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The Advantages of Mass Flow Meters & Controllers in Fuel Cell Test Stands │ Business White Paper

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The Advantages of Mass Flow Meters & Controllers in Fuel Cell Test Stands

Fuel cell engineers use test stands to simulate the performance of fuel cells. The challenge is to mimic reality and determine the optimum fuel mixture and temperature, while also examining failure mechanisms. Another objective is to test the performance of anode/cathode materials, catalysts, and membranes.

Fuel cell test stands consist of systems for mixing, delivering, and humidifying gases, all of which depend on reliable flow measurement and control. A typical test stand uses several thermal mass flow controllers (MFCs) of various flow rates to deliver the precise amount of blended gases to the fuel cell. Since the test stand must imitate normal operating conditions, these flow controllers must react to process signals quickly – much like a car accelerator – to provide a true test of the desired performance. In addition, the MFCs must have a broad turndown to mimic low and high fuel consumption rates. Many fuel cell test stands use MFCs that do not have the performance capabilities to adequately test fuel cells.

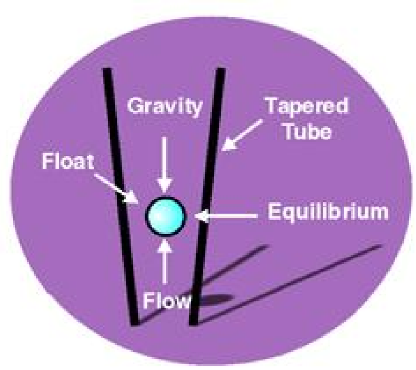
For research, development or manufacturing of fuel cells, engineers need test tools to evaluate and validate fuel cell technology. Test systems must provide flexible data acquisition, monitoring and control to precisely handle the fluid for fuel cell operation and experiments.

As research engineers constantly incorporate new measurements into their tests, they need reliable, accurate and flexible test systems to help shorten development cycles, increase quality, and lower the cost for all stages of fuel cell development, from research and design validation to manufacturing.

One of the most important and complex tasks is the control of gases to the fuel cell and the selection of the best measurement and control equipment.Gas measurement and control can be done with a variety of technologies ranging from a simple variable area meter (VA), commonly know as a rotameter, to thermal mass flow controller. A thermal mass flow controller is the preferred choice by most fuel cell developers due to its response time, turndown capability, and accuracy.

Variable Area Meters (Rotameters)

Measurement and control using a VA meter is accomplished with a glass tube and a float (ball) and a needle valve. The measurement itself is volumetric and readings can be fairly accurate as long as conditions are close to normal pressure and temperature; however, wide variations in temperature or pressure will affect the measurement, often significantly. Nominal accuracy is dependent on the device selected, with a range of 2-10% of full scale. To approximate mass using a VA meter, one must assume that the temperature is 68 degrees F and pressure is sea level, and stay constant throughout



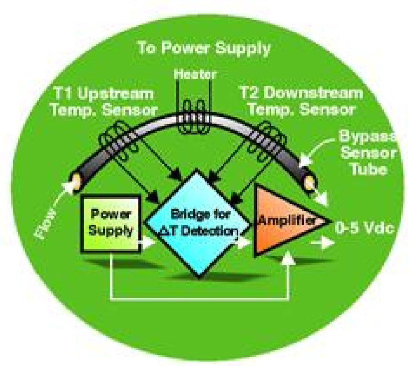
the measurement range. In the early days of fuel cell testing, the VA meter was a commonly used device: it was simple and inexpensive; however too many times when results were compared with those using a mass balance, it was apparent that the VA meter's accuracy was unacceptably inconsistent due to wide fluctuations in temperature and pressure.

Mass Flow Controllers

The Mass Flow Controller (MFC) is the preferred choice for controlling gas flows in today's test stations. Two main measurement technologies are used for doing the measurement, thermal, and pressure/ temperature. Both technologies measure inferred mass. The mass flow measurement using pressure and temperature is based on the ideal gas law. The drawback with this technology is that it assumes that everything stays constant, and, unfortunately, it's not. Accuracy is in the range of 2% of full scale, with a repeatability of 0.5% of full scale, still not a perfect choice for an accurate test and mass balance.

The most common measurement and control instrument is the Thermal Mass Flow Controller (TMFC). It is available in a variety of configurations and with a very wide performance range. In this case the common adage that you get what pay for is very true. While a thermal MFC is a more expensive technology than VA or pressure/temperature mass flow types, the performance benefits significantly outweigh the costs.. The measurement is based on the heat characteristics of a specific gas. A small part of the flow through the TMFC is diverted into a sensor tube where a temperature measurement is made. From this sample, mass flow is automatically calculated.

It is very important to understand the accuracy and turndown limitations. See figure 1.
A thermal mass flow controller with an accuracy of 1% of full scale controlling at 40% of calibrated flow rate will have an accuracy of +/- 2.5%, but at 20% of calibrated flow rate its accuracy changes to +/- 5%. These accuracy ranges make the use of a mass balance almost impossible. A thermal mass flow controllers with an accuracy of 1% of rate stays as a flat line over the entire calibrated range.



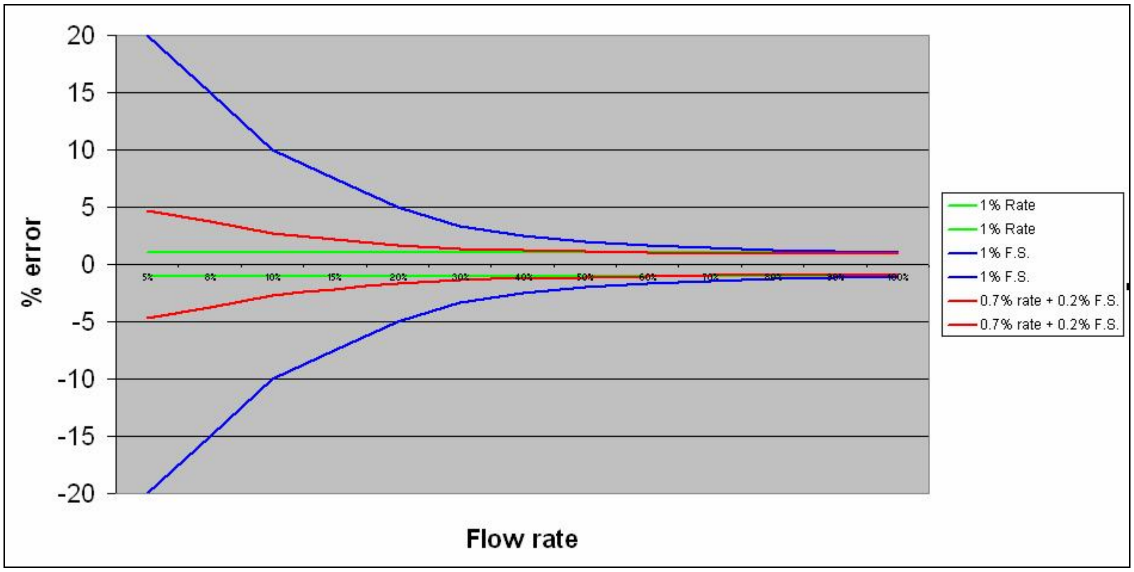


Fig 1.

How an MFC is calibrated is also very important. The thermal characteristics of some gases can be very complex. Mainly with H2 and CO2, the characteristics become three-dimensional, such that the gas factor changes with flow rate, temperature and pressure. Many MFC manufacturers use surrogate gases for calibration and then apply a factor to correct for the actual gas. When choosing an MFC for use on H2 or CO2 it is very important to select a manufacturer who calibrates on the actual gas, that is, a CO2 MFC should be calibrated on CO2.

Digital vs. Analog MFCs

The internal operation of an MFC has changed greatly over the last 10 years, with advances of microprocessor-based MFCs. The zero and span adjustments have been replaced with computer interfaces. Specific gas thermal characteristics are defined as an 'S' curve; the linearization of the 'S' curve is directly proportional to the turndown and accuracy of the MFC. Older analog MFCs have a very limited circuitry for adjusting or "linearizing" the 'S' curve, typically incorporating only two or three points. CO2 has a very complex 'S' curve. A high performance microprocessor-based MFC can use up to 25 points for linearization of the 'S' curve, plus it will also use 4^{th} order polynomials in the calibration. See figure 2.

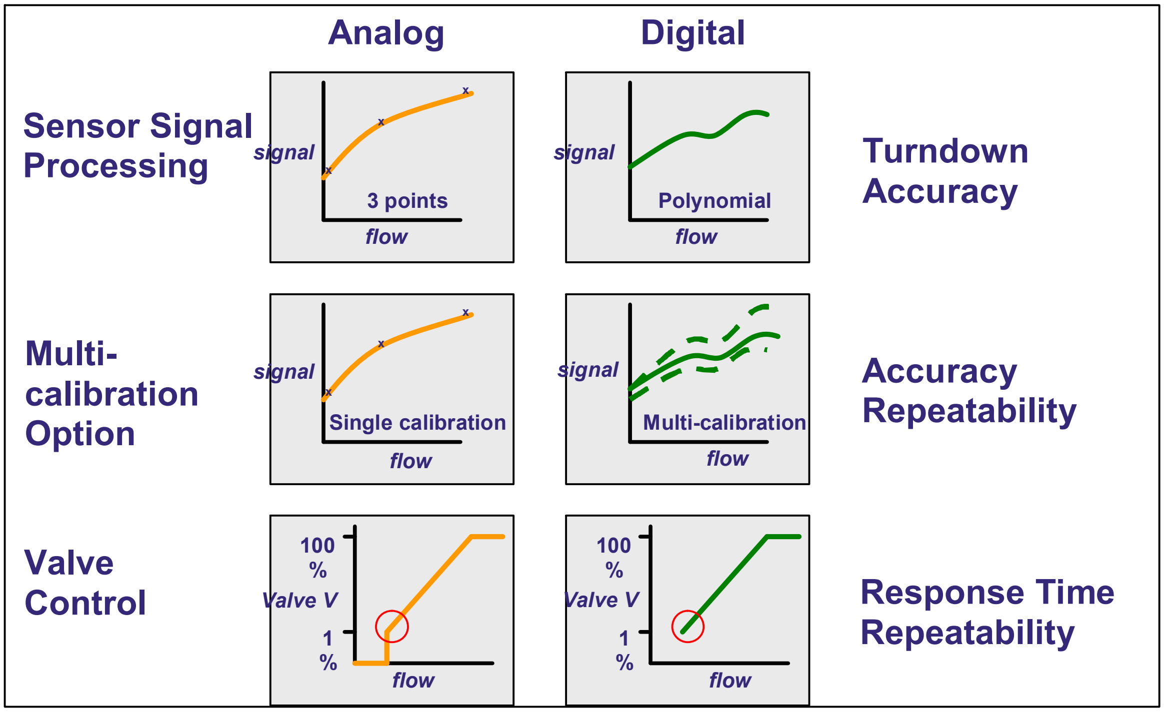


Fig.2

A digital MFC will also allow for multiple calibration curves to be stored in the MFC. These are real calibrations as opposed to gas factors, which are not substitutes for real calibration curves. In reading most manufacturers' instruction manuals, the conclusion is inescapable that applying surrogate gas calibrations or using gas factors will result in +/-5% full scale accuracy, typically inadequate for fuel cell testing and production applications.

In addition to using an MFC calibrated to the actual gas, microprocessor-based electronics will also greatly improve the valve control of the MFC. This is very important for fast response and repeatability.

Conclusion

The use of Brooks digital mass flow controllers in the gas blending/delivery system improves response time from several seconds to less than 1 second vs. other MFCs. Brooks digital MFCs also provide notable improvement in turndown. Turndown of other devices, when measured as control range staying within 2% of rate accuracy, is between 2:1 and 12:1. Brooks MFCs have been tested to 30:1. Overall accuracy and repeatability are also improved with Brooks digital MFCs. They can store up to 10 gas calibration curves, making them more flexible.

The enhanced response time, repeatability and accuracy of Brooks digital MFCs deliver more rigorous and consistent tests, and require fewer tests to achieve the same results.

Greater turndown and multicalibrations yield savings by using fewer MFCs per test stand, and provide more room for other equipment. This in turn saves maintenance and inventory.

About the Author

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Jan Christensen is a graduate electronics technologist with more than 24 years of flow experience and 12 of those years as a field service application specialist. He has worked with most of the world's fuel cell companies over the last few decades, assisting them in developing gas delivery systems.