A closer look at accuracy of measuring and test equipment

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Editor’s Note: See Part 2 in the December issue of Currents.

Inspection and testing are two of the most important activities performed by service centers. These activities involve the collection of two types of data: attribute data (go/no-go information) and variable data (measurement information). When collecting variable data or measurement information, service center technicians obtain data consisting of two components – the actual value of the measured dimension and the error associated with the measurement. The service center should be focused on minimizing measurement error such that the measurement values are as close to actual values as needed to properly evaluate the measured item.

Accurate and Precise

Gauges or instruments used to perform measurements can be referred to as measuring & test equipment (M&TE). Measurement values determined by use of M&TE are a function of the true value as well as the M&TE accuracy and precision. The terms accuracy and precision are often demonstrated and differentiated graphically using an archery example as shown in Figure 1.

Precision refers to the degree of repeatability & reproducibility (R&R) in the measurement system. M&TE repeatability is the ability of a single technician to obtain the same measurement value multiple times using the same M&TE on the same measured item. M&TE reproducibility is the ability of multiple technicians to obtain the same measurement value using the same M&TE on the same measured item. The precision of M&TE is commonly assessed using R&R studies that will be the focus of the second part of this two-part series.

Accuracy is the degree to which the measured value agrees with the true value. The accuracy of M&TE is assessed through calibration, which is the focus of this article.

Calibration

Calibration is a term often misunderstood and misused. Simply put, calibration is nothing more than a comparison. Calibration quantifies the relationship between the readings of the M&TE (e.g., caliper, ammeter, thermometer, pressure gauge) and the relevant standard measurement units. The M&TE readings are compared to the values of a measurement standard under controlled and specified conditions. Properly establishing the necessary conditions and performing this comparison can be a complex process, depending on the nature of the subject M&TE and the accuracy required.

Calibration is formally defined by the Joint Committee for Guides in Metrology (JCGM) in the document JCGM 200:2012, “International vocabulary of metrology – Basic and general concepts and associated terms (VIM).” The definition provided in JCGM 200:2012 §2.39 is:

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Note 1: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2: Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration.

While this definition is fairly concise, it is not necessarily straightforward. For example, there are entire books written on measurement uncertainty alone. Therefore, it is impractical to provide an adequate interpretation of what implementing this definition entails in a brief document. However,
some considerations taken into account are:

- Nominal value of the standard (e.g., dimension, voltage, temperature)
- Known uncertainty of the standard nominal value usually determined using statistical process control techniques
- Specified conditions (e.g., temperature, humidity, vibration) as applicable to the M&TE calibration requirements
- Comparison methods

The definition tells us that if we have a standard and we know its uncertainty (e.g., gauge block of 1.00000+/-0.00001 units) then under specified conditions we can compare an indication or reading from our M&TE to the gauge block (see Figure 2). Using information gained from the comparison, we can determine whether our M&TE gives valid results and assign an associated uncertainty which is usually much larger than that of the standard.

Note 1 tells us that the comparison can be documented in several forms, including curves or tables and that adjustment factors could be involved. For example, an M&TE might indicate a percentage of the value in question (e.g., current transformer).

The definition also tells us that if we have a standard and we know its uncertainty (e.g., gauge block of 1.00000+/-0.00001 units) then under specified conditions we can compare an indication or reading from our M&TE to the gauge block (see Figure 2). Using information gained from the comparison, we can determine whether our M&TE gives valid results and assign an associated uncertainty which is usually much larger than that of the standard.

Note 2 emphasizes that calibration is not adjustment or verification of calibration. Adjustments are used to bring the indicated value of M&TE closer to the standard value. Of course not all M&TE can be adjusted (e.g., ruler, thermometer) even though they can certainly be calibrated. When M&TE cannot be adjusted to provide adequate indications throughout their range of use, they are usually given limited calibration status or removed from service. Verification of calibration is more of an audit function such as reviewing an affixed calibration sticker, equipment calibration log or calibration certificate.

Subcontract calibration

Many service centers subcontract calibration of their M&TE to firms specializing in such services. When choosing subcontract calibration providers, it is worthwhile to consider laboratories accredited to ISO/IEC 17025 whose scope of accreditation is appropriate for the service center M&TE requiring calibration. These labs have been audited by an accreditation body to ensure that they are competent within the scope of their accreditation. For example, a lab may be accredited for temperature but not for voltage. This may not be a practical approach for all motor repair equipment, but in exception cases, the equipment manufacturer may have an adequate calibration service offering.

In-house calibration

Where calibrations are intended to be performed in-house, the service center must maintain traceability and have the necessary environment, laboratory equipment and personnel skills. This can be a feasible and cost-effective approach for certain types of M&TE depending on the available standards and skills of existing service center personnel.

Calibration program development typically involves the following activities:

- Evaluation of equipment capability
- Identification of calibration requirements
- Selection of standards
- Selection of calibration frequency and rules for adjusting the frequency
- Establishment of a recall system
- Implementation of a documentation and reporting system
- Evaluation of the calibration program through audit

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Calibration checks

In-house calibration checks are not considered calibrations and do not need to be treated as such. There are many checks for different types of M&TE that provide the operator with some added assurance that the M&TE is acceptable for use. These optional checks are performed in-between required calibrations at a frequency suitable to the service center. However, calibration is required any time an adjustment is necessary.

For example, an organization may have a practice such that 1-inch micrometers are checked for a zero indication when closed and a 1-inch indication using a working standard before use. This gives the operator a certain level of confidence that measurements taken between 0 and 1 inch will be accurate. Another example would be the use of ice-melting points and steam points with thermometers.

What should be calibrated?

M&TE used for activities affecting quality should be controlled, calibrated at a specified frequency, and adjusted where necessary to maintain required accuracy limits.

Aside from requirements imposed by customers, accreditation and regulatory bodies, it is up to each organization to determine the level of assurance they desire in the process, test & inspection measurements they obtain utilizing their M&TE. Typically, the most reliable measurements are made by qualified technicians using calibrated M&TE in accordance with standard work instructions.

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