Calibration & Recalibration

Techniques & Tactics for Ensuring the Reliability of Your Flow Measurements

By Jesse Yoder, Ph.D.

The process of calibration may be more familiar to people than the actual definition of the term. Any instrument or measuring device that uses units of measurement has to be set up correctly so the units on the measurement scale read accurately. For example, an adjustable bathroom scale that reads 2 lbs. when nobody is standing on it needs to be reset so that it reads 0 lbs. under this condition.

Flowmeter Calibration Defined

A more narrow definition of the term calibration simply involves comparing an instrument or measuring device to a standard, without making an adjustment to make the instrument read correctly. The second step, involving adjustment or "resetting the scale," is sometimes called verification. In ordinary use, however, most people include the verification step in the standard process of calibration or recalibration.

A company that pays $2,000 to have an ultrasonic flowmeter recalibrated is most likely not going to be satisfied with a report that says, "We have tested your flowmeter against an approved standard and found that it is not reading properly." The customer probably already knew that, or they wouldn't have pulled the flowmeter out of service for recalibration. A company that pays to have a flowmeter calibrated expects it to come back reading correctly. This could involve replacing a piece of hardware, adjusting the K factor, making a software modification, or taking some other action to correct or "verify" the operation of the flowmeter.

The author of the well-known book *Fluid Flow Measurement*, E. Loy Upp, defines calibration of an instrument or meter as "The process or procedure of adjusting an instrument or a meter so that its indication or registration is in close agreement with a referenced standard." This definition captures the concept of calibration as it is understood by most people in the instrumentation community. By this definition, the meter must first be tested and then adjusted so it is reading correctly.

Flowmeter Calibration vs. Flowmeter Recalibration

After flowmeters are built, they need to be calibrated before being sent out into the field. Most flowmeter manufacturers have their own flowmeter calibration facilities for performing this initial calibration. An exception is flowmeters that need to be tested under special conditions that may not be easy to duplicate for a flowmeter manufacturer. For example, large line size gas ultrasonic flowmeters for custody transfer applications need to be tested under high-pressure conditions with high speed flowing natural gas. The facilities to perform this type of calibration typically cost millions of dollars to build. As such, most flowmeter manufacturers send these meters to an independent flowmeter facility to be calibrated.

Recalibration, on the other hand, involves calibrating a flowmeter after it has been in service for a period of time. There are multiple methods of recalibrating a flowmeter. Software programs are available for some flowmeters to determine if they need to be recalibrated, while others employ onboard diagnostics to identify any underlying causes that may be affecting the flow measurement reading.

Methods of Flowmeter Calibration

Flowmeters measuring liquid and gas flow are tested or calibrated using somewhat different methods. This article focuses mainly on calibration of flowmeters measuring liquid flow.

There are several main methods for calibrating and recalibrating flowmeters:

- Master Meter
- Piston Prover
- Gravimetric

COURTESY NMI EUROLOOP

NMi EuroLoop master meter section.

Master Meter Calibration

A master meter is a calibrated flowmeter that is used as a calibration standard. The master meter is placed in series with the flowmeter under test, and the results are compared at different flowrates. A master meter must be compatible with the fluid being tested. So, a magnetic flowmeter would not work as a calibration standard for hydrocarbon liquids, but it can potentially work well with water and industrial liquids. Positive-displacement meters are often used as master meters for hydrocarbon liquids.

For a master meter to serve as a calibration standard, its calibration must be traceable back to some national or international standard. This means there is an unbroken chain of measurements back to the primary standard. For example, a master meter might be

COURTESY VSL

Inspection of VSL's liquid flow calibration facility.

calibrated with a flowmeter that was calibrated at the national standards laboratory. According to the VIM, traceability is "the property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty."

In the United States, the national standards laboratory is the National Institute of Standards and Technology (NIST, *www.nist.gov*), with locations in Gaithersburg, Maryland and Boulder, Colorado. In Europe, the main national standards lab is the Netherlands Metrology Institute (NMI, *www.nmi.nl*), also referred to as the Van Swinden Laboratory (*www.vsl.nl/en*). Other countries have their own primary standards organizations. For example, the Korea Institute of Standards and Science (KRISS), located in South Korea, is the standards organization for Korea. In China, the keeper of the standards is the National Institute of Metrology (NIM).

Piston Prover Calibration

Piston provers are a primary standard for flow calibration. A piston prover consists of a round cylinder with a known internal diameter. The cylinder contains a sealed piston. The piston strokes

through known and measured lengths to produce volumetric flow. Flow volume is determined by multiplying the cross sectional area of the piston by the length traveled by the piston. Flowrate is derived by dividing the volume by the time it took the piston to move through the distance it traveled.

The known volume of liquid as determined by the piston prover is passed through the meter under test, and the results are compared. Since the volume of liquid has been accurately measured, this provides a very good indication of the accuracy of the meter under test. This method works for water, industrial liquids, and petroleum-based liquids. In some cases, it is necessary to take temperature and pressure values into account when making the measurements.

COURTESY CEESI

Gravimetric calibration (weigh scale).

Gravimetric Calibration

Another highly reliable method of calibrating liquid flowmeters is to weigh the liquid that passes through the meter under test in a specified period of time, such as 1 minute. In order to obtain an accurate reading of the weight, a calibrated weigh scale is generally used. Actually implementing this method requires a little creativity. Since this is a timed measurement, the piping needs to be filled with flowing liquid before the test begins. At this point, the flow should be going into a discharge container.

To start the test, simultaneously switch the flow into the weighing container and start timing the flow. Once the desired time is reached, simultaneously divert the flow from the weighing container and into the discharge chamber and stop timing the flow. You can derive flowrate by converting the weighed volume to the desired units and then dividing by the time. Now compare this flowrate to the flowrate recorded on the flowmeter. This is a description of a manual process, but automated versions of this process also exist, and they are no doubt more reliable.

Flowmeter Recalibration Options

End-users who need to have their flowmeters recalibrated have several choices of where to send their meter:

- An independent calibration facility;
- The flowmeter manufacturer;
- A mobile service that does on-site calibrations.

There are a number of highly reputable and well-known flow calibration facilities around the world. Probably the leading such facility in the United States is Colorado Engineering and Experiment Station Inc. (CEESI, *www.ceesi.com*), located in Nunn, Colorado and Garner, Iowa. Another important facility for liquid calibration is Alden Research Laboratory Inc. (*www.aldenlab.com*), in Holden, Massachusetts. Flow Dynamics (*www.flow-dynamics.com*), acquired by Badger Meter (*www.badgermeter.com*) in 2010, operates a primary standard calibration facility in Scottsdale, Arizona.

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CEESI's soon-to-open hydrocarbon liquid calibration lab is based on a 26 barrel pipe prover measuring up to 8,000 BBL/h with an uncertainty of 0.025%. Master meters provide an uncertainty of 0.05% with flowrates up to 19,000 BBL/h. Light, medium and heavy oils provide a range of calibration density and viscosity values.

In Europe, two of the leading facilities are NMi-Euroloop (*www.nmi-euroloop.nl*) and VSL, both located in the Netherlands. NMI-Euroloop in Rotterdam does both liquid and gas flowmeter calibration, as does VSL. Besides doing flow calibrations, VSL is the primary metrology laboratory for much of Europe. In the United Kingdom, the leading facility is the National Engineering Laboratory (NEL, *www.tuvnel.com*). Another important facility in Dorsten, Germany is pigsar.

TransCanada Calibrations (TCC, *www.tccalibrations.com*) is a highly regarded facility located just outside of Winnipeg, Canada. TCC opened its doors in March 2000 and specializes in calibration of high-pressure gas flowmeters.

Other facilities around the world that perform liquid flow calibrations include:

- Korea Research Institute of Standards and Science (KRISS) (South Korea)
- Woodjin Inc. (South Korea)
- Industrial Technology Research Institute (Taiwan, R.O.C., *www.itri.org*)
- C & W Meter Service (Trumbauresville, Pennsylvania, *www.cwmeter.com*)

Flow Research has identified more than 50 independent flow calibration facilities located in different regions around the world.

Flowmeter Manufacturer Calibration

Most flowmeter manufacturers maintain their own facilities for initial calibration of flowmeters before they are shipped. Many also offer recalibration services to their own customers, and some offer these services more broadly. End-users who need a flowmeter recalibrated may choose to go back to the company the flowmeter was purchased from to perform this service. Variables to consider include where the company is located, turnaround time, and whether there are independent flowlabs more conveniently located. The type of flowmeter is also a consideration, along with the cost of calibration.

Mobile Flowmeter Recalibration Services

Some companies offer mobile recalibration services that make it possible to recalibrate a flowmeter onsite. Mobile calibration has the advantage of being able to most closely duplicate the actual operating conditions of the meter during the recalibration process. These services work especially well with smaller meters for liquid applications, including petroleum liquids. They do not work as easily with large size magmeters, or with large ultrasonic and turbine meters.

The Future of Flowmeter Recalibration

With the worldwide flowmeter market growing every year, the need and demand for recalibration services can be expected to grow. Every time a flowmeter is sold, chances are high that it will have to be recalibrated at some point in the next three to seven years. In addition, there is a very large installed base of flowmeters in the field that need to be recalibrated periodically. FC

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This article is the first in a two-part series based on the results of upcoming Flow Research studies on flowmeter calibration for liquid and gas applications (www.flowcalibration.org). In the October 2015 issue, Part II will focus more specifically on gas flow calibration. Flow Research has also formed a working group of industry experts to consider the issue of flowmeter recalibration frequency. For more information on this group, visit www.frwg.org.

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