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FLOW MEASUREMENT IN BITTER COLD: How to Use Coriolis Meters In Cryogenic Service

Tim Patten
Emerson Process Management,
Micro Motion Division
and **Keven Dunphy**
Emerson Process Management

With intelligent setup and operation, mass flow measurements can readily be taken even at extremely low temperatures

The usage of Coriolis flowmeters for measuring mass flowrates has become widespread in the chemical process industries, and the range of fluids with which these meters can be employed is likewise diverse. Among those applications, Coriolis flowmeters can readily be applied to cryogenic fluids (contrary to conventional flow-measurement practice with these fluids), provided that the measurement system is set up and used appropriately. Although the guidelines and recommendations presented below are based upon research and field testing of the products offered by the authors' employer, the information should also be useful to operation of other Coriolis flowmeters unless otherwise indicated.

Coriolis flowmeters measure mass flow by taking advantage of the Coriolis Effect. Simply stated, the inertial effects that arise as a fluid flows through a tube are directly proportional to the mass flow of the fluid. In a Coriolis flowmeter, vibration is induced in the process-fluid-filled flow tube(s), then the mass flowrate is captured by measuring the difference in the phase of vibration between one end of the flow tube and the other.

For purposes of this article, cryogenic fluids are fluids that are handled in liquid form at temperatures below –100°C. Two examples are liquid helium and liquefied natural gas, LNG (–268.9°C and –153.1°C saturation temperatures at 1 bar, respectively). There are many applications in which it is useful to store and handle cryogenic fluids. For example, liquid natural gas (LNG) is in many circumstances stored and transported far more efficiently than the product in gaseous state. Furthermore, cryogenic fluids such as helium are useful because of their rapid cooling capabilities.

Cryogenics challenges

However, handling fluids at cryogenic temperatures imposes many logistical and engineering challenges. Process equipment can be adversely affected by the cold; for example, moving mechanical parts and wetted seals can cease to function, fail prematurely, or cause other problems. Also, the metals or other materials of construction must be chosen with care in order to avoid failure due to poor impact strength (pp. 44–47).

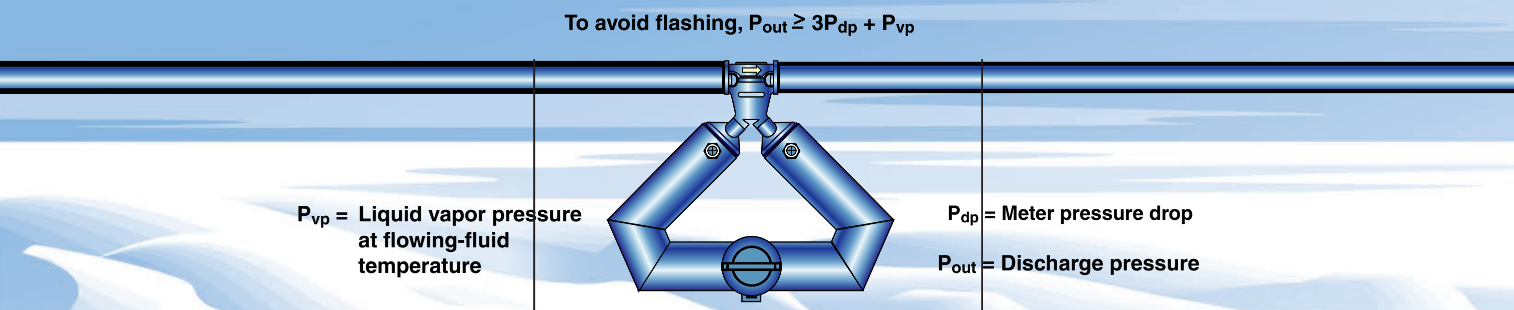
From the flow-measurement standpoint, a more subtle complication arises because the cost of keeping cryogenic fluids cold enough to remain in the liquid state goes up as the temperature goes down. Due to this cost complication, it is common practice to keep cryogenic fluids at temperatures only slightly below their boiling points. As a consequence, as the fluid flows through a pipeline or past an obstacle (such as a valve or other device), the pressure drop, even though small, can cause flashing to occur; accordingly, small or large pockets of gas form in the liquid, which makes flow measurement difficult if not impossible.

For certain flow-measurement applications, the practical impact of this flashing problem is especially severe. Consider, for instance, the bringing of LNG from the site of liquefaction (in many cases geographically remote) to the end-user. For each change of custody between when the gas is first liquefied and when it eventually is converted back to gaseous form at a local distribution plant, the suppliers, shippers, and utilities alike rely upon an accurate accounting of the amount of fuel passing through the system.

The measurement technologies

Up to now, the most common way to determine mass flow in cryogenic applications has been roundabout: measurement of volumetric flow with differential-pressure-based (dP flow) meters, then measurement of density via some other measurement principle; and finally, the calculation of the mass from the volume and density.

Aside from being roundabout, this sequence entails technical drawbacks. A typical dP transmitter cannot be exposed to a fluid at cryogenic temperatures without damage and/or failure, so the fluid must be allowed to warm and gasify to be measured. The warming of the fluid introduces significant measurement error. What's more, the usable turndown ratio of the dP flowmeter is reduced because of increased measurement noise during the gasifi-



cation of the cryogenic liquid. The significant error and reduction in turndown capability may not be acceptable for many applications. Furthermore, to obtain accuracies within the range of custody transfer requirements, expensive and complicated calibrations at working temperatures would need to be performed.

By contrast, the design of Coriolis flowmeters is particularly well-suited to cryogenic service because the extreme cold does not harm meter components. The functioning of this type of meter, as summarized in the second paragraph of this article, requires no moving wetted parts nor temperature-sensitive materials, and the accuracy is sufficient for virtually any application, even to satisfy custody transfer regulations. If the installation and operational guidelines spelled out in the next section are adhered to, Coriolis meters will in fact perform successfully with cryogenic fluids.

Cryo-proofing Coriolis meters

Reduce ΔP by increasing meter size: Pressure drop is a primary concern in cryogenic applications. As implied above, a pressure drop without a corresponding temperature drop results in the formation of significant gas bubbles in the line; in other words, flashing, or two-phase flow. Although Coriolis flowmeters are exceptionally accurate for measuring either gas or liquid flow, two-phase flow in a cryogenic application (especially custody transfer) causes measurement problems. In a typical cryogenic application, a good rule-of thumb for avoiding or minimizing flashing is that the difference between the discharge pressure and the liquid vapor pressure at the fluid temperature should be maintained at a factor of at least three times the pressure drop across the meter.

When a Coriolis flowmeter is used at the high end of its flow range, it is capable of its highest accuracy, but it also incurs its highest pressure drop. Therefore a logical way to minimize flashing is to limit the pressure drop by specifying a meter that is larger than might be used in comparable non-cryogenic service. Advanced digital-signal processing makes it possible to filter out the noise associated with a large meter at a high turndown and still achieve a highly accurate result.

Admittedly, increasing the static pressure or reducing the process temperature could also compensate for the pressure drop and prevent flashing. But these options are likely to be unrealistic, or prohibitively expensive, in a large system.

If field zeroing is required, install fast-closing valves: For flowmeters that must be zeroed in the field rather than the factory, fast block valves should be installed on either side of the meter. The valves must be closed simultaneously, then the flowmeter zeroed, and then the valves reopened quickly. If the procedure is not completed rapidly, cryogenic liquid in the flowmeter will warm and begin to flash, jeopardizing the accuracy of the zeroing process.

Additionally, there must be safety measures in place between the valves to mitigate overpressure with both valves closed.

Be aware of density-measurement limitations: On cryogenic liquids, density measurement is intrinsically difficult. It is in many cases easier and more accurate to instead take other property readings and calculate the density from a suitable equation of state. If, instead, the Coriolis density measurement is to be used, it is recommended that the meter be calibrated on the fluid and that a density-meter factor be applied.

Insulate around the meter, but not necessarily the meter itself: Insulation provides two important functions: it minimizes convective heat transfer and radiant heat transfer. A Coriolis meter using an inert-gas filled secondary containment compartment does not require additional insulation for controlling convective heat transfer; indeed, except for the cast manifold assembly, there are Coriolis meters commercially available that happen to be "insulated" as effectively as most piping systems.

However, if the meter tubes are exposed to sunlight, insulation on the meter will help to minimize radiant affects.

A final point

Be aware that cryogenic temperatures have a nonlinear effect on the temperature correction applied to the measurement in all Coriolis meters. For best results, high-quality flowmeters with nonlinear compensation at cryogenic temperatures should be selected. ■

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Authors

Tim Patten is director of measurement technology for Micro Motion, Inc. (7070 Winchester Circle, Boulder, CO 80301; Phone: 303 527-5200; Fax: 303 530-8459; Tim.Patten@EmersonProcess.com). He has 22 years of experience with fluid handling systems (compressors, pumps, and flow measurement), including 17 years with Micro Motion in test and evaluation, design, and engineering management. He holds a B.S. in mining engineering from the Colorado School of Mines, as well as an M.S. in mechanical engineering from Worcester Polytechnic Institute

Keven Dunphy is Senior Manager, Sales & Marketing, Asia and Asia Pacific for Emerson Process Management, based in Shanghai, China (Phone: 86-21-3895 4788 ext 4003; Keven.Dunphy@EmersonProcess.com). He has 15 years experience in flow measurement and instrumentation with the Micro Motion and Rosemount Measurement divisions of Emerson Process Management. He holds a B.S. in mechanical engineering from Clarkson University, and an M.B.A. from the University of Colorado.