

Five Fuel Cell Testing Tips

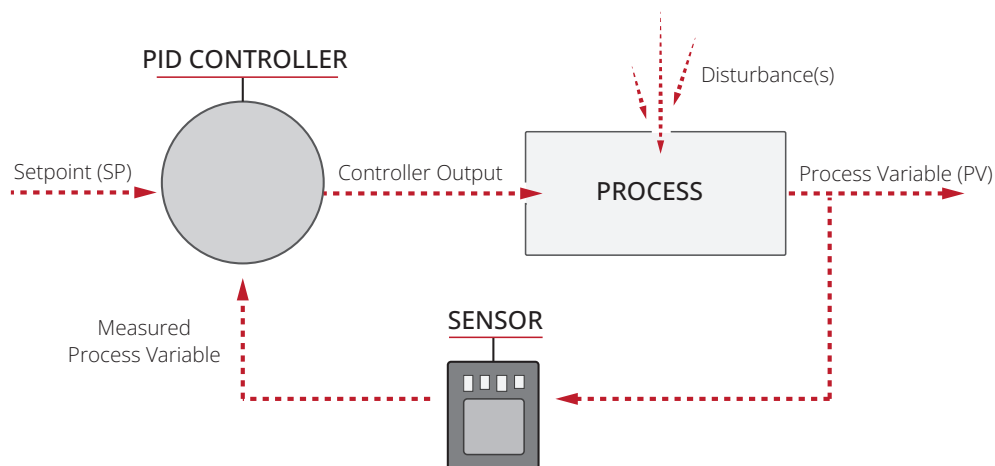
FOR PRESSURE AND FLOW INSTRUMENTATION

Tip #1

Stop power output fluctuations

Power fluctuations in a fuel cell's power output make it difficult to optimize. Maintaining steady control of inlet gas flow prevents fluctuations, minimizing changing variables and simplifying testing.

This stability is so crucial that a mass flow controller (MFC) holding a setpoint can be more important than accuracy specs.



Missed details create instability

Closed-loop control algorithms are used to adjust valve responsiveness within mass flow or pressure controllers. By modifying the variables within these algorithms you control how fast a process reaches a setpoint as well as control stability.

Make sure to give the full details of your process requirements to an applications engineer. They'll ensure that your controller is tuned

correctly. Before shipping, custom controller manufacturers (including Alicat) tune each controller for optimal valve performance at the indicated process conditions. For example, if a controller is ordered to flow air at 25 SCCM, it will be tuned for those specifications. Tuning makes your MFC more responsive. If you use your controller for exactly what you configured it for, the valve tuning and therefore control stability will be solid.

Choosing the correct control valve is critical

When systems require steady mass flow control, a tight valve specification is important. You'll want to strike a balance between control stability and pressure drop. A large valve, for example, tends to create a lower pressure drop than a smaller, more restrictive valve – but it also results in decreased control stability and resolution.

A properly specified valve must be large enough to reach full-scale flow when fully opened, and small enough to maintain resolution at low flow rates. Choose a valve that operates at around 50-75% of capacity. You'll maximize control of changes in operating conditions.

Alicat mass flow controllers are equipped with one of the following valve types:

- Small proportional valve: for flow rates of 20 SLPM or less; may be fitted with a custom orifice size (e.g., PCV30)
- Small proportional valve with the largest orifice (P valve): for flow rates up to 250 SLPM
- All-316L high-pressure proportional valve (PCA): for use with aggressive gases or pressures above 160 PSIA; may be equipped with a custom orifice
- Large Rolamite valve (R valve): for high-flow applications up to 5000 SLPM; may be specified with a custom hole pattern
- Hammerhead valve (H, PH, or RH): pairs two valves together side-by-side to operate as a single valve



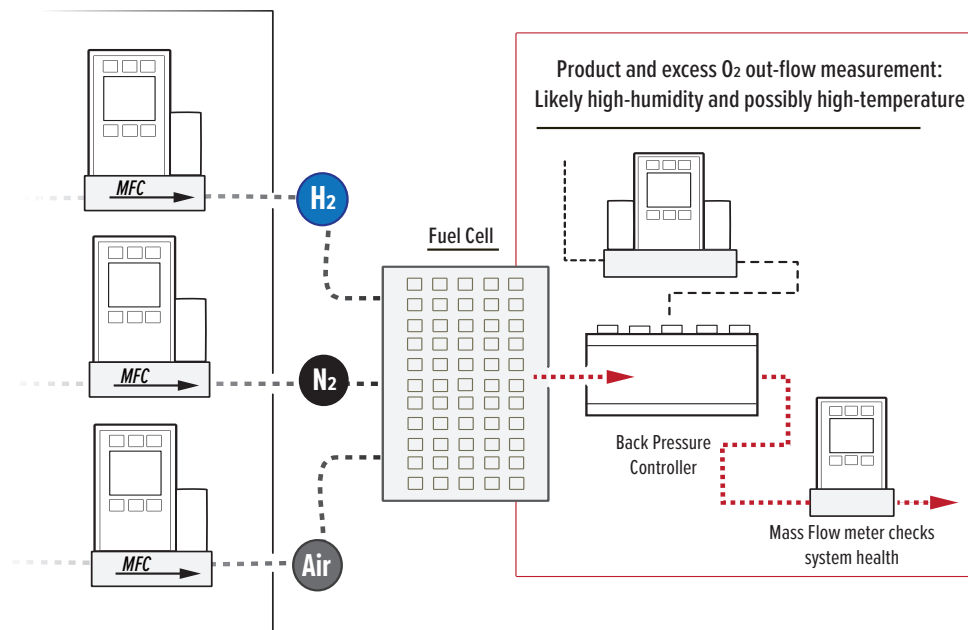
Alicat mass flow controllers

Tip #2

Solve your high humidity process problems

Maintaining system pressure while using a downstream valve requires tightly controlled gas flow at the fuel cell's inlet and regulating back pressure at the outlet. During this process, keeping the device's electronics safe from high temperatures and humidity is important. Good solutions include using stainless steel instrumentation and sensors or employing remote exhaust valves positioned elsewhere in the line away from the electronics.

Alicat differential pressure mass flow units come with integrated pressure sensors that allow for the control of mass flow while simultaneously monitoring pressure. This feature allows engineers who use setups with upstream valves to monitor the fuel cell stack pressure. However, certain systems require a downstream valve instead. In these cases, the pressure sensor will measure upstream supply gas pressure instead of stack pressure.



Maintaining both inlet gas flow and fuel cell system pressure is critical.

Pressure Solution: Dome-loaded, mechanical back pressure regulators

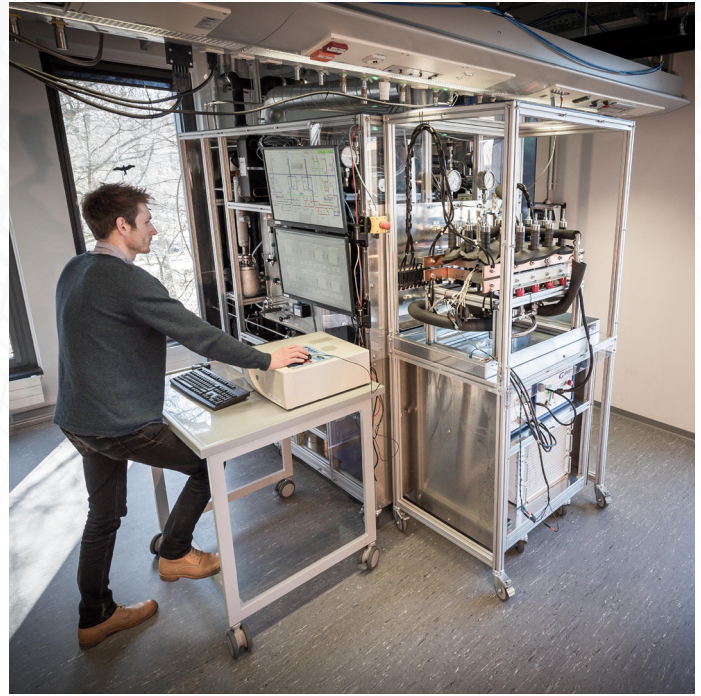
Dome-loaded pressure regulators work well in extreme temperatures and pressures, severe chemistry, and mixed-phase fluids. However, their performance is dependent on the performance of their pilot pressure controller.

Due to the high accuracy and 30 ms response time of Alicat dual valve pressure controllers, they are frequently used to maximize the performance and control resolution of dome-loaded backpressure regulators.

Flow Solution: Coriolis mass flow technology

Coriolis flow controllers accurately measure and regulate the flow of gases or liquids even in harsh operating conditions. These devices run 24/7/365 without needing to be returned to the manufacturer for the typical annual recalibration that other mass flow controllers require. This keeps the long-term cost of ownership low and eliminates downtime.

Coriolis instruments tend to be more expensive upfront than other mass flow technologies, with some costing upwards of \$9,000. This high price makes scaling your process and decreasing hydrogen production costs an issue. However, affordable Alicat standard-accuracy Coriolis devices are an ideal solution depending on system requirements. Get Coriolis accuracy and dependability without the high cost.



Measurement Accuracy Solution: Mass flow compensated for RH

High humidity in hydrogen gas affects your instrument's measurement accuracy. Common methods for solving this issue include installing a gas dryer or knockout pot. These can effectively remove the moisture in gases, but they also increase the footprint of your process.

Use a mass flow instrument with a built-in relative humidity sensor to keep your measurements accurate without needing to install a separate device. This sensor provides relative humidity readings, and these measurements are used by the mass flow instrument to automatically compensate the flow measurements for humidity effects.



Tip #3

Simplify your process with easy-to-use instruments

Easy-to-use means easier to set up, easier to read, and easier to change. All saving time and effort. Easy-to-read backlit screens and local controls on flow and pressure instruments simplify troubleshooting and optimization. Onboard, real-time flow totalizers and averaging

technology provide repeatable, comparable results that guarantee process quality. Worry about fewer devices and use one versatile instrument capable of multivariate measurement and control of mass flow, volumetric flow, or pressure.

Your process made easy with Alicat

Alicat display options ensure that there is one that fits your needs. When actively managing parameters, the integrated touchpad allows for setpoint control or gas composition selection to be done quickly and easily on each unit.

Integrated display options:

- The standard monochrome LCD is easy to read in both direct sunlight and dark environments with its blue backlight.
- The backlit color TFT display makes it easy for users to quickly read important measurements and alerts with color-coded information. Measured flow parameters are shown in white with green engineering unit labels. Parameters turn yellow when they exceed their full-scale ranges, or red when they have exceeded their maximum measurable values.

Remote display options:

- The enclosed remote display is IP54 rated and provides better protection in high EMI environments.
- The remote pane-mount display is seated inside an aluminum bezel with four 5/32" diameter mounting holes making it easy to mount into instrument panels.



Tip #4

Future-proof your system



Make your test stand simple to scale and easily reprogrammable.

Experimenting with different gas mixtures in the early stages of hydrogen system testing is common. Beyond ensuring valves are properly specified to flow the gases for these experiments, you should use highly versatile equipment.

Choosing devices that are calibrated to flow a wide variety of gases ensures that you will be able to flow the gases you need now and in the future.

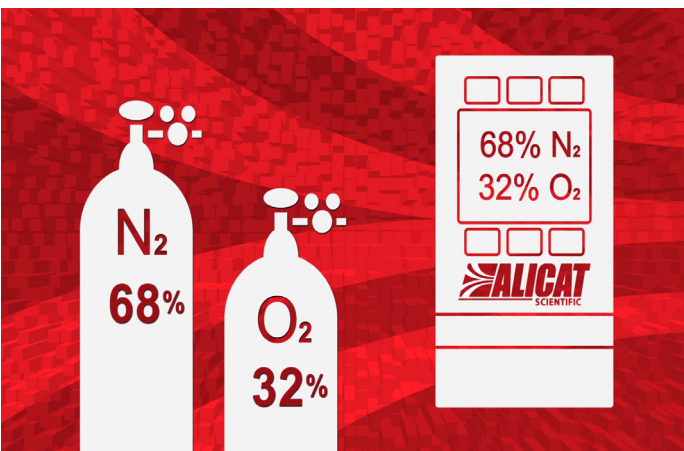
Space becomes a top priority as test stands scale. At higher flows, many thermal mass flow instruments require long, straight runs of pipe. In contrast, differential pressure mass flow technology can be placed in any piping layout. This simplifies fuel cell systems, minimizes their footprint, and lowers their overall cost.

Instant gas calibration and mixing

Alicat devices can be used for flowing multiple types of gases as well as fuel cell gas mixture testing with the Gas Select™ and Composer™ gas mix calibration firmware integrated into Alicat's differential pressure mass flow instruments.

Gas Select™ enables Alicat devices to be quickly calibrated to one of the 98-130 gases with the push of a button.

Composer™ allows you to create and store 20 custom gas mixtures with up to 5 constituent gases from the 98-130 Gas Select™ gas list.

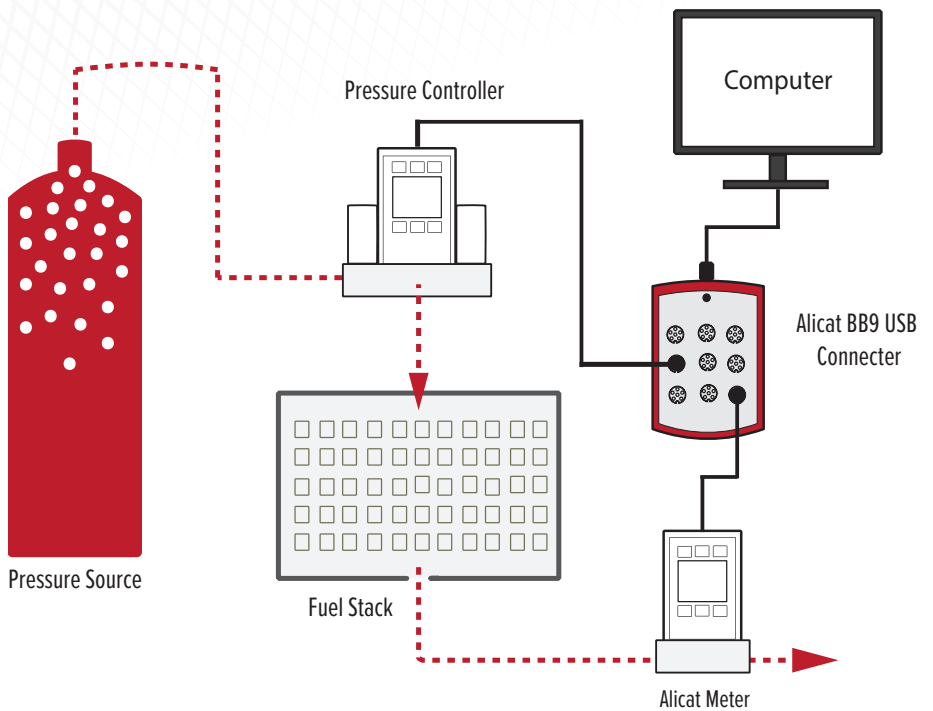


Tip #5

Prevent dangerous and costly leaks

Accurately preventing and detecting the small leaks that occur in PEM fuel cell stack systems requires proper valve selection and highly sensitive instrumentation.

- ▶ Proportional control valves present a risk for leaks, especially when flowing small molecules like hydrogen.
- ▶ ASCO valves' supreme leak specifications make them a good solution.
- ▶ Helium leak testing mass flow and pressure instrumentation provides the utmost assurance that your devices are leak free.



Hydrogen gas is expensive and poses numerous risks to safety, making leak prevention critical.

Make leak checking easy

A low pressure drop Alicat Whisper™ meter in combination with a steady pressure regulator can perform perfunctory leak checks on many different configurations of fuel cell stacks and the plumbing of systems in test stands and fuel cells.



Solutions That Scale With You

PRESSURE AND FLOW INSTRUMENTATION



CODA Coriolis Controllers

Monitor and regulate extremely low flows of water even in harsh operating conditions.

- ▶ 500 ms control response
- ▶ NIST-traceable accuracy as good as $\pm 0.2\%$ of reading or $\pm 0.05\%$ of full scale for liquids
- ▶ Operating conditions -35 to 70°C (fluid); 1500 PSIA most units
- ▶ Full scale range between 40 g/h and 100kg/h
- **Low long-term cost of ownership** with no required annual recalibration
- **Long-term corrosion resistance**
- **High zero stability** and significantly more resistant to external vibrations and bumps than competing Coriolis products
- **Easy integration** with your choice of communication protocol, fittings, electrical connectors, and more
- **Lifetime warranty** and technical support



DP Mass Flow Meters & Controllers

Ensure minimal waste and accurate results with fast, precise differential pressure-based measurement and control of gas flows in fuel cell processes.

- ▶ 10 ms measurement response; 30 ms control response
- ▶ Program and accurately measure and control mixtures of up to 5 gases
- ▶ NIST-traceable accuracy as good as 0.5% of reading
- ▶ Class 1, Division 2 device options available
- ▶ Full scale flow rates from 0.5 SCCM to 5000 SLPM
- **Switch between 130 pre-loaded gas calibrations** with a push of a button
- **Easy integration** with your choice of communication protocol, fittings, electrical connectors, and more
- **Lifetime warranty** and technical support



Absolute and Gauge Pressure Controllers

Maximize efficiency in fuel cell testing with accurate, repeatable pressure control.

- ▶ 10 ms measurement response; 30 ms control response
- ▶ 0.01–100% of full scale control range
- ▶ NIST-traceable accuracy as good as 0.125% of full scale
- ▶ Class 1, Division 2 device options available
- ▶ Custom pressure ranges from vacuum to 3000 PSIG
- **Control pressures in flowing processes or closed volumes** with forward and back pressure options
- **Easy integration** with your choice of communication protocol, fittings, electrical connectors, and more
- **Lifetime warranty** and technical support