Metrology Consulting, Inc.

# METROLOGY INSIGHT

Volume 2, No. 2 April 1999

**I hope you will enjoy** this edition of Metrology Insight. I got even more positive feedback on the last issue than I did on the first one. I appreciate it very much, so keep the E-mail coming.

Metrology Insight is published by HN Metrology Consulting. The purpose of Metrology Insight is to heighten awareness of the details that go into making good metrology and, of course, HN Metrology Consulting as a source of information about these details.

In this issue the first article looks at the concept of traceability. Traceability is one of these concepts that seems relatively simple at first, but turns out to be very complex, if you go beyond the surface. Especially if you are depending on several traceability chains in your measurement, e.g. Volt and Ampere in a resistance calibration.

The other article looks at temperature influences and laboratory design considerations, primarily for dimensional metrology.

I hope you find Metrology Insight useful and educational. If you have a suggestion for a topic or any other comment or suggestion, please do not hesitate to contact me.

\- Henrik Nielsen

**Training Seminars by HN Metrology Consulting are now offered through several training providers, see page 4**

## What is traceability and why do we calibrate?

We usually require traceability of measurements and calibrations, but often we are not very precise about exactly what it is we require and what we hope to achieve with the requirement.

The International Vocabulary of Basic and General Terms in Metrology defines traceability as:

> *"property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties."*

The first thing to notice is that only *the result of a measurement* or *the value of a standard* can be traceable.

Measuring equipment cannot be traceable in and of itself. What is traceable about the equipment is the determination of its imperfections during calibration. What we mean when we talk about traceable equipment is that it is potentially able to produce traceable measuring results.

Likewise, a standard cannot be traceable, but the value assigned to it can.

A commonly accepted way of formally proving traceability in this country has been to quote a NIST test number.

However, this approach does not account for the uncertainty in all the links in the traceability chain between whatever was calibrated at NIST and the equipment used in the actual calibration, as required in the definition. It also does not demonstrate that there is a proper relationship between the uncertainties in each link.

But what should we do instead? To answer this question, we need to look at the purpose of the traceability requirement. We intuitively understand that the requirement has to do with the quality of the measuring results. The customer requiring traceability wants some assurance that the measurements are "right".

The only way to prove that measurements are right, is to prove that their uncertainty is low enough to allow the desired conclusions to be drawn from the results, such as whether or not a workpiece meets its specification.

From a technical point of view this makes traceability part of substantiating the stated uncertainty for the measurement. Therefore the best way of demonstrating traceability is by starting with the uncertainty budget for the measurement.

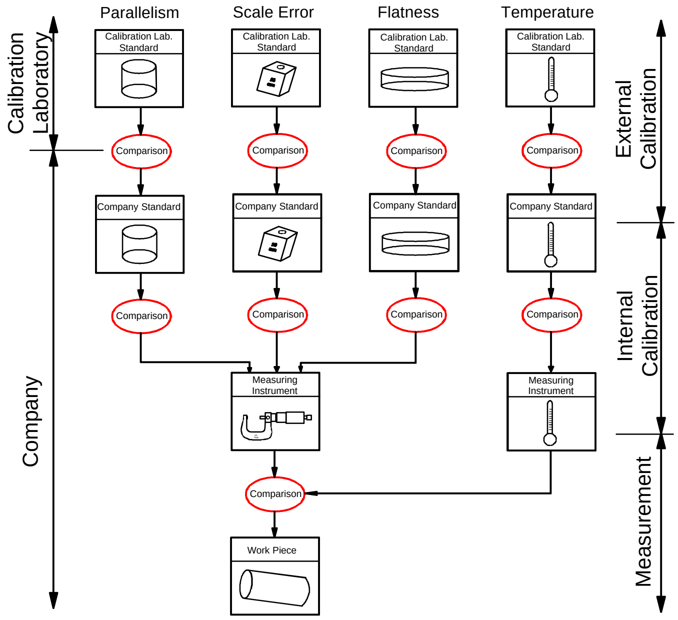


***Figure 1:*** *Traceability chains for a length measurement. The parallelism, scale error and flatness chains control the attributes of the micrometer, the temperature chain controls the conditions during the measurement. Each comparison represents a measurement or a calibration, linking an item to the item above in the traceability chain.*

From the uncertainty budget you can find all the significant contributors to the measurement uncertainty (e.g. everything larger than 10-20 % of the largest contributor). Some of those contributors depend on the measurement procedure and others depend on the calibrations of the equipment, sensors, standards, etc.

Traceability may therefore require calibration of several attributes of the measuring equipment and not all of them may be in the unit of what we are measuring. For example the uncertainty of a length measurement may be highly dependent on temperature and therefore the ability to measure temperature. Thus the traceability of the calibration of the temperature sensor becomes a significant part of the uncertainty for the length measurement.

Consequently, we can state our requirement more specifically by saying that for a measurement to be traceable, the equipment has to be traceably calibrated *for the characteristics that influence the uncertainty budget* to the tolerances that are assumed in the budget.

This means that traceability is a recursive condition. It shall be possible to follow the uncertainty budgets and the calibration of significant attributes of the equipment for each link in each chain all the way back to the appropriate level, e.g. a national laboratory.

Using this logic, the information needed to prove that a measurement is traceable in the technical sense is:

- A list of the significant uncertainty contributors for the measurement.
- A list of the equipment (serial no. etc.) used in the measurement that adds significantly to the uncertainty.
- For each piece of equipment a reference to its traceability (Calibration scope, calibration source, calibration date and calibration id, e.g. certificate number).
- For each calibration source, evidence of its credibility, e.g. accreditation.

The requirement of credibility of the calibration source is what recursively ensures that this information is available at each link in all the chains all the way back to the national laboratory level.

Accreditation is intended to provide this credibility. Accreditation is essentially a third party putting a seal of approval on the comparisons and the accompanying uncertainties that a calibration laboratory performs.

One of the requirements that is put on accredited laboratories is that they can only have their standards and equipment calibrated at other accredited laboratories.

The result is that each accredited laboratory maintains one or a few links in the chain of comparisons back to the SI unit. By documenting the links they maintain and the source for the next link in the chain, the accredited laboratories ensure the continuity of the traceability chain.

Therefore all the information needed to follow the traceability trails back to the National Laboratory level is now available and traceability can be proven.

## Controlling the environment

A significant part of making good measurements is controlling the laboratory environment. But what do we need to control and how well do we need to control it?

The discussion in this article is limited to dimensional laboratories, but the basic principles carry over to other metrology disciplines.

In dimensional metrology, the one environmental factor that mainly influences the measurement is temperature. Humidity is usually also controlled, but this is mainly to prevent rust (too humid) and static electricity (too dry).

There are two things we want to control about our laboratory temperature:

1. Closeness to standard temperature (20 ºC or 68 ºF)
2. Variation in time and space

Depending on the application, one or the other may be the main contributing factor. We have to go to the uncertainty budget to find out what our real requirements are.

Generally, when the measuring equipment and the workpiece are made from the same material, the overall temperature is less critical. The reason is that the two have the same nominal thermal expansion coefficient and it is only the variations from this nominal value that creates an error if the temperature is not kept at standard. For steel the variation in coefficients is typically estimated to be 10 % of the book value of 11.5 ppm/ºC or 6.4 ppm/ºF.

However when the equipment and the workpiece are made of dissimilar materials (measuring aluminum or plastic parts with steel gages), then the overall temperature becomes crucial to making measurements with low uncertainty.

Unfortunately, it is generally much more difficult to limit the time and space variations of the laboratory temperature, than it is to control the average temperature.

The main reason for this difficulty is localized heat sources in the laboratory. It is fairly easy to maintain a very uniform laboratory temperature, if there isn't anybody in the laboratory and all the equipment is turned off. However the laboratory's ability to hold temperature under these conditions is of course irrelevant to the laboratory's ability to accommodate good measurements.

One way of thinking about a laboratory is like a shower. The conditioned air washes the energy away from the heat sources. The more heat load there is in the laboratory and the lower the acceptable temperature gradients are, the more air flow is needed to wash the energy away.

Another way this analogy can be used is to explain how equipment should be arranged in the airflow. The measurements requiring tighter temperature control should be placed upstream, so they are the first thing the air passes over when it comes out of the inlets, so the air is not "contaminated" by passing over heat sources before it reaches the critical measurement setups. Heat sources include power supplies, computers (especially monitors), light, motors and people.

A good layout ensures that the air passes over the critical equipment before it reaches these heat sources, so their influence on the measurements will be minimized.

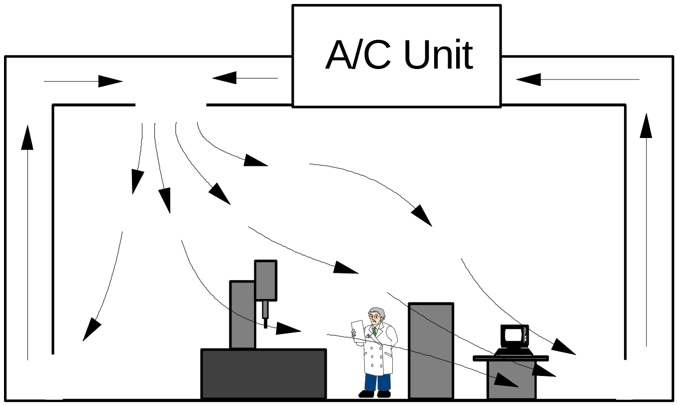


***Figure 2:*** *Example of a good laboratory layout. The air coming from the inlet in the ceiling passes over the CMM before reaching the operator, the control cabinet and the computer.*

The temperature variations in time can mostly be controlled by keeping a stable heat load.. This can be achieved by keeping all equipment and lighting turned on at all times, locating the laboratory such that it does not have external walls facing south and avoiding windows to the exterior in the laboratory enclosure.

In many respects, the worst and most unpredictable heat source is the operator: He moves around and takes breaks during the day and insists on going home at night, thus introducing a variable heat load in the laboratory. To limit this influence, the operator should as far as possible be situated downstream from the measurement setup.

Spatial gradients can be reduced by ensuring that the airflow is matched to the local heat load. This can be done either by ducting air towards heat sources, such as computers and electrical control cabinets, or by having dedicated fans and ductwork transport the hot air away from each heat source and out of the laboratory.

It should also be noted that a lot can be saved and much better results can be obtained, if you start with a careful analysis of what your true requirements are.

What is important is the temperature of the equipment and the work pieces in the laboratory. The control of the air temperature in the laboratory is only a means to this end and therefore only of secondary importance.

Focusing your effort on developing a good, sound equipment layout and controlling the temperature of the equipment and the work pieces in the critical locations will usually result in much better results at a much lower cost than trying to keep a given air temperature specification in the full laboratory volume.

## Training from HN Metrology Consulting:

HN Metrology Consulting offers in-house training seminars on metrology, measurement uncertainty and quality assurance for calibration laboratories.

The following 2 day seminars are available at short notice and can be tailored to your specific needs:

**Managing Measurement Uncertainty**

**Quality Assurance to ISO Guide 25**

Contact HN Metrology Consulting for more information on these seminars and to request the brochure.

HN Metrology Consulting no longer offers public courses directly. Instead I have started working with two professional training organizations to provide more focused and targeted training.

## Training offered through MTI Corporation:

These are very intense 1 day seminars. They cover a lot of material in a very short time.

**Advanced Metrology:**
**Surface Roughness and Roundness**
May 20 in Grand Rapids, MI
May 27 in Plymouth, MI

**Estimating Measuring Uncertainty**
May 21 in Grand Rapids, MI
May 28 in Plymouth, MI

These seminars are offered nationwide. New seminars are scheduled every month.

Call MTI Education at (630) 978 6469 for more information, to sign up for a seminar or to find out when a seminar may be scheduled in your area.

## Training offered through Blue Mountain Quality Resources:

These are more in-depth 2 day seminars. They contain more advanced material and extensive group exercises.

**Managing Measurement Uncertainty**
June 21-22 in Rolling Meadows, IL

**Quality Assurance to ISO Guide 25**
June 23-24 in Rolling Meadows, IL

These seminars are offered nationwide. Call Blue Mountain Quality Resources at (800) 982 2388 for more information, to sign up for a seminar or to find out when a seminar may be scheduled in your area.


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