SGR FOCUS ARTICLE

Using Mass Flow Controller-Based Dynamic Gas Blenders to Produce Accurate Calibration Gas Standards

by Tom Bramford

Electronic mass flow controllers and mass flow meters ensure that vapor gas flow measurement and control is accurate producing gas standards.

Mass flow devices, developed in the 1960's, are critical components is systems that produce the specialty gas standards required to calibrate a wide variety of instruments that analyze gases.

Mass flow devices generate a signal that is proportional to the mass flow of a gas. Since the specific heat of a gas is unique to a particular gas, mass flow devices are essentially independent of fluctuations in pressure and temperature. Thus, the signal they generate is very accurate and stable.

If the signal voltage from a mass flow device is used to indicate flow, it is classified as a mass flowmeter (MFM). If the signal from such a device is used in conjunction with a reference signal and a controlling valve, it is classified as a mass flow controller (MFC).

When several MFC's are operated in parallel, and are electronically controlled within tight limits, the gas mixtures produced are extremely accurate. This is the principle behind a commonly used filling technique called "Dynamic Blending."

Dynamic Blending

When a certified gas mixture is ordered from a producer of calibration gases, lead time and price are important considerations. These factors can affect whether your analytical instrument is properly calibrated.

Where volume and urgency are major considerations in meeting calibration requirements, the purchase of a dynamic gas blender may be more cost-effective than purchasing the calibration gas. Dynamic gas blending is preferred to other types of systems that produce calibration standards since they can, in some cases, produce the end product more quickly and at a lower cost, and still ensure high accuracy.

Some dynamic gas blenders that are used to produce mixtures for calibrating ambient air pollutant monitors, also produce precision levels of ozone. This ozone can then be used to calibrate ambient ozone monitors and oxides of nitrogen (NOx) monitors that use gas phase titration with ozone.

Many factors can affect the overall accuracy of an MFC-based dynamic gas blender. These can range from the selection of the MFC to the care taken by the end-user in operating and maintaining the equipment.

Some Applications for an MFC-Based Dynamic Gas Blender

Although the dynamic gas blender is used in a variety of markets and applications, following is a list of applications under the heading of Calibration Gas Standards: Ambient air monitors; EPA Method CTM-007 for Continuous Emission Monitors (CEMS); EPA Methods TO-14 and TO-15 for VOCs; Gas Chromatographs; Mass Spectrometers; Auto Emission Analyzers; Handheld detectors; Gas and Chemical Sensors; and other gas analytical instrumentation.

Qualifying and Selecting a Mass Flow Controller for a Dynamic Gas Blender

Just as the MFC is the heart of a high-accuracy gas blender, the flow sensor is the heart of a mass flow controller. The most common and traditional technique for measuring and controlling mass flow is with a thermal mass flow controller. As noted earlier, this type of device measures the temperature shift (or differential) that occurs in a small tube as heat transfers to and from the gas.

A thermal mass flow sensor is shown in Figure 1. As gas flows through the sensor tube, it gathers heat when it enters the tube and transfers some heat back to the tube as it exits. The temperature differential in the tube is measured by two independent temperature sensors, TC1 and TC2. The electrical signal generated by the sensors, is amplified and transformed to a linearized signal that is commonly recognized by instrumentation.

When selecting an MFC for a gas blender, it is important to review sensor data provided by the MFC manufacturer. The data should include long-term stability and repeatability. Manufacturers of gas blenders need to have on hand all of the research data on the type of sensor employed to ensure that no inherent flaws may be present.

When flow controllers are calibrated, they should be calibrated in conjunction with the process gas that is to be analyzed. However, this is not always possible. When the process gas cannot be used for calibration, a surrogate gas can be used as a substitute. A conversion factor (K) is applied during this calibration to ensure that the flow through the MFC is accurate with respect to the process gas. It is incumbent upon the manufacture of the dynamic gas blender to confirm that his supplier of the MFC device has committed sufficient time to the proper evaluation and development of accurate K-factors for all of the gases that will be used with the blender. Ideally, K-factors should be derived empirically. Figure 2 is a partial list of one company's K-factors and the methods used to derive them. (NOTE: A "K" factor is defined as the ratio of the actual gas flow rate to the equivalent nitrogen flow rate. To obtain the equivalent nitrogen flow rate, divide the actual gas flow rate by the K factor. Example: The K factor for argon = 1.45. QEQUIVALENT NITROGEN = (QACTUAL GAS / K) = 101.94 slpm / 1.45 = 70.3 slpm.)

The most important step that a gas blender manufacturer can take when selecting an MFC is to evaluate one set of MFCs, over a period of several months, from each qualifying manufacturer. The most important characteristics to analyze are repeatability, stability, and short and long term drift. Figure 3 illustrates an evaluation that spanned seven months. On the day of each test, the MFC was flow-tested, using a primary flow standard at four points, throughout the full-scale range; 10 repeatability points

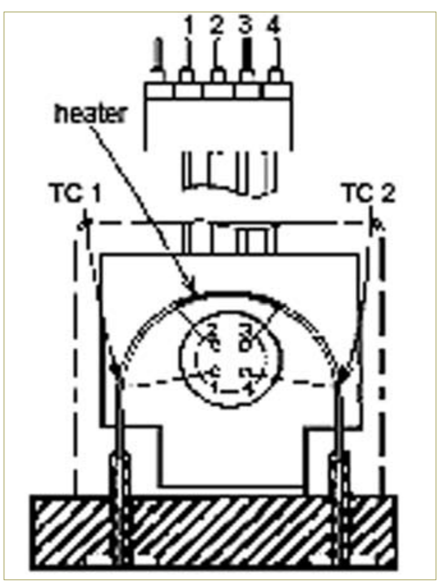

Figure 1. A thermal mass flow sensor.

Rec #	Gas	Symbol	GCF	Derived	Density (g/L) 25° C / 1 atm	Density (g/L) 0° C / 1 atm	Gamma (Cp/Cv)25	R J/gm°K
1	Acetone	C_3H_6O	0.3576	4	2.374	2.591	1.2	4.942
2	Acetonitryl	C_2H_3N	0.5186	4	1.678	1.832	1.2	6.991
3	Acetylene	C_2H_2	0.6262	4	1.064	1.162	1.23	11.023
4	Air	Air	0.9980	1	1.185	1.293	1.4	287.000
5	Allene	C_3H_4	0.4490	4	1.630	1.787	1.2	7.104
6	Ammonia	NH_3	0.7010	2	0.696	0.760	1.32	16.052
7	Argon	Ar	1.4010	1	1.633	1.782	1.65	7.184
8	Arsine	AsH_3	0.7592	5	3.186	3.478	1.2	3.602
9	Boron Trichloride	BCl_3	0.4426	4	4.789	5.228	1.2	2.449
10	Boron Trifluoride	BF_3	0.5438	4	2.771	3.025	1.2	4.293
11	Bromine	Br_2	0.8025	4	6.532	7.130	1.4	1.756

Derived:
1. Empirical determination
2. Calculated using a least squares fit to NIST tables.
3. Calculated using the virial coefficients of independent investigators' empirical data using both temperature and pressure as variables.
4. Calculated using virial coefficients determined by functions of temperature only.
5. Calculated from specific heat data at 0C at 1 atmosphere.

Figure 2. Gas conversion factors for HFC-202

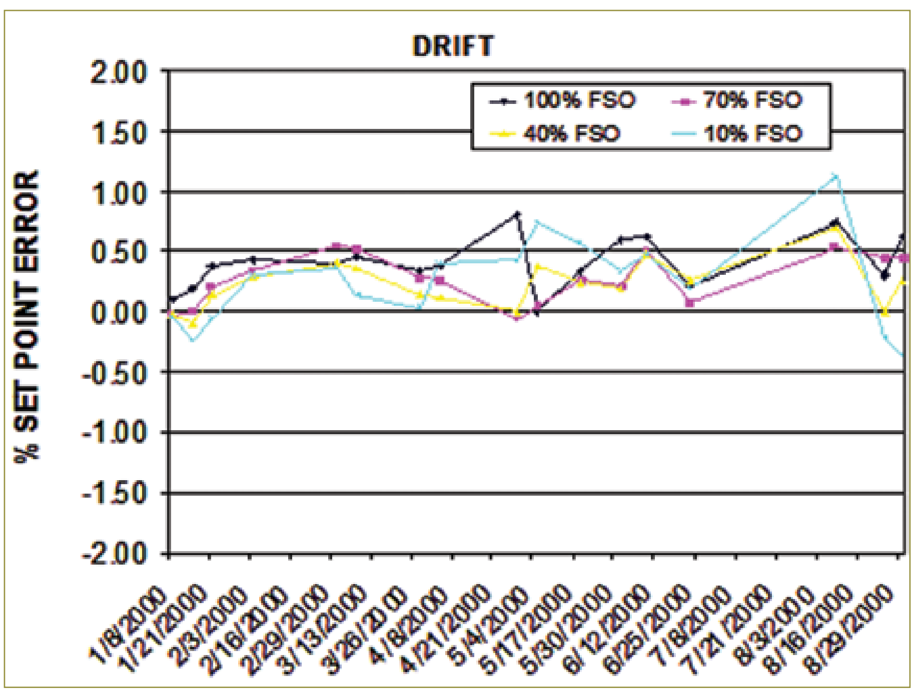

Figure 3 illustrates an evaluation spanning seven months. On the day of each test, the MFC was flow-tested, using a primary flow standard at four points, throughout the full scale range; 10 repeatability points were taken at all four major flow rates to establish the average repeatability of each test.

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Developing and Manufacturing an Accurate Dynamic Gas Blender.

Starting with a highly accurate MFC is only one part of developing an accurate gas blender. Another is how well a company develops the software and controls that will confirm the accuracy chain.

When using MFCs controlled by an analog voltage, a minimum of 12-bit DAC and ADC should be designed into the instrument. Equally important is the accuracy of the precision reference voltage applied to these devices. With 12-bit resolution, increments of .0012 VDC are applied to the MFC to achieve precision control. Both the equipment and the MFCs should be CE certified. This ensures that the instrument will not be susceptible to electrical interference. The system should be built using 316 SS electropolished tubing, fittings, and MFCs. Alternate tubing and seal materials may be compatible with different gases. Proper selection can save considerable costs.

When developing software that will control a gas blender, improving the MFC specifications should be the primary focus. Some blender manufacturers, who use thermal mass flow controllers, have been known to install an MFC as it was received from the manufacturer without conducting any further calibration.

Depending on the accuracy of an MFC manufacturer's specification without verifying them with your own tests can result in a blender with faulty specifications. A good gas blender manufacturer always uses a calibration standards lab to confirm an MFC's factory specifications.

Double Check the Flow Standard

Every MFC installed in the a gas blender should be calibrated using an accurate flow measuring instrument that has a specification of .2% of reading or better. To achieve the highest, most accurate results with a blender, a minimum of eleven calibration readings should be gathered on the flow standard. The calibration data should then be entered into the gas calibrator software and used as a reference table. A flow-correcting algorithm, ex. linear interpolation should then be applied by the blender software to improve the accuracy and linearity of the MFCs. The gas blender also should have an option that permits purging of the entire gas path using an inert gas.

The same principle should be applied to K-factor correction. Once an MFC manufacturer has been selected, that manufacturer's library of K-factors should be used by the blender control software to make corrections as alternate gases are used.

Figure 4 illustrates one blender's MAINTAIN PORTS mode. This mode permits the operator to enter the gas types being fed into the equipment's input ports and MFCs. The software has a built-in standard that permits it to automatically compare the process gas to the original calibration gas for each MFC installed (up to 9 MFCs). Each bottle of gas can have up to (???) the individual component gases in a balance gas (typically nitrogen). The system automatically calculates and applies the K-factor for all the gases relative to the calibration gas of the MFC. This figure also shows three component gases in a nitrogen balance.

The Responsibility of the End User to Maintain the Accuracy Chain.

The responsibility of maintaining accuracy lies with the end-user and owner of the gas blender. Input gases fed into any gas blender should be clean and free of moisture. Most anhydrous gases are inert so they are unaffected by the standard materials used in a gas blender. However, in the presence of moisture, anhydrous gases can become corrosive. Contamination can develop over time and, if contaminants are carried downstream into the MFC sensor, they can render the MFCs useless. Contamination on the sensor tube walls reduces the effectiveness of the heat transfer between gas and sensor tube and may also block the small inner diameter of the tube, often rendering the MFC completely inoperable. NOTE: Make sure that all gas ports are capped when they are not in use. This ensures that moisture, particulates, and other airborne contaminants will not enter the system plumbing.

When possible, cylinders with 100 percent pure gases should be used. A pre-mixed gas that is not check or properly handled can be the first source of contaminants the lead to errors in the gas blending system.

When uncertified cylinders of premixed gases are used, very large errors can be introduced; a dynamic gas blender cannot compensate for these errors. When there is no choice other than to use a premixed gas, certified cylinders should be used for instrument calibration procedures, especially when guidelines or regulations mandate it.

The most important responsibility incumbent upon the end-user is that he

COMPUTE K-FACTOR

Gas #	Concentration		K-factor	Gas Name	
1	BALANCE		1.0	NITROGEN	N2
2	20.0	%	0.737	CARBON DIOXIDE	CO2
3	1000.0	PPM	0.844	HYDROGEN SULFIDE	H2S
4	30.0	%	0.686	SULFUR DIOXIDE	SO2
5	0.0	PPM	1.0	NITROGEN	N2
6	0.0	PPM	1.0	NITROGEN	N2
7	0.0	PPM	1.0	NITROGEN	N2
8	0.0	PPM	1.0	NITROGEN	N2
9	0.0	PPM	1.0	NITROGEN	N2
10	0.0	PPM	1.0	NITROGEN	N2

Cylinder Identification: MULTI-BLEND

K-factor = 0.827 referenced to AIR

PPM OR % GAS TYPE REF TYPE ACCEPT CYL ID INIT EXIT

Figure 4. Model 2000 application of K-factor correction.

follows all manufacturer-prescribed maintenance and calibration precautions stipulated for that equipment. Even if guidelines and regulations do not mandate calibration of the gas blender used to produce the calibration mixture, the dynamic blender should be calibrated on a periodic basis—typically once every year. Following all these simple guidelines will ensure a long and accurate life of an MFC-based dynamic gas blender. SGR

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