## 6.1 Technical Criteria for Dimensional Laboratories[1]

### 6.1.1 Scope

The purpose of this section is to identify the specific technical criteria needed to meaningfully assess the competence of a calibration laboratory that performs dimensional calibrations. The artifact calibrations currently included in the Recognition program are:

1) steel tapes; and
2) rigid rules.

**NOTE:** Much of this section applies to dimensional measurements that are more complex than the calibration of tapes and rules; however, it is the responsibility of the laboratory to determine which sections are applicable.

### 6.1.2 References

[1] ANSI/ASME B 89.6.2, Temperature and Humidity Environment for Dimensional Measurements (1973, Reaffirmed 2003).

### 6.1.3 Statistical process control

**6.1.3.1** All sources of variability for the calibration should be monitored by subsystem calibration (e.g., thermometer, force gage calibration) and the use of check standards to ensure that the calibrations are carried out under controlled conditions. The laboratory should maintain and document some form of statistical process control (SPC) commensurate with the uncertainty levels of the calibration. The SPC control parameters should be based on measurements of check standards (or closure parameters resulting from self-calibration or ratio methods) and the repeatability of multiple measurements. The frequency and number of process control checks should be appropriate for the number of calibrations as well as the level of uncertainty and reliability claimed for the calibration.

**6.1.3.2** The laboratory should have control artifacts that adequately span the range of materials and sizes normally calibrated by the laboratory. Every measured value of each control should be recorded and compared to its historical value to determine that the process is in control. The comparison may be made via a plotted control chart with appropriate control limits or by numerical comparison using the t-distribution. The expected control values should be updated at least yearly using the most current one of more years of data.

### 6.1.4 Accommodation and environment

**6.1.4.1** The temperature in the calibration area should nominally be 20 °C (degrees Celsius) with a maximum variation and rate of change depending on the materials and the uncertainty level needed for the calibration. Measurements at temperatures other than 20 °C may be made if the proper thermal expansion corrections are applied and the component of uncertainty reflecting the uncertainty in thermal expansion coefficients of the artifacts is calculated and added to the total uncertainty of the calibration. For comparison measurements the uncertainty component should reflect the uncertainty in the thermal expansion of both the master and unknown artifacts.

**6.1.4.2** For length calibrations of the type in legal metrology laboratories, the immediate environment should be 20 °C ± 2 °C, and should be measured with an accuracy of 0.5 °C. The temperature variation should be less than ± 1 °C over 24 h and ± 0.5 °C during any 1-h period. Other environmental conditions may be acceptable as long as the effects are included in the uncertainty determination.

**6.1.4.3** The measured length should be corrected to a reference temperature of 20 °C using the known linear thermal expansion coefficient of the material.

---

[1] This section is adapted from the NVLAP Handbook 150-2F, Calibration Laboratories Technical Guide and is modified for WMD application.

**6.1.4.4** The temperature stability of the environment should be sufficient for the gage and measurement system to be in thermal equilibrium. Measurements may be made in slowly changing environments if a suitable measurement model, that includes the effects of the drift, is used. Theoretical and experimental verification of the model should be available.

**6.1.4.5** For typical gages made of well characterized materials (steel, carbide or ceramic), 0.000 001 per °C should be used as the thermal expansion coefficient uncertainty unless there is documentation of a lower value.

**6.1.4.6** The relative humidity in the calibration area should not exceed 50 percent to avoid problems with dimensional standards related to rust or other corrosion.

**6.1.4.7** Excessive vibration should be avoided in the calibration room. If an obvious source of vibration exists, precautions should be taken to prevent adverse effects on the laboratory's measurements.

**6.1.4.8** The laboratory should have a documented policy regarding responses to problems with the environment.

### 6.1.5 Equipment and reference materials

**6.1.5.1** The laboratory should have the equipment needed to make auxiliary measurements on artifacts (e.g., flatness of gage blocks, roundness of ring gages).

**6.1.5.2** The laboratory should have temperature measuring capabilities suitable to the calibration procedure. Calibrations involving direct comparisons of artifacts of similar size and materials will, in general, have modest requirements. Absolute calibrations or comparisons between artifacts of different sizes and/or materials will require more accurate temperature measurement.

**6.1.5.3** A laboratory that certifies artifacts to tolerance grades should demonstrate a measurement uncertainty which does not exceed 25 % of the tolerance (unless otherwise stated in normative standards). Exceptions to this ratio should be accepted for measurement systems that are documented to be the state-of-the-art and approved by the customer.

**6.1.5.4** A laboratory that makes mechanical comparisons of masters and test pieces of dissimilar materials should have force measuring equipment to determine the force on the probe or probes. A correction for differential probe penetration should be applied as long as the probe has maintained its rounded shape. On old comparators the probe radius may be altered to the point where a correction would induce error.

**6.1.5.5** A laboratory that makes absolute measurements using displacement measuring sensors, such as interferometers or linear scales, should have environmental monitoring equipment appropriate to the sensor.

**6.1.5.6** A laboratory that makes absolute measurements using a contact device should have force measuring equipment to determine the force on the probe or probes. A correction for probe penetration should be applied if appropriate.

**6.1.5.7** A laboratory that makes interferometric measurements should have: (1) equipment for making high-accuracy temperature measurements, and (2) equipment for determining the index of refraction of air.

### 6.1.6 Calibration methods

**6.1.6.1** When calibrations are made by comparison to master gages of the different nominal sizes the temperature control of the gages and the measurement environment should be improved.

**6.1.6.2** The laboratory should have a manual outlining the procedures to be followed for each type of calibration. For calibration of graded sets, the procedure should name the grades that are calibrated by the procedure.

**6.1.6.3** The procedures used for related services, such as checks of roundness, relapping, repair, or replacement of damaged or out-of-tolerance gages should be clearly stated.

**6.1.6.4** Procedures related to the calibration of rigid rules and tapes used by legal metrology laboratories are as follows from NIST Handbook 145:

1) Bench method for tapes (SOP 11);
2) Tape to tape method for tapes (SOP 12);
3) Rigid rule calibration (SOP 10); and
4) Pi tape calibration (SOP 23 - draft).

**6.1.7 Handling of calibration items**

**6.1.7.1** Artifacts should be cleaned and stored in a manner to prevent accidental contact with material which could damage the gaging surfaces.

**6.1.7.2** Care should be taken to prevent steel artifacts from rusting. Steel artifacts should be coated with a rust inhibiting grease whenever there is a potential for exposure to an environment over 50 % relative humidity. If artifacts cannot be greased other materials (e.g., rust inhibiting paper) or methods should be used to inhibit rust.

**6.1.7.3** After cleaning, artifacts should be allowed to come to adequate thermal equilibrium in the calibration environment before measurement. Artifacts should be placed on a soaking plate or in position on the measuring machine long enough to ensure that they are at the proper temperature. The soaking time will depend on the size and the thermal properties of the artifacts and plate. Specific guidelines for soaking times should be stated in the measurement procedure. The heating effects from optical radiation, body heat, and system location should be minimized.

**6.1.7.4** In general, to prevent thermal changes and corrosion of the gaging surfaces, artifacts should not be handled with bare hands. Gloves or tongs should be used whenever possible.

**6.1.8 Calibration certificates and test reports**

**6.1.8.1** In addition to meeting the criteria in section 5.10 of this handbook, all calibration certificates or test reports of calibration should contain an uncertainty statement which is scientifically determined from measurement data and which agrees with the laboratory's stated definition.

**6.1.8.2** The uncertainty should be derived from a model of the measurement system that includes (as applicable) the uncertainties caused by:

1) master artifact calibration;
2) long term reproducibility of measurement system;
3) thermal expansion correction for gages and measurement scales;
    a. thermometer calibration,
    b. thermal expansion coefficient,
    c. thermal gradients (internal, gage-gage, gage-scale),
4) interferometry;
    a. measurement uncertainty of refractometer,
    b. index of refraction formula,
    c. environmental measurements (air temperature, air pressure, humidity, etc.),
    d. calibration of light source frequency,
    e. phase correction for reflected light,
    f. obliquity and slit corrections,
5) instrument geometry;
    a. abbe offset and instrument geometry errors,
    b. scale and gage alignment (cosine errors),
    c. gage support geometry (anvil flatness, block flatness),
6) probe penetration correction;
7) rotary axis errors (radial and axial displacements, tilt);
8) analysis algorithms (data fitting, filtering); and other factors as appropriate.

The method used to affix the calibration items should be described in detail. In general, differences in fixture configurations between calibration and use will introduce errors in the calibration.