



Flow Calibration: Heart of Flow Meter Accuracy

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You can't fix what you can't see; blind flow calibrations don't ensure process accuracy. Traceability is the key to accuracy.

The military and aerospace industries have long required traceability of their instrument calibrations to accepted government standards. Unfortunately, the process industries have not always been as rigorous in adhering to established national standards.

Some industrial users of flow meters, for example, develop a false sense of security by merely performing frequent calibrations without really understanding the implications of calibration uncertainties and errors. Others do not fully realize that flow calibration techniques based on credible metrology procedures are necessary to compensate for fluctuating variables such as fluid temperature and pressure, or atmospheric temperature and pressure. Additionally, the number of "measurement transfers" involved in attaining traceability to National Institute for Standards and Technology (NIST) standards can erode traceability to the point where, in reality, it is essentially worthless.



A third group assumes that because their end product is manufactured to specification, they do not need to re-examine the quality of their calibration source, or its traceability to industry standards. Still another group takes on good faith their vendor's assurances that "our flow meters don't require calibration."

What these process industry metrologists overlook is that instrument calibrations not traceable to NIST standards can lead ultimately to inconsistent or inferior products. Today's competitive global economy requires production processes that reduce inefficiency and loss of raw materials. The more assured your instrument measurements, the less energy and resources that are wasted, and the greater your ability to compete in the marketplace.

This situation is particularly applicable to manufacturers seeking ISO 9000 certification. These companies realize that calibrations traceable to NIST not only help support the procedures and documentation prescribed by ISO, but also ensure the initial accuracy of their flow measurements as well as the quality of their end products.

Key Issues

A clear definition of "NIST traceability" is essential to begin this discussion. The term refers to the real ability to establish assurance and quantify all of the imprecisions of the components of a given measurement, and assess the systematic error of the final result. These errors are not only the uncertainties of the NIST artifacts, but also the uncertainties of every step in the process chain down to the measurement you are counting on. Put another way, it is the root sum squared (RSS) of all the measurement errors.

However, the issue of NIST traceability may lead some flow meter users to ask: "Why should I care if my flow meter calibrations are traceable to NIST? My manufacturing process works fine so far. Why fix what isn't broken?"

The answer is: The only way you can be certain that your flow meter is measuring against a known and consistent accuracy standard is to require NIST traceability. If your previous calibrations were not NIST-traceable, you cannot be sure of their real accuracy.

Many small, local flow calibration service centers simply cannot afford precision equipment, and lack the experience to perform the sophisticated metrology procedures needed for a NIST-traceable calibration.

These service centers often use simplified flow calibration systems that are so far removed from the NIST standard that they contain unacceptable levels of uncertainty.

Moreover, these systems can introduce additional error into the flow meter under test by not compensating for such variables as temperature, pressure, density, and viscosity changes during the actual calibration.

Ideally, companies should audit their outside flow calibration service periodically to ensure that adequate equipment, procedures, and documentation exist to ensure NIST traceability. But if you cannot justify the cost and time required to perform these on-site audits, the use of an ISO 9000-certified or MIL-STD-approved calibration supplier is an acceptable alternative.



Flow Calibration Basics

When evaluating a calibration program, one should be aware of certain basic techniques and terms, and be prepared to ask the flow calibration supplier whether they meet the basic requirements for NIST traceability, such as what were the conditions, quantified results, and test schedules that established it.

There are many definitions and interpretations of traceability. But realistic traceability of a calibration facility means that performance testing has been done on the facility, and this testing – including the units tested, the test conditions, and the associated instruments and personnel – is typically used in

operating the facility. The results of the testing (i.e., the realistic traceability) are quantified with respect to the reference standards. The testing is done periodically so that the resulting data base provides assurance that the measurements are as specified. Round-robin flow meter testing programs have proven to be an effective way of establishing and maintaining realistic flow measurement traceability.

To understand the two major types of calibration error, Precision (or random) and Systematic (or bias), it is helpful to picture an archery target. Imagine that an archer is target shooting with the goal of consistently hitting the bull's-eye (which represents perfect accuracy).

Precision error means that the archer's shot grouping is poor – his shots are random and scattered all over the target. In the next instance, the archer's precision is good; the shots are no longer random, but are very repeatable, dependable, and tightly grouped, even though not in the bull's-eye.

This illustration shows the difference between a less sophisticated flow calibration supplier and a calibration lab experienced in the sciences of flow measurement, calibrations, and metrology. The more experienced lab will implement all necessary compensation techniques in order to provide a dependable, precise calibration.

The archer has attained high precision and also hits the bull's-eye dependably. Thus, he does not have any significant bias or systematic error. The flow calibration techniques represented here demonstrate a comprehensive knowledge of accurate calibration. It practices and documents proper metrology procedures. In this case, the archer has found the right answer because he has determined the bias of his aim and has corrected it in order to hit the bull's-eye.

Although precision error can be determined by the calibration data, systematic error must be based on the accumulation of errors found in tracing back to the NIST "golden ruler." That is why systematic error is blind to the end user without traceability. Moreover, it should be noted that both precision and systematic error are difficult to eliminate. Precision error can be removed only with the use of the correct instrumentation and through a complete understanding of the measurement being made. Systematic error, as we stated previously, can be eliminated only through direct traceability to NIST standards.

Total system uncertainty is the statistical equation that describes how metrologists combine both systematic and precision error. Metrologists use the formula: $U = \pm(B+t95S)$ where B is the bias limit, S is the precision index, and t95 is the 95th percentile point for the two-tailed students "t" distribution.



It is also important to review compensation techniques that take into account the varying conditions under which flow meters operate. You might assume that your calibration has great precision when, in reality, a host of critical parameters have been overlooked. Changes in fluid makeup, temperature, pressure, viscosity, and density can significantly distort a flow meter's output signal and result in an inaccurate measurement. Plus, installation effects can significantly alter the measurement.

In addition, the environmental effect upon the calibrator itself can affect accuracy. For example, the temperature in the calibration lab can change the shapes of the vessels used to produce the flow calibration, hence influencing the accuracy of the measurements.

Primary Vs. Secondary Standards

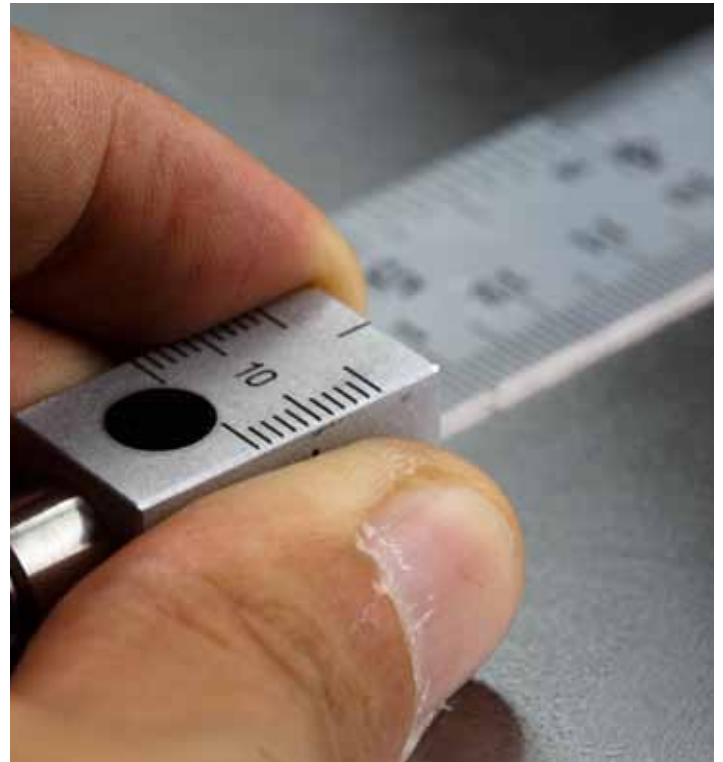
The extent to which a calibration is NIST-traceable depends on whether the system used is a primary standard or secondary standard, although the various sciences involved in this field may disagree on terminology.

For the sake of this article, a primary standard calibration is one that is based on measurements of natural physical parameters (i.e., mass, distance, and time).

This calibration procedure assures the best possible precision error, and through traceability, minimizes bias or systematic error.

A secondary standard calibration is not based on natural, physical measurements. It often involves calibrating the user's flow meter against another flow meter, known as a "master meter," that has been calibrated itself on a primary standard.

To better understand the differences between primary and secondary standard calibrations, it helps to think of the NIST standards for accuracy as "golden rulers" situated at the top of a pyramid. Each step down the pyramid results in an additional amount of random and bias error. For this reason, it is crucial to have traceability and thereby know the precision of your instrument, and the degree of difference between it and the primary standard just above it in the hierarchy. Some common examples of primary standard calibration systems include positive displacement (PD) calibrators, continuous flow loop calibrators, and time-weigh calibrators. Secondary standards include flow transfer standards and sonic nozzle stands.



Reports And Data

A good primary standard calibration lab is audited periodically. At this time, traceability documents are made available, and a trained metrologist may be on hand to substantiate the accuracy and traceability of the calibrations. These audits traditionally have been required by military contractors, but are becoming more common among industrial flow meter users.

However, if the calibration supplier is ISO 9000 certified, the user has assurance that quality procedures and traceability records are maintained, and these costly, time-consuming audits may not be needed.

A NIST-traceable calibrator's system software should retrieve all relevant data and organize it into a final report that will accurately represent your flow meter's performance based on established parameters. Certified data sheets that contain traceability information should be provided upon request with every calibration run. These data sheets offer a paper train back to the NIST standards for the instruments that were used to "calibrate the calibrator."

If your calibrator supplier cannot produce the proper certifications, then you have no verified traceability to NIST, and therefore no assurance of true accuracy. Frequent recalibrations to an unknown standard will only duplicate your mistake.

Where Do You Go From Here?

If your in-house flow calibration equipment or outside flow calibration service center is NIST-traceable, and you have access to the certificates and documentation to prove it, then you know your flow measurements are as accurate, consistent and reliable as possible. Otherwise, the calibration data you receive is suspect, and an inherent inaccuracy will likely be introduced into your manufacturing process and products, perhaps causing you to waste raw materials in ways that can never precisely be determined.





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