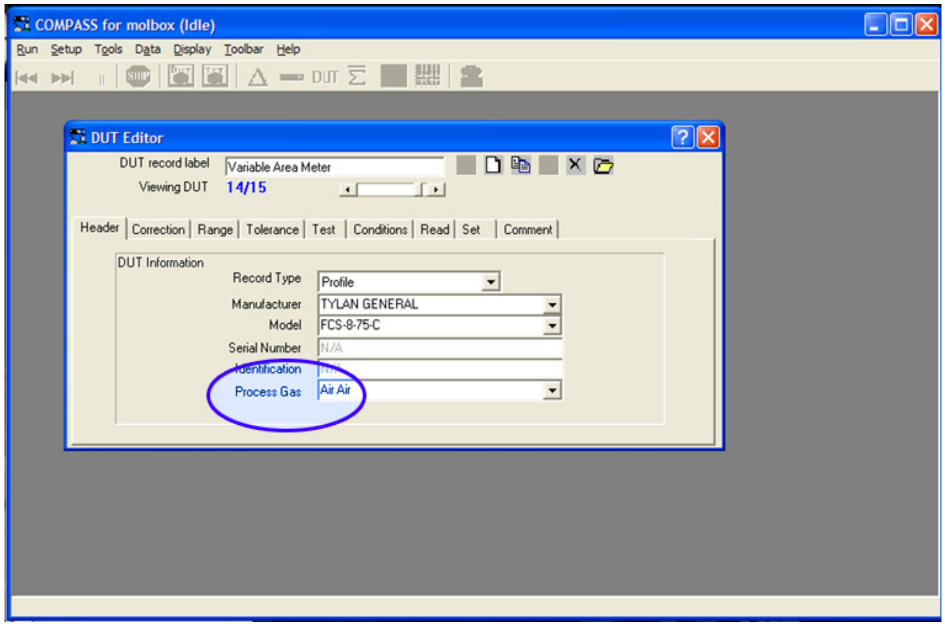
Tech Tips:

The density correction calculated by COMPASS is applied to the reference flow value and placed into the “Ref Flow DUT Cond” data field. Be sure to include this data field in the display grid and report templates.

Do not use the COMPASS density corrections for a mass flow DUT or one that makes its own internal correction for density.

Do not use the COMPASS density corrections for a volume flow device that outputs in volume flow units. Choose the proper volume units in the DUT range setup.

Select the gas species from the pull-down list.



Select the Gas Density Type required, and enter the normal operating conditions of the device under test.

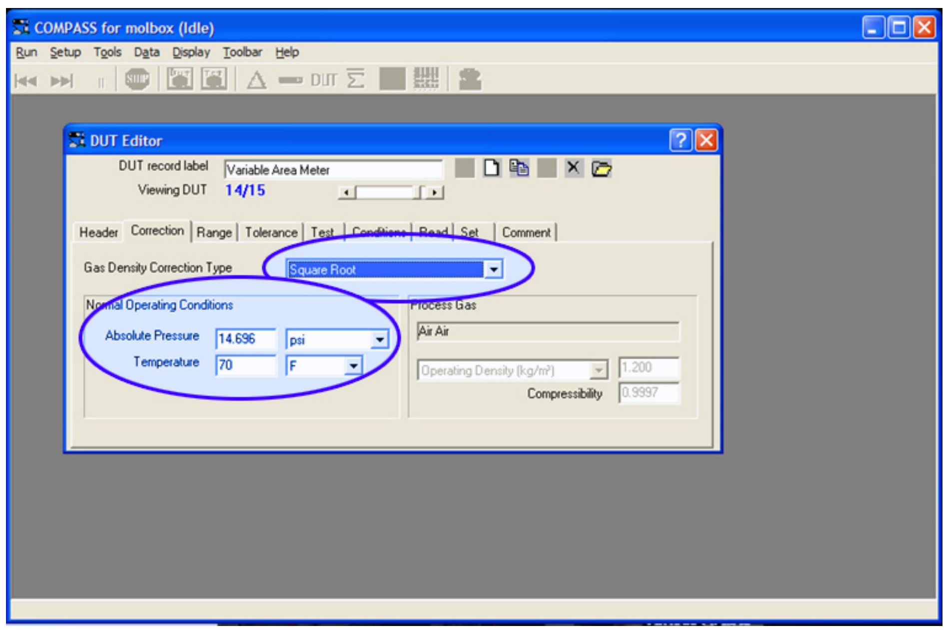


Figure 1. Entering the process gas name and the normal operating conditions of the DUT

The COMPASS for molbox proportional and square root density corrections are for use with volumetric type flowmeters that are calibrated for, or indicate in, mass flow units. Do not use either of these density corrections for mass flow devices that make their own internal calculation of mass flow, and indicate in mass flow units.

Do not use either of these density corrections for a volume flow device that outputs in volume flow units. This conversion takes place when selecting the volume flow units (such as accm, alm, acfm, etc.) within the DUT range setup.

In order for COMPASS to make a density correction, the user must enter the process gas name, and the normal operating conditions of the DUT. This is shown in Figure 1.

Square Root Density Correction

The COMPASS Square Root density correction is used for devices that are based upon the Bernoulli phenomenon that relates volume flow to differential pressure. Examples of this type of device are variable-area flow meters (rotameters), orifice plates and sub-sonic venturis.

The calculation for the corrected reference flow is as follows:

$$Q_{corr} = Q_{ref} \times \sqrt{\frac{\rho_{normal}}{\rho_{actual}}}$$

Where:

Q_{corr} is the reference flow if the device was operating at its normal conditions

Q_{ref} is the uncorrected molbloc/molbox reference flow rate

ρ_{normal} is the density of the process gas at the DUT's normal conditions

ρ_{actual} is the density of the calibration gas at the DUT's actual conditions

Proportional Density Correction

The COMPASS Proportional density correction is used for devices that are volume based, output in mass flow units, but do not have their own density compensation. Examples of this type of device are turbine meters, soap-film meters and critical flow venturis without electronic hardware.

The calculation for the corrected reference flow is as follows:

$$Q_{corr} = Q_{ref} \times \frac{\rho_{normal}}{\rho_{actual}}$$

Where:

Q_{corr} is the reference flow if the device was operating at its normal conditions

Q_{ref} is the uncorrected molbloc/molbox reference flow rate

ρ_{normal} is the density of the process gas at the DUT's normal conditions

ρ_{actual} is the density of the calibration gas at the DUT's actual conditions

Tech Tip:

The molbox system supports a number of volumetrically based mass flow units of measure. Since there is no universally accepted definition of standard conditions, the molbox supports the three most common variances.

- ***Standard* units (sxxx):** The "s" prefix indicates ***standard***. Volumetrically based mass flow units preceded with the letter "s" (e.g., sccm, slm, scfh) define standard conditions as pressure of 101.325 kPa absolute (14.6959 psia) and temperature of 0°C (32°F) and take into account the true compressibility of the flowed gas.
- ***User* units (uxxx):** The "u" prefix indicates ***user***. This option is designed to provide support for volumetrically based mass flow units with a reference temperature other than 0°C. Volumetrically based mass flow units preceded with the letter "u" (e.g., uccm, ulm) define standard conditions as pressure of 101.325 kPa (14.6959 psia) with the user specifying the reference temperature. User units take into account the true compressibility of the flowed gas.
- ***Perfect* units (pxxx):** The "p" prefix indicates ***perfect***. This option is designed to provide support for volumetrically based mass flow units that assume ideal gas compressibility for all gases. Volumetrically based mass flow units preceded with the letter "p" (e.g., pccm, plm) assume a gas compressibility factor of 1 for all gases and define standard conditions as pressure of 101.325 kPa (14.6959 psia) and temperature of 0°C (32°F).

Automate the input of pressure and temperature for COMPASS density corrections

DH Instruments recommends the RPM4 A200Ks (see Figure 2) for the measurement of gas pressure, and the Hart Scientific model 1523 readout (see Figure 3) with 5665-P Thermistor Probe for gas temperature for DUTs operating at less than 200 kPa (15 psig). Consult DH Instruments, a Fluke Company for more information.

Figure 2. DHI RPM4 A200K Reference Pressure Monitor

Figure 3. Hart Scientific 1523 Reference Thermometer

Total Solutions in Calibration

In 2007 DHI joined Fluke Precision Measurement (FPM). This exciting change allows us to provide our customers with enhanced services and the convenience of one-stop shopping.

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Flow calibration

molbox1™ gas flow calibration systems from DH Instruments, a Fluke Company

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