WHITE PAPER

Mass Flow Controllers

Advancing Mass Flow Technology with Multi-range and Multi-gas Programmability

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In the past 10 years, mass flow controllers with multi-range and multi-gas programmability have redefined the flow control industry. Gone are the days when process engineers needed to remove an MFC from a gas line in order to select new gas calibrations and full-scale ranges. This has led to higher accuracy, better reliability and lower cost of flow control operations.

Now in their fourth generation, MFCs with this multi-range and multi-gas programming capability, also known as MultiFlo™, provide the most accurate and broadest range performance. This is due to the extensive refinement and physical validation on critical process gases.

The Advent of MultiFlo Technology

The move toward MultiFlo-enabled MFCs began not long after digital technology moved into the industry. The development of digital electronics with a microprocessor and on-board memory enabled MFC manufacturers to move beyond the limitations of fixed, three-point calibrations (zero, linearity and span).

Onboard memory enabled multiple factory calibrations, or “gas pages,” to be stored on the MFC. Each gas page is created using the optimum surrogate calibration and response gases. While this was an improvement, the factory calibrations were still based on a single-point conversion factor to a surrogate calibration gas. This limited overall process gas accuracy and forced end users to guess which gases they would use in the future when ordering a new MFC.

Further, although extra factory calibration curves could be added, their range was limited to the primary calibration’s nitrogen equivalent. So, if an end user purchased a 500 sccm device, it could be programmed for the equivalent full-scale flow of other gases (for example, 359 sccm NH3, 429 sccm Cl2 or 707 sccm Ar). This was often a highly limiting factor in how useful the extra calibration curves could be.

As the accuracy of the original single-point conversion factor became limiting to the overall usefulness of MFCs in advanced process control, a physics-based model was developed. This method more accurately predicted the MFC sensor’s responses to gases with known properties. This was achieved by calibrating each thermal flow sensor on nitrogen. Then a universal sensor calibration curve based on a similarity theory was applied to create an accurate process gas calibration curve. This improved accuracy was initially offered for nine surrogate calibration gases.

The combination of a digital MFC’s ability to store multiple calibration pages and its improved accuracy from the physics-based gas similarity model enabled users to select new gases and store their own calibration pages. This feature became known as multi-gas programmability.

By improving the linearity of the flow restrictor (a.k.a. bypass), very low sample flows could be precisely and reliably diverted and measured through the calibrated thermal flow sensor. This allowed accurate measurement at very low sensor flows, enabling the MFC range to be electronically scaled down. This became known as multi-range capability, which permitted users to range down the factory nitrogen full-scale calibration by a factor of 3:1.

Figure 1: Data is collected in our state of the art Gas Lab on multiple MFCs in order to create an extremely accurate gas data base

Using the combined multi-gas/multi-range capability was a simple process of connecting the digital MFC to PC-based MultiFlo software. This software reads the factory calibration, takes the customer input for gas and range, and builds a new calibration curve with optimized PID control parameters. The new gas and range is then downloaded to a new gas page on the digital MFC.

Today, the traditional nitrogen accuracy of 1% full scale has been surpassed by using 10 calibration points. The additional calibration points and digital capability enables 1% of set point accuracy. The accuracy improvement delivered depends on the set point being run as shown in Figure 2.

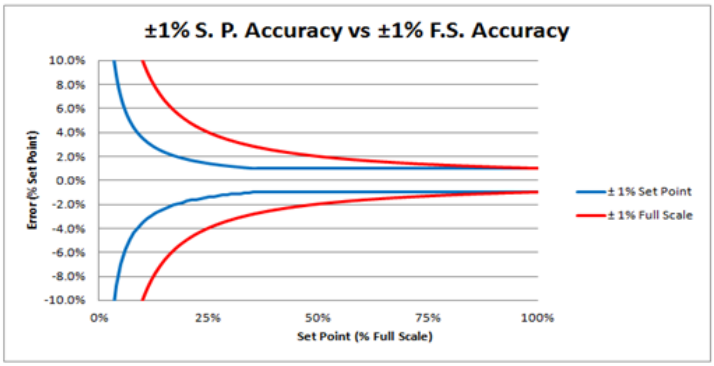

Figure 2: Plot comparing ±1% of set point accuracy to ±1% of full scale accuracy. Please note that for the set point accuracy it is ±1% of set point between 35-100% control range, and 0.35% of Full scale from 2-35% control range.

Benefits of MultiFlo Technology

The three primary benefits of the MultiFlo technology are its actual process gas accuracy, its flexibility, and its simplicity.

Actual Process Gas Accuracy

A major advancement over traditional single-point gas conversion factors, MultiFlo technology delivers a significant improvement in actual process gas accuracy. This is achieved through advanced gas modeling that is optimized through actual gas testing. This testing provides compensation for non-linear gases. This can be seen in Figure 3 and Figure 4 below.

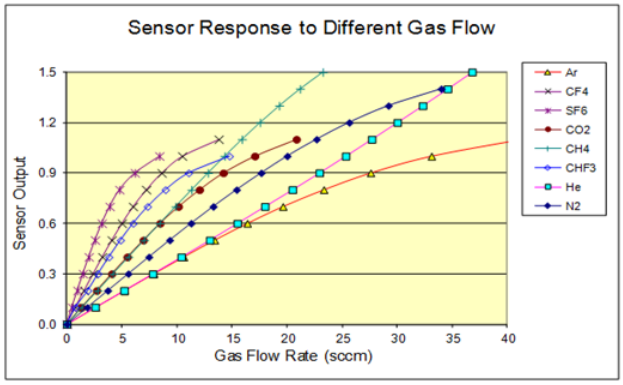

Figure 3: Flow sensors respond very differently with different gases. While gas conversion factors may work better for some gases, most do not have a linear relationship between the flow rate and the sensor output which causes inaccurate readings

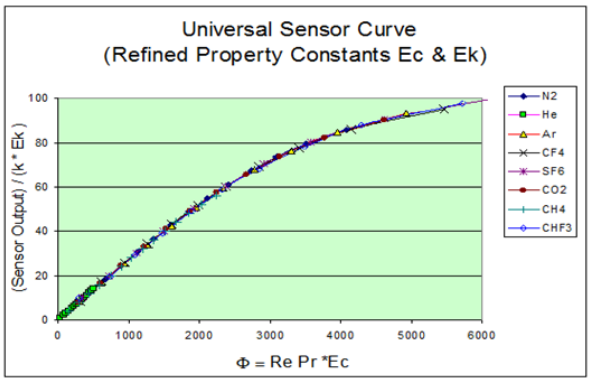

Figure 4: Each sensor is N2 calibrated and a universal senor calibration curve as well as Similarity Theory is used to determine the MultiFlo process-gas calibration curve (US Pat #7,043,374)

MultiFlo also allows the MFC to be quickly and easily configured for another gas and/or flow range without sacrificing accuracy or rangability. Selecting a new gas automatically creates a new calibration curve, establishes optimized PID settings for dynamic control, automatically compensates for gas density effects, and ensures smooth, overshoot-free transitions between flow rates with excellent steady state stability.

By collecting years of actual process gas accuracy data, which includes challenging and/or toxic gases in addition to standard gases, Brooks is able to claim superior process gas accuracy vs competitors' Multi-gas/Multi-range process gas accuracy as shown Figure 5, Figure 6, and Figure 7.s

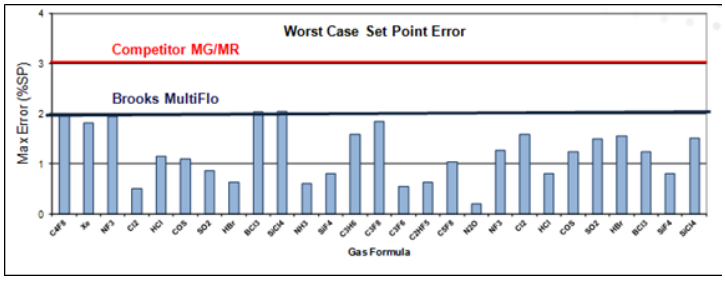

Figure 5: Brooks vs. competitor process gas accuracy comparison

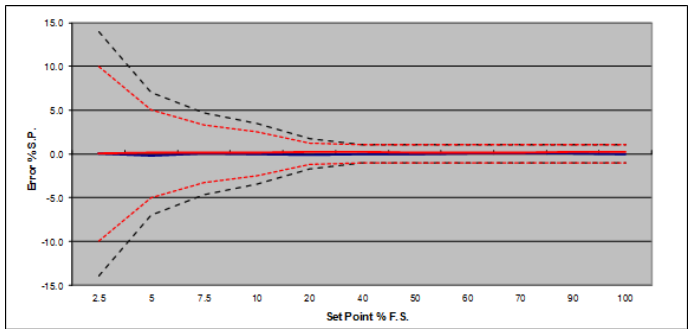

Figure 6: Brooks GF Series and Competitor perform comparably within specification on Nitrogen

Figure 6 shows that the competition performs comparably to Brooks when a device is calibrated using a gas such as nitrogen. However, Figure 7 shows that the competition's MG/MR capabilities do not compare to MultiFlo's ability to provide excellent process gas accuracy.

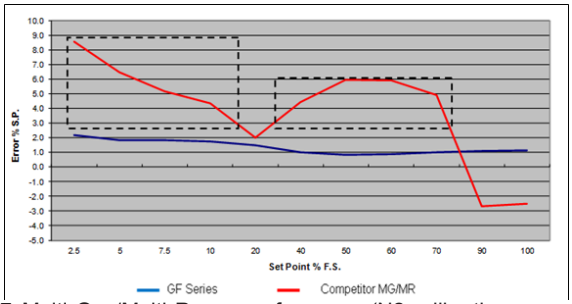

Figure 7: Multi-Gas/Multi-Range performance (N2 calibration, SF6 accuracy)

Flexibility

MultiFlo technology offers unparalleled flexibility as well. For example, a single MFC can be programmed for thousands of different gas and flow range configurations. Re-programming is simple and fast, as MultiFlo gives users the ability to program a new gas and range in less than 60 seconds.

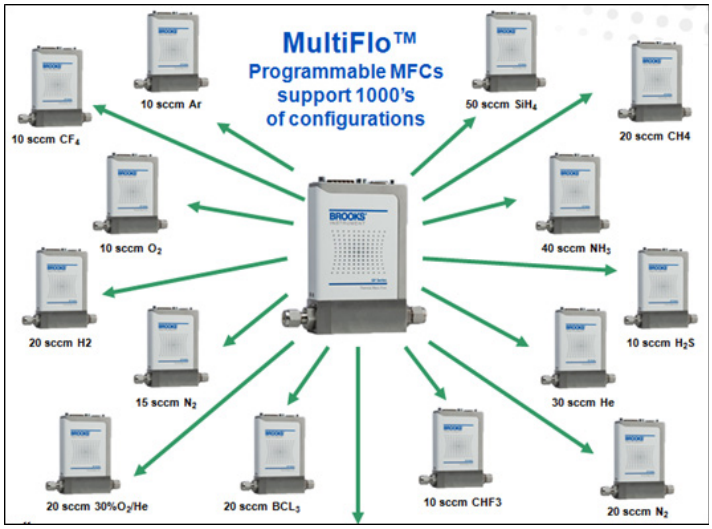

Figure 8: MultiFlo Technology allows a single mass flow controller to have 1000's of configurations.

Users of MultiFlo-enabled MFCs across various industries have reported the following benefits:

- Dramatically reduced inventory costs
- Optimum process and inventory flexibility because MFC full-scale flow range can be re-scaled down by a factor of 3:1 with no impact on accuracy, turndown or leak by specifications.
- Off-the-shelf technology spares programmability and enables rapid process recovery
- Satisfies a broad range of industry applications with one device without removing device from the system.

Simplicity

MultiFlo software is easy to use which makes switching to a different gas or range a breeze. The software can be downloaded free of charge from the Brooks Instrument website by visiting the "Documents & Downloads" section. Both the MultiFlo Configurator and the FloCom Database must be downloaded in order for the MultiFlo Software to work (See Figure 8).

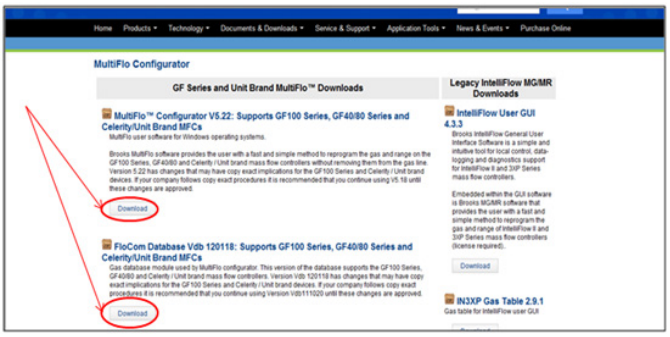

Figure 9: Screen shot of MultiFlo Software on www.BrooksInstrument.com

Once the software has been successfully installed, connect the power cable and the MultiFlo cable to the MFC in order to power up and communicate with the device. Then poll the network to locate any devices that are connected to the computer. If successful, a screen similar to the one shown in Figure 9 should appear.

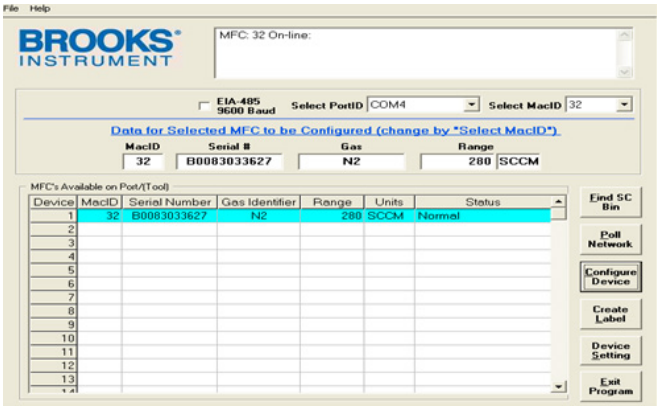

Figure 10: MultiFlo Configurator after network has been polled and connected device located.

In order to change the gas or range of the MFC, simply select "Configure Device" on the right hand side of the menu. From there, use the drop down menu to select a new gas or type in the new desired flow range, both highlighted in Figure 10.

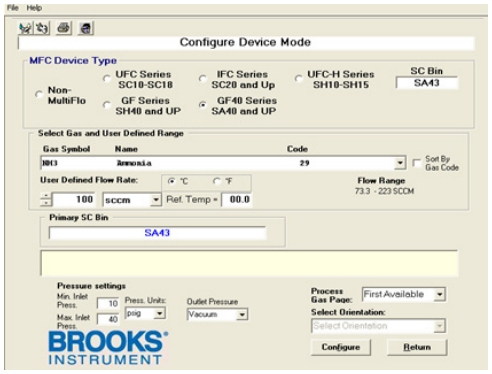

Figure 11: The process gas and flow range can both be changed from this screen, as well as the reference temperature and the MFC's pressure settings.

In order to simplify this process even further, multiple gas pages can be saved to a MultiFlo capable MFC so that the user can switch between various gas configurations in the blink of an eye. Gas configurations that have already been saved to the device will show up in the screen shown in Figure 11.

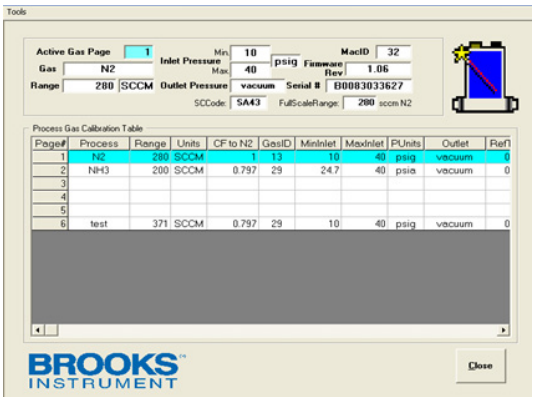

Figure 12: Saved gas configurations show up in the Process Gas Calibration Table

MultiFlo Applications

MFCs equipped with MultiFlo technology can be specified for a variety of applications across many industries. Here, we share some of those applications, as well as some specific cases of how digital MFCs with MultiFlo are being used in flow measurement.

Gas Blender and Dilution Systems

Traditionally, gas blenders and dilution systems require two to four MFCs per system. The MFCs in this system take individual gases and mix them to obtain a desired mixed gas concentration by controlling the individual gas flow rates. In the event that a new gas concentration is desired then the

gas or range that the MFC was originally configured for can be reconfigured to meet the new process specifications.

With the flexibility of MultiFlo, spare MFCs can be quickly reconfigured to replace any other MFC no matter what the gas or range is. This allows the customer to keep fewer replacement devices on hand. These systems are used in the following applications:

- Testing stack gas monitors
- Developing calibration gas mixtures
- Creating modified atmospheric packaging (MAP) and equilibrium modified atmospheric packaging (EMAP)
- Welding shielding gases
- Blanketing Gases
- Ozone generation
- Catalyst reduction testing
- Sensor calibration and testing

OEM Equipment

Many types of systems use MFCs to control the flow of gas addition during analysis. For example, one process analytical OEM uses MFCs to control the flows of fuel (hydrogen) oxygen or air, and sample gas in order to oxidize all sulfur-bearing compounds to SO2 which is then measured using UV-fluorescence. Others use MFCs to control gas sample flows for a variety of analytes.

A powerful advantage that MultiFlo brings to OEMs is a reduction in part numbers. Normally, an OEM might have a large number of part numbers to support due to the number of different gases and flow ranges that they use in their range of equipment. MultiFlo takes those different devices and condenses them into a few or limited number of MFCs allowing reduced production inventory and reduced and simplified after-sale service inventory.

Coating Equipment

Many thin films are deposited with chemical vapor deposition (CVD) techniques. In CVD, gases and vapors are introduced to a vacuum chamber to deposit a material of interest on a substrate. CVD systems also employ MFCs used to control the flow of gases used to purge and clean the chamber. Depending on the complexity of the system MultiFlo MFCs can reduce spares inventory, permit gas type and range to be changed on-tool, and provide excellent process control.

Conclusion

The use of Brooks' MultiFlo technology in thermal mass flow controllers provides superior process gas accuracy with the help of data generated by over thousands of different data points over the course of 10 years. This allows a single MultiFlo capable MFC to replace many different MFCs no matter what gas or range is required, thus reducing inventory of replacement MFCs. Brooks' MultiFlo software is extremely easy to learn, allowing configurations to be modified quickly and with little effort. Devices can be reconfigured without the MFC even being removed from the system with the use of the MultiFlo cable and the external diagnostic port. By combining the various benefits associated with MultiFlo, such as improved system up time, improved process control, and reduced cost of ownership, with the quality and reliability that comes with the Brooks' name, you get a product that is able to vastly improve any system it is used in.