Best Practices for Mass Flow Controllers and Mass Flow Meters

White Paper

Abstract

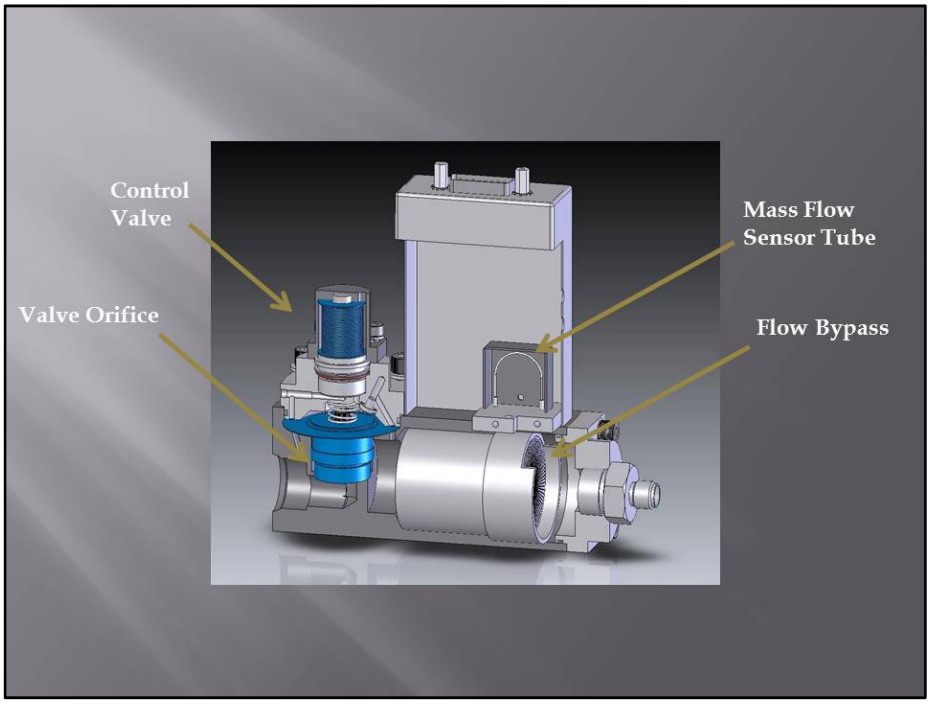
Mass Flow Controllers (MFCs) are versatile, rugged, and accurate measurement/control instruments. They can be used in a wide variety of gas flow applications with different environments. In this white paper, we will discuss considerations to get more out of your MFC in terms of accuracy, stability, and reliability.

Cleanliness

Many users do not think about cleanliness when installing MFCs. But installation contamination is an easy pitfall to avoid. In order to understand the problem, it is helpful to think about how an MFC senses and controls gas flow. In Fig. 1, we show a typical thermal mass flow sensor and control valve. Most of the gas flow travels through the flow bypass, but some of the flow passes through the small capillary sensing tube. In the sensing tube, the rate of thermal transfer of the flowing gas is measured. If this tube contains debris from MFC installation, then the accuracy of the flow sensing may be compromised.

In the control valve, the gas flow must pass through an orifice. This orifice is sized based upon the gas, flow rate, and pressure conditions. In some cases (for example, a 5 sccm hydrogen with dP of 30 psi), the orifice can be as small as 0.001" which is about the diameter of a hair. If this orifice collects any debris during MFC installation, then the valve may not work properly.

Figure 1 Cutaway Drawing of Mass Flow Controller



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So what are the sources of debris during MFC installation? First, MFCs should be installed in a dust free environment. If you are working on a bench or in a chassis, then ensure that the area is vacuumed and/or wiped down before MFC installation. In the case of an MFC with pipe thread fittings, the user must be careful to not allow bits of thread tape to enter the gas stream. If the valve orifice is known to be very small (<0.005"), then it is a good practice to use powder-free gloves during installation.

All contaminants could affect the accuracy of the Thermal sensor including moisture and impurities from the ambient environment. Greases or lubricants used during installation have to be carefully considered and monitored due to their possible reactivity with the gases used in the controlled line. Any lubricant that coats the inside of the sensor capillary tube will "thermally short", or at least dramatically skew, the flow characteristics of the Mass Flow Meter / Controller.

A common cause of MFC failure is the installation of a new or newly serviced MFM / MFC in a line that still carries contamination. These are few pointers in avoiding this problem:

1. Preventive Removal: When removing the faulty MFC, a purge with inert gas should precede any other step. Most systems have the capability to divert N2 or Ar through the desired line and in doing so removes any trace of the used gas and possible contaminants from the line. Inspect the Inlet / Outlet connections on both the Device removed and the line. Cleaning all connections involved with a white lint-free wipe will indicate areas to be further reviewed for possible contaminants.
2. Purge: The most common method is to use a "spool piece" (a piece of straight pipe that emulates the MFC length) that can be installed in lieu of the MFC. This allows the maintenance team to execute a purge flow through that particular line straight to exhaust in an effort to "flow out" all possible contaminants in the line and / or cleaning byproducts.
3. Clean Install: The MFC is received from the manufacturer / service center sealed in a cleanroom bag. Remove the bag right before installation so the MFC has minimum exposure to the ambient. Only install the new MFC in a system that has been deemed "contaminant free" by the maintenance team. Consult manufacturer specs for the type of connections your system uses and the MFC Manufacturer.

Filtration

Now that we are thinking about cleanliness issues, we can discuss gas line filtration. In some applications, debris and other contaminants such as trace amounts of oil may be present in the gas stream. As we have seen before, with small geometries in the flow sensor and/or valve components, the MFC might be affected by contaminants that build up over time. One approach is to place a filter inline with the MFC to prevent contamination from reaching the internal components of the MFC. A picture of an inline filter is shown in Fig. 2.

Figure 2 Inline filter. Photo courtesy of Gentec

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It is helpful to know what type of contaminant is being prevented. In the case of air generated by a compressor, oil may be suspected. If particulate contamination is suspected, then a 15 micron filter should improve MFC reliability. For your specific application, you may need to try different filters with different replacement schedules to determine the best approach for your situation. You will also need to keep in mind that adding an inline filter upstream of the MFC will have some affect on the pressure drop of the gas flow control system. For example, with a high inlet pressure of 500 psig at a flow rate of 20 SLM (STP: 0o C & 760 Torr), a 15 micron filter will have approximately 0.5 psi pressure drop. Replace in-line filtration each time you have suspected contamination in the MFC area. Once contamination has reached the inlet of the MFC the filtration has been compromised. In addition, a compromised filter will continue to release contaminants in the system contributing to the failure of your process.

Consult with the factory for the specific filtration needs in your application.

Pressure Regulation

Earlier, we discussed how the valve orifice is selected based upon the gas, flow rate, and pressure conditions. Although the MFC's control feedback loop can handle a wide variety of pressure conditions, ideally a well-known set of upstream and downstream pressures is given so that the ideal orifice can be installed in the MFC. The use of a pressure regulator upstream of the MFC will ensure that the pressure condition is well known. In Fig. 3, a picture of a typical pressure regulator is shown. The regulator must be set up for the upstream pressure that is expected by the MFC.

Figure 3 High Purity Pressure Regulator. Photo courtesy of CONCOA

In Fig. 4, the MFC label is shown. Notice that the upstream and downstream pressure ranges are given. It is important that the regulator be capable of handling the maximum flow rate expected in the gas line. A regulator that is undersized may "starve" the MFC for gas or not regulate properly which in turn may lead to MFC oscillation. A properly selected regulator can be an excellent investment for a gas line. When buying a regulator, make sure you review your application so that your regulator can handle the flows and pressures. Also, make sure that there are not any gas compatibility/usage issues (e.g. oxygen).

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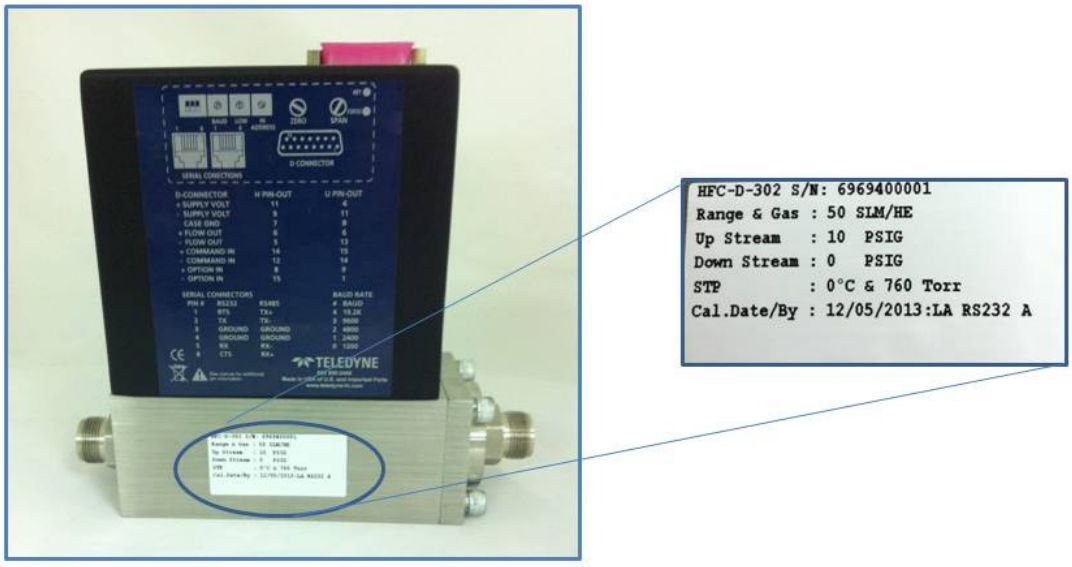
In many cases we recommend the installation of a “Point of use Regulator” that should be adjusted to the MFC required pressure. Consult with the factory for the specific pressure regulation needs in your application.

Figure 4 MFC Label. Note the ideal conditions for the valve.



Line Size

Another aspect of MFC installation is line size. If the tubing leading to the MFC is undersized in diameter with a long length of run, then a significant pressure drop along the gas line can occur. As with an undersized regulator, this can starve the MFC of gas supply. Also, as the MFC attempts to control flow, its upstream pressure can fluctuate due to the flow-dependent pressure drop between the MFC and the regulator. This can lead to valve oscillations. If there are multiple MFC’s on a manifold, the fluctuation in upstream pressure caused by one MFC can affect the others.

Straight Piping

In the case of metering large flows (above 50 SLM) with a laminar flow element, it can be important to install a length of straight run pipe upstream of the flow meter. This will help decrease the amount of turbulence as the gas enters the flow meter’s flow bypass which in turn will result in better accuracy and repeatability. There are different guidelines that have been suggested. A good recommendation is to have a straight run of at least 5X pipe diameter upstream and 1X pipe diameter downstream. In other words, if you are using a thermal mass flow meter mounted on a 2” laminar (See Fig. 5), then the recommended straight run of pipe upstream would be 10”.

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Figure 5 Allow adequate run of straight pipe before and after flow instrument

Electrical Connections

There are a few things to keep in mind when wiring your MFC. First, in environments that have electric-magnetic interference (EMI), it is a good practice to use shielded cable. Many MFCs will reject EMI to a certain level, but only if they are wired correctly. In some cases, this may require one of the connector pins of the MFC to be connected electrically to earth-ground. Review your MFC manual for particular wiring requirements associated with your MFC. Also, be sure to use a power supply that is capable of supplying enough power at the maximum draw. If a power supply's output droops, then the flow signal output may become less accurate.

4-20 mA

This topic could be an entire white paper by itself. 4-20 mA I/O can be useful in cases where the MFC is located in very noisy environments or far from the power supply or PLC. In these cases, use of 0-5 VDC I/O may be problematic due to noise pick-up or signal loss along the cable length. If your MFC is located more than 50 feet (15 m) from the power supply or PLC, you should consider use of 4-20 mA . There are three questions that you need to address regarding your 4-20 mA MFC before you begin to make electrical connections:

1. Is the MFC an "active" (supplying power) or "passive" (relying on loop power) component in the 4-20 mA loop?
2. In either case, is the signal output isolated from power and common, or non-isolated?
3. Is the MFC command input "sinking"/non-isolated or passive/isolated?

Calibration Interval

ISO 17025 is the international standard for "General requirements for the competence of testing and calibration laboratories". In the standard, it is stated that a calibration certificate or label shall not contain any recommendation on the calibration interval. So that raises the question: When should an MFC be calibrated?

An MFC installed in a clean system running chemically inert gases can give many years of performance that comply with the manufacturer's specifications. However, if the MFC is being exposed to aggressive gases or perhaps subjected to contamination, the accuracy of the flow measurement may become worse

with time.

One approach is to commission the MFC with an initial calibration interval of one year. After that time, if the As Received calibration data for accuracy is far outside the expected value, then consider reducing the calibration interval. In the other case, if after two or three calibrations that give accuracy results within specification, consider increasing the calibration interval.

Questions?

Your flow application may have unique requirements. We are ready to work with you; talk to us. While other companies hide behind email and computerized phone systems, we distinguish ourselves by providing personal, polite, and responsive service. **HOW MAY WE HELP YOU?**

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