White paper WP/FLOW/001-EN

Mass or volume?
A weight off the bottom line

Understanding the difference between mass and volume flow measurement

Measurement made easy

Introduction

Confusion often arises over the difference between mass and volume flow measurement and when a particular measurement should be applied. Yet this is a business critical issue that if incorrectly calculated can impact negatively on an organization's bottom line. If businesses are clear on whether their processes or systems require volume or mass-based measurement they are able to benefit from both improvements in process performance and better cost effectiveness.

So, what is the difference between mass and volume measurement and how do you correctly select the right flow variable for your business?

Defining mass and volume

Mass can be defined as the amount of matter that something contains, it is directly related to weight and is measured in units, such as grammes, kilogrammes or tonnes. Volume, however, is the amount of space taken up and is usually expressed in units such as cubic metres, cubic decimetres, cubic centimetres or litres.

Where measurement of the flow of a liquid, gas or steam is concerned, the relationship is always governed by the equation D=M/V, where D is density, M is mass and V represents volume. Flowrate is measured by using the two basic units of mass and volume, this is expressed as either the mass flowrate qm (e.g. g/sec or kg/hr) or the volume flowrate, qv (e.g. l/sec or m^3/hr).

The nature of the relationship between density, mass and volume is such that a change in one will have an impact on another. So, allowing liquids with different densities to flow through a volumetric flowmeter at the same velocity will have no impact on the flow rate, as the result will be expressed in terms of how much space the liquid is occupying. But, repeating this with a mass flowmeter will result in differences between the two flows, as the difference in densities will have an impact on the mass measurement.

For example, a high density liquid will give a high mass flow rate compared to a low density liquid flowing at the same volumetric flowrate. As an illustration, one litre per second of vegetable oil may give a mass flow rate of 950 grammes per second, whereas sodium chloride solution would give a mass flow rate of 1.1 kilogrammes per second.

Mass or volume?
A weight off the bottom line

Gases and steam

Mass flow measurements can be expressed in volumetric units but careful consideration is needed. To be able to compare volumetric-based flowrates for gases, it becomes necessary to factor in standard or normalised conditions for temperature and pressure. If a comparison is to be accurate, it is essential to ascertain whether the gas measurements in question are being expressed in normalised units, standardised units, such as standard cubic feet (scf) or as actual units.

The importance of this is demonstrated by the following comparison between normalized volume and actual volume:

Actual		Normalized
0.1m^3 at 0 °C and 10.13 bar	=	1m^3 at 0 °C and 1.013 bar.

If both of these volumes were run through a system, the volume flow of 0.1m3 actual per second is actually equal to 1m3 normal per second. Although the volume flow in both cases is different, the mass flow rate is identical.

The key point to remember when using actual volumetric measurements is that accurate measurement of different flows will only be possible where those flows are subject to identical temperature and pressure conditions.

Factoring in compression

The situation also becomes slightly more complicated in applications measuring gas or steam as they can be compressed, resulting in a shift in density. As you compress a gas, the volume measurement changes, but its mass remains the same. Therefore it is not the volume of steam that's the critical measure of the amount of energy moving around the system. What needs to be known is the mass.

Having access to proper information about steam and hot water flows around a site is a tremendously powerful tool for monitoring and controlling energy use. Strategically positioned meters form the front line in energy management systems.

Volumetric or mass flow?

As with most issues relating to the selection of flow measurement technology, there are no hard and fast rules favouring the definite selection of volumetric technology over mass technology, or vice versa. Instead, there are a number of different factors to be considered.

Foremost amongst these is to decide what is needed, and this will be determined by what a product, process or business is based on - is it volume or weight measurement? When buying or selling by volume, then volumetric flowmeters may provide the best solution. However, if weight is being used as the final measurement or to derive the value of a product, such as fuel, then mass flow will provide the most accurate measurement.

Consideration must also be given to the level of accuracy required by a system process or sector. Although liquids and gases can be measured using both volumetric and mass flow measurement, mass flowmeters are particularly appropriate for high accuracy applications, as the measurement remains unaffected by the effects of temperature or pressure.

Differing meter types

There are three main types of mass flow measurement technology available.

Coriolis

For liquid mass flow measurements, coriolis mass flowmeters use the momentum of the fluid to directly determine the mass flow. Although comparatively more expensive than other mass flow methods, they are highly accurate, and have an extremely wide turndown.

Offering long term benefits in terms of increased process efficiency, production cost savings and reduced cost of ownership, they also provide direct density measurement making them invaluable for product quality assurance purposes.

Thermal

Thermal mass flowmeters work by measuring the amount of heat that a gas carries away from a heating element as it flows past. This is a direct measurement of the mass flow so it is more straightforward, and hence easier (and often cheaper) to implement than techniques that derive the mass flowrate of gases indirectly. A volumetric flowmeter would also need to know the temperature and pressure of a gas in order to compute its mass flow, which means buying, installing and maintaining extra instrumentation.

This technology offers an economical solution, particularly in large pipe sizes and across wide measurement ranges, enabling accurate measurement even at very low flows.

Multivariable DP

The third type of mass flow technology is the multivariable DP flowmeter. These devices measure the temperature and pressure of the gas or liquid as well as its flow. This information is then used to assess the density as well as the volumetric flow, from which a mass value can be derived.

These are considered an indirect method of measurement, as the mass flow information is inferred using temperature and pressure values.

Summary

Understanding the difference between mass and volume is a key concept for many sectors and if applied correctly, will directly benefit business whether that be through reduced energy costs, accurate measurement of ultra-flow rates or varying process flow techniques.

Contact us

ABB Limited
Process Automation
Oldends Lane
Stonehouse
Gloucestershire GL10 3TA
UK
Tel: +44 (0)1453 826661
Fax: +44 (0)1453 829671
email: instrumentation@gb.abb.com

For more product information visit:
www.abb.com/measurement

WP/FLOW/001-EN 01.2015

Power and productivity
for a better world™