Specific Criteria for Accreditation
Metrology and Calibration

Eighth Edition July 2020

The NZ mark of competence
Tohu Matatau Aotearoa

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Metrology and Calibration

AS LAB C5

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Contents

1 Introduction

International Accreditation New Zealand (IANZ) Specific Criteria amplify or particularise the IANZ general accreditation criteria, for specific fields of technology or for specific types of business activity.

This document must be read together with current issues of the IANZ general criteria for accreditation ISO/IEC 17025 *General requirements for the competence of testing and calibration laboratories*, IANZ Technical Policies and the IANZ publication *Procedures and Conditions for Accreditation* (describing the organisation and operation of the IANZ Laboratory Accreditation Programme). It defines technical requirements for accreditation of Metrology and Calibration laboratories in addition to those of ISO/IEC 17025 and IANZ Technical Policies.

This document also provides information on classes of test, staff, accommodation, equipment and other aspects of good laboratory management practice which are considered a minimum standard for Metrology and Calibration laboratories. Detailed criteria are also described for uncertainty of measurement, including some worked examples, as well as recommended calibration periods for equipment.

The field covers all types of calibration including:

(a) Engineering metrology

(b) Electrical

(c) Temperature

(d) Optical and radiometry

(e) Mass, volume and density

(f) Pressure and flow.

A list of Specific Criteria published to date is available on the IANZ website (www.ianz.govt.nz) or from IANZ on request.

2 Definitions and Acronyms

(a) Calibration and Measurement Capability (CMC) is defined in the ILAC Policy for Uncertainty in Measurement (see reference 7). The CMC appears in the laboratory's scope of accreditation associated with a measurement parameter or range of parameters. See section 11.2 below for more detail.

(b) Device under calibration (DUC)

(c) European Co-Operation for Accreditation (EA)

(d) International Bureau of Weights and Measures Key Comparison Database (BIPM KCDB)

(e) International Laboratory Accreditation Cooperation (ILAC)

(f) Measurement Standards Laboratory of New Zealand (MSL)

(g) National Institute of Standards and Technology (NIST)

(h) National Measurement Institute, Australia (NMIA)

(i) National Measurement Institute (NMI)

(j) Système International d'Unités (SI): International System of Units

(k) United Kingdom Accreditation Service (UKAS)

3 Scope of Accreditation

Accreditation by IANZ does not constitute a blanket approval of all of a laboratory's activities. Therefore, a means of identifying those activities where competence has been demonstrated and for which accreditation has been granted is necessary.

Accreditation is normally granted only for work which is performed regularly and for which the laboratory is appropriately equipped and has demonstrated its capability.

The field of Metrology and Calibration covers those measurements listed in Appendix 1. Note that where reference is made to “tests”, these should be interpreted as measurements for the purposes of accreditation in this field.

Issued Schedules to the Certificate of Accreditation (Scopes of Accreditation) can be viewed via the IANZ Directory at www.ianz.govt.nz.

3.1 Requested extensions to scope of accreditation

It is relatively common for Metrology and Calibration Laboratories to expand their calibration capabilities into other areas, or to extend a range of measurement for a given calibration type. Depending on the reference equipment, environment requirements, level of technical competence and other factors, such an extension may be reviewed and authorised by IANZ without a visit to the laboratory. However, in a lot of cases and at the discretion of IANZ, a limited assessment with a technical expert will be required. In any case, time spent by IANZ staff on extensions to scope, where substantial, is chargeable, as is time given by a technical expert.

Please see the Procedures and Conditions for Accreditation (reference 10) for more information.

4 Calibration

Calibration involves controlled comparison of the device under calibration (DUC) against a “known” instrument over the range of values of use of the DUC. The differences between the “known” instrument and the DUC are tabulated as corrections to the DUC for a range of pre-selected calibration points. Calibration does not involve adjustment; that is a separate process which may also be carried out as part of the service offered by the calibration agency.

Many calibrations (and electrical in particular) are complicated by the possibility of hardware, firmware or software adjustment during the comparison.

Where instruments submitted to a calibration laboratory are likely to be adjusted, appropriate “as received” measurements must be made and reported where possible (except if otherwise requested by the client). The full calibration can then be carried out after the adjustment. If this procedure is not followed then historical stability data is lost, as is the submitting laboratory’s ability to take appropriate corrective action on out-of-calibration equipment.

Where adjustment of hardware or software takes place during servicing this may invalidate the current calibration certificate, for example any of the following will invalidate a balance calibration certificate:

- Re-programming of scale factors stored in microprocessor memory
- Any adjustments, such as to linearity or corner-load error
- Replacement, re-machining or alteration of internal weights or parts associated with the load cell.

Calibration certificates endorsed with the logo of an ISO 9001 certifying body alone will not be accepted for critical measurements where traceability is required.

5 Traceability of Measurement

Traceability of a measurement result is ensured when the result can be related to a stated reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty (see reference 4). The IANZ policy on traceability of measurement is set out in the IANZ Technical Policy No.1: *Traceability of Measurement*. All IANZ accredited Metrology and Calibration laboratories are required to maintain conformity with this policy.

The calibration certificates issued by accredited laboratories must be endorsed in accordance with the requirements of the accreditation bodies concerned. This constitutes proof of traceability to national standards. The calibration certificate must include a statement on the traceability to the SI (or appropriate International Reference, such as ITS-90 for temperature), and reference may be made to the national measurement institute if desired. An example of such a statement is: “Measurements reported in this certificate are traceable to the SI via the Measurement Standards Laboratory of New Zealand” or similar.

The endorsement on a calibration certificate does not automatically mean that the calibration is fit for the purpose and meets the requirements of the laboratory. However, a laboratory receiving a calibration certificate will need to consider its contents before placing the reference equipment back into use. If this step

is missed and/or if a piece of reference equipment had not been appropriately verified before being put back into service, it can mean that the laboratory may need to recall work which has already been completed and reported in endorsed reports.

For example, some things to consider may be: are all the required ranges and/or parameters reported, is the uncertainty presented in an understandable and appropriate way, are there any non-compliances with specification, or measurements in the window of uncertainty (WOU), is the report suitably (fully) endorsed.

Equipment and Traceability sections of ISO/IEC 17025 contain more information.

6 Laboratory Accommodation and Safety

6.1 Accommodation

Accommodation requirements for Metrology and Calibration laboratories vary depending upon the nature of the items to be calibrated and the uncertainty with which measurements are to be made. A formal laboratory area will be required for precise measurements but many calibrations may be satisfactorily performed in production areas or in the field.

Formal laboratory areas must have good lighting (a minimum of 400 lux is recommended for laboratory areas), adequate bench space, freedom from dust and fumes, freedom from vibration and acoustic noise and appropriate control of temperature and humidity. The extent to which these environmental factors apply will vary according to the type of measurement and the uncertainty with which calibrations are performed.

When precise measurements are to be made in laboratories the following factors will assume greater importance:

(a) Isolation from sources of mechanical vibration and shock likely to have a detrimental effect on sensitive instruments, e.g. lifts, plant rooms, busy roads, etc.

(b) Smooth, antistatic finishes for walls, ceilings and floors and, where necessary, air filtration to facilitate dust control

(c) Insulation of walls and shading from direct sunlight

(d) Temperature control of the laboratory at a selected temperature (20 °C or 23 °C ±2 °C for example)

(e) Humidity control in the region of 35 % RH to 70 % RH

(f) Freedom from fumes likely to have an adverse effect on equipment (e.g. corrosion of switch contacts)

(g) Isolation from electromagnetic interference. This is less likely to be necessary for DC and low frequency AC measurements but assumes importance at RF frequencies. Screening may be necessary for some precise electrical calibrations

(h) Stabilisation or filtering of incoming mains power supply where purity of waveform and constancy of voltage is important.

6.2 Safety

While safety falls outside the scope of accreditation, metrology and calibration laboratories are expected to comply with the Electrical Safety Regulations and any other relevant health and safety requirements. AS 2243 is recommended as a guide to safe practices in laboratories.

7 Branch Laboratories and Site Calibration

Some metrological measurements for which formal laboratory accommodation is not essential or not possible - for example machine tool checks, balance calibration, field pressure or temperature calibrations, field calibration of metering installations - may be performed in situ and accreditation may be granted for these tests even though the laboratory has no specific test room set aside for this work. In these circumstances IANZ considers that the staff, reference standards, measuring equipment, storage facilities, transport and office facilities make a laboratory.

Where an accredited calibration laboratory offers on-site calibration from more than one branch, with all branches having the same scope and procedures, the accredited main branch(es) will be fully assessed as usual. The assessment will cover staff from all sites and their records and equipment details. In addition,

each subsidiary branch operation shall, where relevant and at the discretion of IANZ, be assessed at least once between routine reassessments. The accredited laboratory's quality management system must encompass all branch and site operations and every branch must be included in the accredited laboratory's internal audit schedule.

The accredited laboratory's scope of accreditation shall list all branches from which on-site calibration services are offered. On-site calibration capability must be clearly identified in the scope of accreditation along with the CMC (least uncertainty) for each accredited measurement range.

8 Computer-Controlled Calibration Equipment and Data

Appropriate quality assurance is needed of all in-house developed software (see ISO/IEC 17025). Automatic test equipment must be calibrated in a similar manner to other calibration equipment.

The following comments apply to the use of computers or other instrumentation for direct data capture and control of the calibration operation. Where control is by proprietary software such as that supplied with some calibrators, validation will only be required of the individual calibration routines for instruments and not for the programme supplied by the manufacturer.

For in-house developed software, standard data sets of raw data can be developed for feeding through the system to check routines if they are new to the laboratory, updated, or modified. Care should be taken to ensure that such data sets cover the expected range of values and include combinations of peculiar circumstances to highlight faults in basic logic of the programme or its subroutines. Alternative systems using spreadsheets or other software may also be used.

Reference artefacts may be held to check the operation of the whole system at appropriate intervals. The results of this testing should be recorded and incorporated in the maintenance history. Software maintenance should include a back-up regime and a system recovery plan.

Electronic data must be treated in an equivalent way to hard copy data to ensure it is not lost or changed without an audit trail. In most situations this takes the form of version control and change history.

9 Laboratory Staff

ISO/IEC 17025 gives the general requirements for laboratory personnel.

Key Technical Personnel within Metrology and Calibration laboratories are expected to hold an appropriate tertiary qualification, for example, a degree, diploma, National Certificate or other post-secondary qualification together with suitable experience (alternatively employees with suitable experience and theoretical knowledge may be deemed appropriately qualified). Key Technical Personnel requirements are specified in Appendix 3 of this document.

At least one staff member must be able to determine CMCs and perform appropriate uncertainty analyses, as required by Section 11 of this Schedule.

Courses run by MSL in relevant fields of calibration and measurement uncertainty are usually offered at least once annually.

10 Calibration Methods

Where calibration methods are based on manufacturers' methods, these must be customised for the laboratory's use. The procedures must exercise all relevant parts of the hardware and software of the instrument (full range of parameters), particularly for calibration purposes.

Where standard methods or references are available for calibration purposes (for example, BS EN 837-1 for pressure gauges, EN ISO 7500-1 for materials testing machines, along with MSL Technical Guides) these should be used, at least as a basis for an in-house method. Some detailed technical requirements are given below. These are not exhaustive and cover only a small range of the measurements that can be accredited in the metrology and calibration field.

Useful guidance on other measurements can be found in the European Co-operation for Accreditation (EA) Guidelines documents. A list of these can be obtained from IANZ.

References to MSL technical guides and other documents below were valid at the time of publishing this schedule and may be superseded in the future.

Note: Although there are few standard methods in calibration, IANZ considers that assessment and appropriate measurement audits and proficiency tests (including inter-laboratory comparisons with an accredited laboratory) can be considered to validate in-house developed methods.

10.1 Balances and weighing devices

Information on methods for the calibration and quality assurance of balances are given in MSL's Technical Guide 25: Calibration Balances and 12: Assuring the Quality of Weighing Results. Additional information can also be found in Monograph 4, The Calibration of Weights and Balances by Morris and Fen of NMIA.

10.2 Masses

The reference methods and supporting information for the calibration of masses is given in MSL's Technical Guides 6: Magnetic Effects in Weighing and 7: Calibrating Standard Weights. Additional information can also be found in Monograph 4, The Calibration of Weights and Balances by Morris and Fen of NMIA.

10.3 Thermometers and hygrometers (humidity meters)

Reference 3 gives much detail about the working of thermometers and how to make traceable measurements including during calibration. It describes calibration procedures and how to determine uncertainty for glass thermometers, resistance thermometers, thermocouples, amongst others. It also gives examples of calibration certificates. For supporting information please refer to MSL Technical Guides.

10.3.1 Thermocouples

All base-metal thermocouples (Type T, N, K, J, E) suffer from errors due to metallurgical changes that occur at temperatures above 150 °C. Because the thermocouple emf is produced by those parts of the thermocouple located in temperature gradients (not at the thermocouple tip as commonly thought), thermocouples exposed to these temperatures may be sensitive to immersion conditions and history of thermal exposure. For the highest accuracy at these temperatures, thermocouples should be used only for a single application and fixed in position so the immersion conditions cannot change. Where accuracy better than the indication given by the manufacturers 'limits of error' is required, they must be (i) calibrated in situ, or (ii) taken new from a batch for which a sample has been calibrated, and (iii) replaced regularly according to observed drift rates and users accuracy requirements.

The effects of inhomogeneity caused by cold work or previous heat treatment, compensating leads, cold junction compensation and thermal losses on temperature measurements should be included in the uncertainty assessment. Calibrations of thermocouples must include the compensating lead to be used.

An approximate expression for the standard uncertainty due to inhomogeneity in base-metal thermocouples can be obtained using the following formula:

$u = 0.15 + 0.0003 \cdot t + 0.000004 \cdot t^2$

where:

u = standard uncertainty for thermocouple inhomogeneity,

t = temperature in degrees Celsius.

10.4 Pressure Gauges and Transducers

The MSL course on Pressure Gauge Calibration and the published course notes have valuable information on making pressure measurements, on determining uncertainty and also on how to report. See also the MSL Technical Guide 13: Pressure Gauge Calibration.

10.4.1 Assessment of hysteresis for both Bourdon-tube and digital pressure gauges

For a laboratory that is calibrating Bourdon tube gauges to BS EN 837-1 (or an in-house method based on that standard), the laboratory must decide compliance or non-compliance on both error in reading and error due to hysteresis as stated in that standard.

For a laboratory that is calibrating a gauge to manufacturers' specifications that include limits on hysteresis, then hysteresis must be included in the compliance decision. Note that reputable manufacturers of digital gauges generally have specifications for hysteresis.

For a laboratory that is calibrating a gauge to a standard or specification that does not include limits for hysteresis, the laboratory must at least calculate the hysteresis, and if the hysteresis is clearly discernible and large (i.e. greater than two gauge divisions) then it is recommend that the laboratory suggests to the client that the gauge be repaired or replaced.

10.5 Revenue Meters – electricity and gas

Calibration of electricity revenue meters is covered in the Electricity Industry Participation Code, Part 10 Metering.

Accuracy specifications for electricity meters along with limits for variation in supply voltage, temperature, electromagnetic fields and other influence quantities are given in meter standards such as IEC 61036 and IEC 60687 (superseded but still in use) and in the IEC 62052 and IEC 62053 series of standards.

Calibration procedures for gas meters are given in NZS 5259.

10.6 Use of wavelength and absorbance filters in spectrophotometer calibration

The recommendation for an initial five year calibration and subsequently an interval of ten years for wavelength filters is in view of the fact that there may be changes to procedure, changes to advice as to how to use the filters, and changes to the conditions under which the filters are used (in particular, bandwidth). Given sufficient evidence, the intervals can be extended in consultation with IANZ and/or MSL.

Intervals for recalibration of absorbance filters will also depend on each individual laboratory's ability to demonstrate stability of their filters and their associated cleaning and handling procedures. See also the MSL Technical Guide 38: Reference materials for the calibration of UV/visible light spectrophotometers.

11 Uncertainty of Measurement

Metrology and Calibration laboratories must document a policy on calculation of the uncertainty of measurement of any DUC.

Laboratories are strongly advised to follow the policy outlined in the guidance document (reference 2) and to incorporate its guidance and the following IANZ policy into their own policy statement. Appendix 4 provides sample calculations of uncertainties. References 2 and 3 also provide worked examples that are informative and helpful. MSL Technical Guides normally contain uncertainty analyses, and there are also some helpful uncertainty calculators available on the Internet, including the MSL uncertainty calculator.

The IANZ measurement uncertainty policy is:

All known components of uncertainty arising from type A and type B contributions must be considered, evaluated and prepared in an uncertainty budget including:

(a) Calibration uncertainty from the certificate of the reference standard calibration certificate

(b) Any known drift-related effects not allowed for in the original calibration certificate or covered by the specified calibration interval (also becomes part of the CMC)

(c) Any influence quantity effects caused by method, environment, DUC, or operator effects and not able to be randomised i.e. allowed for in a type A assessment. Where information is available from inter-laboratory trials or measurement audits this should be used

(d) Type A contributions obtained by repeating the measurements, preferably 10 times or more but normally not less than 5 times over a range of normal operation of the equipment.

These contributions will be designated and evaluated as standard uncertainties from type A or type B components. The combined standard uncertainty is normally determined from the contributing standard uncertainties using the root sum square (RSS) method of reference 2.

Note: In circumstances where the input quantities might be correlated, such as for a group of weights all calibrated with the same reference, the individual standard uncertainties will be summed.

The expanded uncertainty is calculated to give a 95 % level of confidence about the result of the measurement (the best estimate of the value of the measurand) by multiplying by a coverage factor. In many cases the coverage factor will be close to 2 but laboratories need to justify the coverage factor used in their

particular determinations. The coverage factor can be calculated accurately using the Welch-Satterthwaite formula.

11.1 Definition and calculation of a CMC

An accredited laboratory must also calculate its CMC. The CMC for each accredited measurement or range of measurements applied for is submitted by the applicant laboratory and then reviewed by IANZ for addition to the laboratory's scope of accreditation. The informative annex of reference 7 provides the definition of CMC that IANZ uses:

A CMC is a calibration and measurement capability available to customers under normal conditions.

There are notes accompanying the definition in reference 7, which are important. These are summarised below.

N1. CMC is equal to BMC (best measurement capability).

N2. The calibration or measurement is performed according to a documented procedure with an associated uncertainty budget, performed on a regular basis, and is available to all customers.

N3. An NMI can perform 'special calibrations' with uncertainties lower than those on their scope but these shall not be endorsed.*

N4. Uncertainty calculations should comply with the GUM (reference 2). They can be represented by a range, an equation, a fixed value or a matrix.

N5. Uncertainty contributions from the client's instrument are usually not included in the CMC, but a contribution (measured, with recorded evidence) from the best existing device should be included in the CMC (can include a device not commercially available).**

N6. NMI's CMCs are available via the BIPM KCDB and the CMCs of accredited laboratories with traceability to those CMCs should be consistent with them.

N7. Traceability to an NMI's CMCs is a recognised source of traceability.

*Laboratories are not permitted to endorse reports which contain uncertainties less than the CMC outlined in their scope of accreditation. The only exception to this is if a laboratory produces a calibration certificate for internal purposes (as long as that type of calibration is included in the scope of accreditation), and the note N3 above.

**A best existing device could be, for example, a very good client's instrument or a device similar to the laboratory's reference instrument.

12 Certificates of Calibration

In addition to these requirements for reporting in ISO/IEC 17025 and Appendix 1 in *Procedures and Conditions for Accreditation*, calibration certificates shall contain:

(a) The laboratory's accreditation number;

(b) The confidence level and calculated k value appropriate to the uncertainty of measurement reported;

(c) The statement that the certificate shall not be reproduced except in full.

Units and unit symbols shall be in the form specified in the SI unless the device being calibrated reads in other units or where contractual arrangements demand otherwise.

12.1 Reporting uncertainties

General rules are given here but references 2 and 11 should be consulted for more detail.

(a) The estimated uncertainty should be rounded to two significant figures, for example a calculated uncertainty of 2.521 becomes 2.5. Normal rounding rules apply – see reference 11 for more detail and examples.

(b) Results (corrections) should be reported at the same level of significance as the uncertainty. For example, if the correction for a mass is computed to be 1.3578 mg with a rounded uncertainty of 0.58 mg, the correction should be reported as 1.36 mg.

The uncertainty should be in the same units as the results. However, there may be cases where it is more practical for the uncertainty to be reported as a percentage that applies to all results.

13 Compliance with Specification

Laboratories may report compliance with a metrological specification or a manufacturer's specification, along with the calibration results, in order to verify a DUC. The preferred way to do this is to report compliance with the specification to the edge of the "window of uncertainty" (for example upper limit minus uncertainty) and not make a statement within the window below the limit.

If the accredited laboratory issues endorsed certificates which include compliance statements, there are four conditions to consider (see Figure 1):

- Where the measurement result is compliant, and with the addition of uncertainty is still compliant, a 'pass' statement must be made;
- Where the measurement result is non-compliant, and the addition of uncertainty is still non-compliant, a 'fail' statement must be made;
- Where the measurement result is compliant but adding the uncertainty would make it non-compliant, a 'window of uncertainty' statement must be made i.e. the user cannot be sure whether this result is compliant or not;
- Where the measurement result is non-compliant but adding the uncertainty would make it compliant, a 'window of uncertainty' statement must be made i.e. the user cannot be sure whether this result is compliant or not.

IANZ will not usually accept the reporting of compliance with specification unless the results and uncertainty are also reported. Reference should be made to the ILAC Guidelines on the Reporting of Compliance with Specification (reference 6).

A certificate which reports compliance only (no numerical results and uncertainty) will only be allowed with the client's written approval, where it is not intended to be used in support of the further dissemination of metrological traceability, and as long as full supporting records are maintained and are accessible to the client if requested.

Alternatively, the laboratory may state compliance up to the limit but draw attention to the uncertainty. Under no circumstances can compliance be implied above an upper limit or below a lower limit (see references 7 and 8 for further guidance).

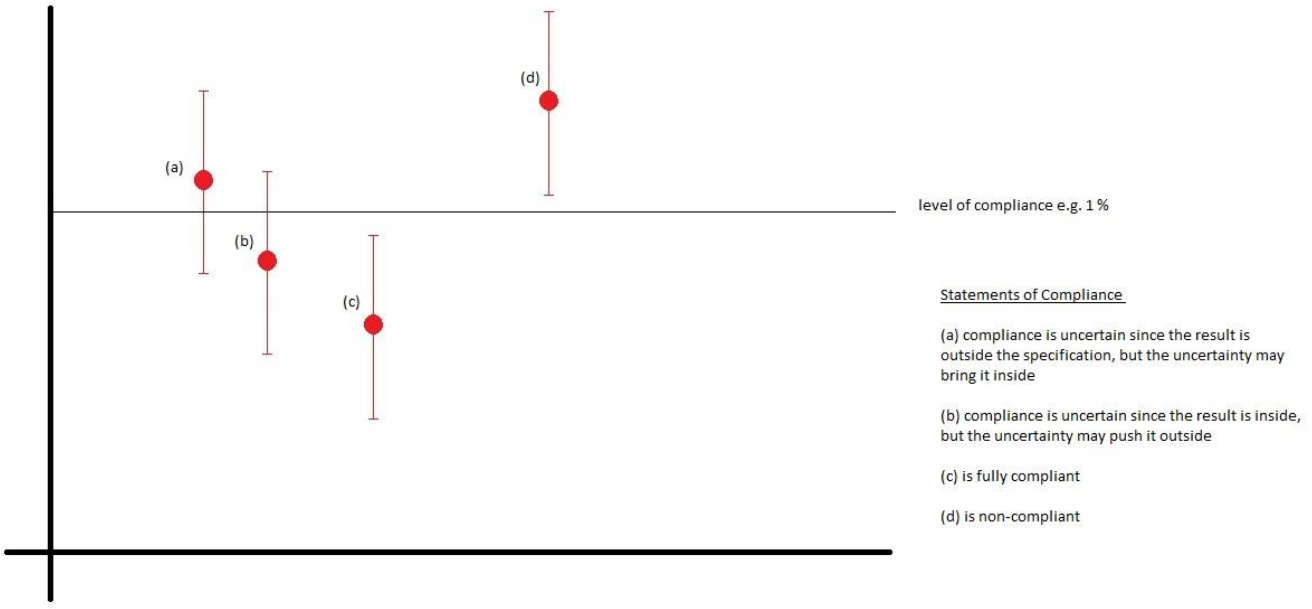

Figure 1: Graphical representation of the four scenarios for statements of compliance

14 Proficiency Testing

The IANZ policy on participation in proficiency testing activities is set out in the IANZ Technical Policy No.2: *Participation in Proficiency Testing Activities* (reference 9). All IANZ accredited Metrology and Calibration laboratories are required to maintain conformity with this policy.

15 References

1. UKAS M3003: *The Expression of Uncertainty and Confidence in Measurement for Calibration*
2. JCGM 100:2008 (GUM 1995 with minor corrections) - *Evaluation of measurement data — Guide to the expression of uncertainty in measurement*
3. J V Nicholas and D R White, *Traceable Temperatures*, Second Edition, John Wiley, 2001
4. ISO/IEC Guide 99: 2007 - *International vocabulary of metrology -- Basic and general concepts and associated terms (VIM)*
5. OIML G13: *Planning of Metrology and Testing Laboratories*
6. ILAC-G8: Guidelines on Assessment and Reporting of Compliance with Specification, (http://ilac.org/publications-and-resources/)
7. ILAC P14: *Policy for Uncertainty in Measurement* (http://ilac.org/publications-and-resources/)
8. IANZ Technical Policy 1: *Measurement traceability policy* (AS TP1)
9. IANZ Technical Policy 2: *PT Participation Policy* (AS TP2)
10. IANZ General Criteria: *Procedures and Conditions for Accreditation* (AS 1)
11. NIST GLP9: *Good Laboratory Practice for Rounding Expanded Uncertainties and Calibration Values*

Appendix 1: Classes of Test

5.01 Engineers' Limit Gauges *[see Note (a) below]*

(a) Plain plug, ring and gap gauges. Taper plug and ring gauges.

(b) Parallel screw plug and ring gauges. Adjustable thread calliper gauges for parallel threads.

(c) Taper screw plug and ring gauges. Adjustable thread calliper gauges (3 roll type) for taper threads.

(d) Profile gauges

(e) Position and receiver gauges involving both linear and angular measurements.

(f) Spline and serration gauges.

(g) Other gauges involving measurements similar to those under (a) and including depth gauges, height gauges and gauges involving plane coordinated position of holes and spigots.

5.02 Jigs, Fixtures, Cutting Tools and Components *[see Note (b) below]*

5.03 Engineers' Measuring Tools and Instruments *[see Note (d) below]*

(a) Test sieves

(b) Engineers' straightedges

(c) Toolmakers' straightedges

(d) Surface plates

(e) Toolmakers' flats

(f) Engineers' parallels (steel)

(g) Vernier callipers

(h) Vernier height and/or depth gauges

(i) Feeler gauges (including film thickness gauges)

(j) External micrometers

(k) Internal micrometers (including stick micrometers)

(l) Depth micrometers

(m) Plunger gauges – dial or digital

(n) Dial test indicators (lever type)

(o) Bevel protractors

(p) Squares (Engineers, Cylindrical and Block types)

(q) Angle plates

(r) Rules (including retractable types)

(s) Levels (Engineers and Dumpy types)

(t) Inclinometers

(u) Engineers' comparators for external measurement (magnification up to 2,000)

(v) Coordinate Measuring Machines

(w) Other tools and instruments

5.04 Machine Tools

(a) Geometric testing including
- Flatness of beds and tables
- Straightness of guideways
- Alignments (parallelism, squareness, etc)
- Accuracy of lead screws
- Accuracy of gear drives
- Accuracy of built-in measuring systems

(b) Practical tests including
- Performance tests
- Deflection tests

5.05 Geometric Form

(a) Surface texture

(b) Roundness

(c) Straightness

(d) Flatness

(e) Eccentricity

(f) Squareness

(g) Angle

5.06 Gears, Splines and Serrations

(a) Machine cut gears – helical and straight spur

(b) Bevel gears (machine cut)

(c) Gears for traction

(d) Worm gearing

(e) Fine pitch gears

(f) Gears for turbines and similar drives

(g) Straight-sided splines and serrations

5.11 Working Standards of Length and Angle

(a) Gauge blocks and accessories

(b) Length bars and accessories

(c) Cylindrical standards, internal and external

(d) Spherical standards

(e) Thread measurement accessories

(f) Precision linear scales

(g) Laser measuring systems

(h) Precision graticules including stage micrometers and haemacytometer counting chambers

(i) Surveying tapes and petroleum dip tapes

(j) Screw pitch reference standards

(k) Angle gauges and precision polygons

(l) Precision circular scales

(m) Reference standards for surface finish

(n) Geodetic baselines

5.12 Precision Measuring Instruments *[see Note (c) below]*

(a) Length measuring machines

(b) Screw diameter measuring machines

(c) Screw pitch measuring machines

(d) Precision projection apparatus

(e) Taper measuring machines

(f) Drunkenness measuring machines

(g) Auto-collimators and other optical instruments used in engineering metrology

(h) Dividing heads and tables

(i) Gear in hob measuring equipment

(j) Extensometers for determination of modulus of elasticity

(k) Engineers' comparators with magnification greater than 2,000

(l) Sine bars and sine tables

(m) Cryptometers

5.13 Area Standards

(a) Flexible circular area standards

5.14 Laser Frequency

(a) Stabilised lasers of the mise en practique

(b) Other stabilised lasers

5.16 Gas Instrumentation

(a) Gas analysers

(b) Breath analysers

(c) Dynamic gas blenders

(d) Other instruments

5.21 Masses

(a) Examination of laboratory standards of mass

(b) Examination of industrial standards of mass

(c) Determination of the mass of solid objects

5.22 Precision Laboratory Balances

Examination of the performance of precision laboratory balances having a nominal measurement uncertainty not exceeding 1 part in 100,000 of maximum capacity.

5.23 Industrial Balances

Examination of the performance of industrial balances having a nominal measurement uncertainty exceeding 1 part in 100,000 of maximum capacity.

5.24 Industrial Weighing Appliances

5.25 Pattern Approval Tests

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(a) Anemometers

(b) Mechanical type meters

(c) Variable aperture meters

(d) Dry meters

(e) Wet meters

(f) Electromagnetic meters

(g) Turbine meters

(h) Vortex meters

(i) Differential pressure meters

(j) Open channel water meters

(k) Weir type structures

(l) Other devices

5.31 Volumetric Equipment *[see Note (f) below]*

(a) Examination of laboratory volumetric glassware including examination for compliance with the Class A or Class B requirements of the relevant national or international standards

(b) Examination of other types of volumetric apparatus (including gas meters)

(c) Calibration of tanks, cylinders and other industrial volumetric apparatus including calibration by strapping and calibration by internal measurements

5.32 Density
- (a) Density of solids
- (b) Density of liquids
- (c) Density of gases
- (d) Nuclear moisture and density meters

5.33 Hydrometers
- (a) Density hydrometers
- (b) Specific gravity hydrometers
- (c) Brix hydrometers
- (d) Proof spirit hydrometers

5.34 Densitometers
- (a) Liquid densitometers
- (b) Gas densitometers

5.35 Hygrometry
- (a) Humidity measuring devices
- (b) Environmental chambers

5.41 Barometeric indicators or transducers

5.42 Differential Pressure Measuring Devices (including Manometers)
- (a) Diaphragm types
- (b) Liquid column types, inclined and vertical
- (c) Transducers and transmitters
- (d) Other types

5.43 Pressure Gauge Calibrators and Pressure Balances

5.44 Pressure and Vacuum
- (a) Pressure gauges
- (b) Vacuum gauges
- (c) Pressure transducers
- (d) Pressure recorders

5.51 Force Measuring Devices
- (a) Proving devices
- (b) Elastic force measuring devices and force dynamometers

5.52 Strain and Displacement
- (a) Extensometers
- (b) Strain gauges
- (c) Dial gauges
- (d) Other devices

5.53 Testing Machines
- (a) Tension and universal machines in tension
- (b) Compression and universal machines in compression
- (c) Vickers hardness machines
- (d) Rockwell hardness machines
- (e) Brinell hardness machines
- (f) Izod impact machines
- (g) Charpy impact machines
- (h) Deadweight rubber hardness testers
- (i) Micro-hardness rubber testers
- (j) Rubber hardness meters (durometers)
- (k) Plastic hardness testers
- (l) Torsion machines
- (m) Tension-torque machines
- (n) Road friction testers
- (o) Other testing machines

5.54 Mechanical Testing Equipment
- (a) Portable Brinell measuring microscopes
- (b) Indenters for hardness machines
- (c) Hardness blocks for metals testing
- (d) Other equipment

5.55 Speed Measuring Devices
- (a) Tachometers
- (b) Speedometers
- (c) Velocity transducers

5.61 Temperature Measuring Equipment
- (a) Rare metal thermocouples
- (b) Base metal thermocouples
- (c) Platinum (and other metallic) resistance thermometers
- (d) Germanium thermometers
- (e) Thermistors and other semi-conductor thermometers
- (f) Liquid-in-glass thermometers
- (g) Clinical thermometers
- (h) Optical pyrometers
- (i) Strip lamps
- (j) Radiation thermometers
- (k) Vapour pressure thermometers

(l) Filled metal systems

(m) Bimetallic systems

(n) Digital quartz frequency units

(o) Indicators, recorders and controllers

(p) Other direct reading temperature measuring systems

5.63 Temperature controlled enclosures

(a) Ovens and furnaces (including autoclaves)

(b) Baths

(c) Incubators

(d) Refrigerators and freezers

(e) Conditioning rooms and cabinets

(f) Other enclosures

5.64 Thermal Radiation

5.65 Photometers and Radiometers

(a) Photometers

(b) Illuminance meters

(c) Luminance meters

(d) UV meters

(e) Irradiance meters for solar radiation
(i) Pyrheliometers
(ii) Pyranometers
(iii) Ultraviolet pyranometers
(iv) Pyrradiometers
(v) Albedometers
(vi) Pyr-albedometers

(f) Erythemal meters & other broadband radiometers

(g) Laser power meters

(h) Detector spectral responsivity measurement

5.66 Lamps, LEDs, Lasers & Other Light Sources

(a) Lamps: Luminous intensity

(b) Lamps: Luminous flux

(c) LEDs

(d) Lasers: Power

(e) Illuminance

(f) General sources: Spectral irradiance

(g) General sources: Broadband irradiance

(h) Photoluminescent materials

(i) Luminaires: Luminous intensity distribution

5.67 Colour of Light Source and Colorimeters

(a) General sources: Colour emitted

(b) Displays: Colour emitted L*a*b*

(c) Colorimeters

(d) Lamps: Colour temperature

(e) Colour temperature meters

5.68 Optical Properties of Materials: Spectral

(a) Regular transmittance and absorbance

(b) Wavelength calibration filters

(c) Diffuse transmittance

(d) Diffuse reflectance

(e) Specular reflectance

5.69 Optical Properties of Materials: Spectrally integrated

(a) Luminance transmittance

(b) Luminous reflectance

(c) Chromaticity and luminance factor

(d) Retroreflectors: CIL value

5.70 Optical Instruments

(a) Focal length

(b) Image plane principal point and nodal points

(c) Field of view

(d) Refractive index & refractometers

(e) Polarimeters

(f) Sacharimeters

(g) Quartz control plates

5.71 Acoustic Equipment

(a) Microphones

(b) Sound level meters including sound survey meters and impulse sound level meters

(c) Sound spectrum analysers and filters

(d) Acoustic calibrators, including pistonphones and reference sound sources

(e) Sound level recording systems

(f) Instrumentation and professional tape recorders

(g) Acoustic interferometers (impedance tubes)

(h) Standard sound sources

(i) Noise dose meters

(j) Audiometers

(k) Other specified equipment

5.72 Ionizing Radiation

5.75 Vibration Measuring and Calibrating Equipment

(a) Vibration transducers including accelerometers, velocity and displacement pickups

(b) Vibration measuring systems

(c) Analysers and filters

(d) Vibration recording systems

(e) Vibration calibrators

(f) Other vibration measuring equipment

5.81 Conductors and Resistance Alloys

(a) Resistivity

(b) Resistance of length of conductor

(c) Temperature coefficient

(d) Physical properties

5.82 Resistors, Resistance Boxes and Potential Dividers

(a) Precision resistors, resistance boxes and conductance boxes

(b) Volt ratio boxes and potential dividers

(c) DC shunts

(d) AC shunts

5.84 Capacitors

(a) Precision capacitors

(b) Capacitance attenuators

(c) Capacitance potential dividers

5.85 Inductors and Transformers

(a) Inductors, self and mutual

(b) Ratio transformers

(c) Power transformers and reactors

(d) Current transformers: protection and measurement

(e) Voltage transformers: protection and measurement

(f) Audio transformers

(g) RF transformers

(h) Pulse transformers

(i) Auto transformers

(j) Phase shifting transformers

(k) Reference ballasts

(l) Neutral earthing transformers

5.86 Voltage Standards and Current Standards

(a) Standard cells

(b) Electronic emf reference devices

5.87 Transfer Instruments (AC/DC)

5.88 Calibrators for Instrumentation

(a) DC voltage

(b) AC voltage

(c) DC current

(d) AC current

(e) Resistance

(f) AC power sources

(g) Capacitance

(h) Phase

(i) Other

5.89 Indicating Instruments and Recording Instruments

(a) DC voltmeters

(b) AC voltmeters

(c) DC ammeters

(d) AC ammeters

(e) Wattmeters

(f) Varmeters

(g) Phase angle indicators

(h) Power factor meters

(i) Ohmmeters

(j) LCR meters

(k) Galvanometers and null detectors

(l) Energy meters

(m) Graphic recording instruments

(n) Digital storage recorders

(o) Instrumentation tape recorders

(p) Electric field strength meters

(q) Other specified devices

5.90 Bridges, Potentiometers and Test Sets

(a) DC bridges
(b) DC potentiometers
(c) AC bridges
(d) AC potentiometers
(e) Ratiometers
(f) Current transformer testing sets
(g) Voltage transformer testing sets
(h) Partial discharge test equipment

5.91 Time and Frequency

(a) Frequency meters
(b) Wavemeters
(c) Counters
(d) Time interval meters
(e) Clocks and watches
(f) Stroboscopes
(g) Frequency standards

5.92 Waveform

(a) Frequency characteristics
(b) Input characteristics
(c) Timing characteristics
(d) Distortion
(e) Other characteristics

5.93 Signal Sources

(a) Frequency characteristics
(b) Output characteristics
(c) Modulation characteristics
(d) Sweep characteristics
(e) Other characteristics

5.95 Communications Equipment

(a) Line transmission measuring equipment
(b) Radio transmission measuring equipment
(c) Field intensity measuring equipment
(d) Electrical noise and interference measuring equipment
(e) Impedance and reflection measuring equipment
(f) Spectrum analysis measuring equipment
(g) Data transmission equipment
(h) Power measuring equipment
(i) Attenuators and amplifiers
(j) Waveguide and coaxial components
(k) Communication systems
(l) Data acquisition systems
(m) Processor controlled systems
(n) Other equipment

5.96 Electronic Equipment

(a) High voltage impulse and disturbance tests
(b) Transducer indicators and calibrators
(c) Doppler radar equipment
(d) Miscellaneous equipment and tests

5.97 High Voltage

(a) Direct voltage
(b) Alternating voltage
(c) Impulse voltage
(d) Impulse current
(e) Partial discharge
(f) Dielectric tests
(g) Other specified tests

Notes on classes of tests

(a) Accreditation for adjustable thread calliper gauges (class 5.01) is granted only to laboratories which can perform complete examinations. It is not granted for "setting only". Facilities are required for checking geometry of the anvils including thread form, eccentricity and taper of roller anvils and relative position of fixed anvils. It is usually necessary for laboratories to have their own facilities for the checking of setting plugs. In some circumstances regular checking of setting plugs by an IANZ accredited laboratory or by MSL may be accepted.

Examination of the gauges specified in BS 2059 is included in class 5.01(g).

(b) Class 5.02 covers measurement of jigs, fixtures, cutting tools and components which are similar to the gauge measurement in class 5.01. It includes also the examination of laboratory moulds and cutting dies such as cement cube moulds, vicat moulds, rubber specimen cutters such as tension test dies, compression set test cutters and tear test dies. Examination of gear cutting tools such as hobs and rack type cutters is also included in class 5.02.

(c) Engineers' comparators with magnifications greater than 2000 and precision measuring instruments are included in class are included in class 5.12.

(d) A wide range of laboratory instruments come within the scope of class 5.03(w), including:

- (i) Torque transducers;
- (ii) Torque tools, for example screwdrivers and wrenches;
- (iii) Vicat apparatus (cement testing);
- (iv) Pensky-Martens apparatus (petroleum testing);
- (v) Penetration needles (bitumen and grease testing);
- (vi) Thickness gauges for rubber, plastics, textiles and other materials;
- (vii) Airflow nozzles and petrol jets.
- (viii) Crimping tools

(e) Acceptance test charts for metal working and wood working machines have been published:

- (i) Jointly by the Institutions of Mechanical Engineers and Production Engineers
- (ii) By the Machinery Publishing Co Limited – Testing Machine Tools, by Dr G Schelsinger and Dr F Koenigsberger
- (iii) ISO 230 - Machine Tool Test Code together with specific ISO recommendations.

(f) Special purpose laboratory items are included in class 5.31(b), including:

- (i) Pipettes;
- (ii) Dean and Stark apparatus;
- (iii) Diluent trap for testing crankcase oil;
- (iv) Degassing chamber for gas content of insulating oils.

Appendix 2: Recommended maximum equipment calibration intervals

The following table sets out recommended maximum periods between successive calibrations for a number of reference standards and measuring instruments. It must be stressed that each period is generally considered to be the maximum appropriate in each case providing that the other criteria specified below are met:

(a) the equipment is of good quality and of proven stability, and

(b) the laboratory has both the equipment capability and staff expertise to perform adequate internal checks, and

(c) if any suspicion or indication of overloading or mishandling arises the equipment will be checked (and recalibrated if necessary) immediately and thereafter at frequent intervals until it can be shown that stability has not been impaired.

Where the above criteria cannot be met, appropriately shorter intervals may be necessary.

IANZ is also prepared to consider submissions for extension of calibration intervals based on factors such as history of stability, frequency of use, accuracy required, ability of staff to perform regular checks and successful participation in measurement audits. It is the responsibility of the laboratory to provide evidence that its calibration system would ensure that confidence in the equipment could be maintained.

Items marked with an asterisk in the table are those which can be calibrated by the staff of a laboratory if it is suitably equipped and the staff is competent to perform such recalibrations. Equipment inter-comparisons are usually performed by laboratory staff. Where calibrations have been performed by the staff of a laboratory, adequate records of these measurements must be maintained.

The second column shows the maximum recommended period between the initial calibration and the first recalibration. The third shows the maximum period between subsequent recalibrations provided that the two earlier calibrations indicate that the item is stable. These recalibration intervals apply only to equipment of good quality and stability that is used, handled and stored with care. High usage of equipment may lead to a reduction in these periods.

These intervals may need to be more frequent if the laboratory uses certain standards, methods, or is governed by certain regulations.

Equipment	**Recommended maximum period (years) between successive calibrations**	
	Initial Calibration	**Subsequent Calibration**
Accelerometers	One	One
Acoustic calibrators	One Inter-compare every six months	One
Anemometers	One	One
Angle gauges (a) Reference (b) Working	 Three Two	 Five Four
Attenuators	Three (Frequency response). Resistance and return loss check annually where appropriate	Three
Balances	One (see also MSL Technical Guide 12)	Three
Bandpass filter sets	Two	Two

Equipment	Recommended maximum period (years) between successive calibrations	
	Initial Calibration	Subsequent Calibration
Barometers		
(a) Fortin and Kew types	Five	Five
(b) Digital/Aneroid	One	Two
(c) Indicators, transducers and calibrators	One	Two
Bridges	Three (Full calibration) Range check annually	Three
Calibration baths and furnaces	Three Complete temperature survey initially	Five
Capacitors	Three Inter-compare annually	Three
Dead weight testers	Five	Five
Density bottles	Two	Five
Digital multimeters*	One	Two
Calibrators with self-checking	Two	Two
Calibrators without self-checking	One	Two
Dividing heads	Three	Five
Environmental chambers	Three Time and spatial (temperature variations, recovery time, rate of ventilation)	Five
Filters - optical for calibrating spectrophotometers	See also Section 10.6 above and MSL Technical Guide 38	
(a) Absorbance filters		
(i) Neutral-density glass	Two	Two
(ii) Metal-on-quartz reflecting	One	Two
(iii) Sealed cuvettes of solution	One	Two
(b) Wavelength filters		
(i) Holmium and didymium	Five	Ten
Frequency analysers	Five	Five
Frequency counters*	One	Five
Frequency standards	See “Time” below	

Equipment	Recommended maximum period (years) between successive calibrations	
	Initial Calibration	Subsequent Calibration
Force testing machines	Two to five years depending on type. *Where required by a standard method, this period will be less*	
Gauge blocks (a) Reference (b) Working	 Three Two	 Five Four
Height setting micrometers and riser blocks	Two	Four
Hydrometers	Three	Five
Hygrometers* (a) Assman and sling type psychrometers	Six months (compare thermometers at room temperature with wick dry). Five years (complete calibration)	
(b) Mechanical (e.g. hair type) thermohygrometers	Three months	One
(c) Electrical impedance sensor	One	One
(d) Chilled mirror sensor	One	Five
(e) Other	One	One
Inductors	Three Inter-compare annually	Three
Instruments, electrical* (analogue)	Three Inter-compare every six months or more frequently as required	Three
Instrument and ratio transformers	Five	Five
Instrument transformer test sets	Three (Full calibration). Annual inter-comparison of transformers to detect major problems	Five
Lamps Irradiance sources	50 hours or five years	50 hours or five years
Length bars (a) Reference (b) Working	 Three Two	 Five Four

Equipment	Recommended maximum period (years) between successive calibrations	
	Initial Calibration	Subsequent Calibration
Levels Precision	Three	Five
Linear scales Precision	Three	Five
Manometers (a) Liquid (b) Digital/mechanical*	Two One	Five Two
Masses (integral, stainless steel or nickel chrome alloys) (a) Reference (b) Working*	One One	Five Three
Masses (all other types) - Working*	One	Three
Micrometers, dial gauges, callipers etc.	*See IANZ Technical Guide AS TG 1*	
Microphones	One Three monthly check of frequency response and sensitivity. Calibrate annually or when ±1 dB change is detected whichever is sooner	One
Optical flats	Three	Five
Optical parallels	Three	Five
Orifice plates and nozzles	Initial dimensional calibration Six monthly visual inspection	
Photometers	One	Three
Oscilloscopes	One	One
Pistonphones	One Inter-compare every six months	
Potentiometers	Five	Five
Precision polygons	Three	Five
Pressure and vacuum gauges (a) Reference (b) Working*	One One (with three-to-six monthly internal intermediate checks)	Two One

Equipment	Recommended maximum period (years) between successive calibrations	
	Initial Calibration	Subsequent Calibration
RF noise sources	Two	Two
RF power measuring equipment	One (Power references) Three years for thermistor sensors Annual check of VSWR	Three
Radiometers (a) Visible (b) UVA (c) UVB, UVC (d) Irradiance meters for solar radiation	 One One One One	 Three Two One One
Reference glass filters	Five	Ten
Resistors	One After initial drift rate has been established, inter-compare annually	Three
Rollers and balls	Three	Five
Roundness standards	Three	Five
Roughness standards	Three	Five
Screw check plugs for ring gauges	Three	Five
Screw pitch reference standards	Three	Five
Setting cylinders	Three	Five
Setting rings	Three	Five
Signal generators	One	Two
Sound level meters	Two Check every three months	Two
Sound power sources	Five	Five
Spectrophotometers	Six months (see also MSL Technical Guide 38)	Six months
Squares (a) Try squares (b) Block squares	 Two Three	 Five Five

Equipment	Recommended maximum period (years) between successive calibrations	
	Initial Calibration	Subsequent Calibration
Standard cells, electronic	One Inter-compare at least three monthly to establish drift rate of a group. One cell in a group needs to be calibrated annually. Then inter-compare within group as required	One
Surface plates		
(a) Cast iron	Three	Five
(b) Granite	Three	Five
Thermocouples (probe only)		
(a) Rare metal	100 hours use or three years whichever is the sooner	
(b) Base metal	Calibration intervals to suit the particular application	
Thermometers		
(a) Reference liquid-in-glass	Five (full calibration) Check ice point immediately after initial calibration then at least every six months	Five
(b) Working liquid-in-glass*	Five (full calibration) Check ice point immediately after initial calibration then at least every six months	Five
or alternatively	Inter-compare with reference thermometer(s) at points in the working range every six months. *See IANZ Technical Guide AS TG 3*	
(c) Electronic (sensors that are thermocouples, thermistors or other integrated circuit devices)*	One (full calibration)	One
Thermometers contd.		
(d) Resistance	Five (full calibration) or when the ice point drift is more than five times the uncertainty of calibration Check at ice point before use or at least every six months *Working hand-held resistance thermometers can be checked using the alternative procedure for glass thermometers*	Five
Thread measurement cylinders	Three	Five

Equipment	Recommended maximum period (years) between successive calibrations	
	Initial Calibration	Subsequent Calibration
Thread measurement vee pieces	Two	Five
Time*, time interval, and frequency standards*	One But calibration interval dependent on equipment frequency type and accuracy required. This may be as frequently as daily if the highest possible performance is required (via TV line six). Audit the data collection system every two years	
Transfer standards, ac-dc	Five (maximum) With annual self-check for a standalone passive instrument; two years for active devices	Five
Volt ratio boxes	Three Annual resistance checks	Three
Volumetric glassware*	Five	Five
Watt-hour meters (electromechanical)	One Inter-compare every three months	Two
Watt meters and watt-hour meters (electronic)	One With regular inter-comparisons - intervals to be based on history of performance	Two

Appendix 3: Key Technical Personnel and Other Staff

Supervisory staff in accredited organisations must be competent and experienced in the technical areas covered by their accreditation. They must be able to oversee the operations and cope with any problems that might arise in their work or that of their colleagues or those who report to them. Such staff members, formally appointed by the senior management of the laboratory, are referred to as Key Technical Personnel.

Key Technical Personnel are the knowledgeable staff members who, where relevant:

(a) Develop and implement new procedures
(b) Design quality control procedures, set action criteria and take corrective actions
(c) Identify and resolve problems
(d) Authorise the release of reports
(e) Take responsibility for the validity of calibration results.

Every accredited organisation must have at least one Key Technical Person covering each class of calibration activity on its scope of accreditation. Accreditation is automatically suspended for any scope item(s) where there is no Key Technical Person for the item(s) due to Key Technical Personnel leaving the organisation or otherwise losing their approval for that part of the scope.

The qualifications and experience required of Key Technical Personnel and other technical staff members cannot be rigidly specified but must be appropriate to the work in which they are engaged. Key Technical Personnel would normally hold tertiary qualifications or equivalent professional recognition in the relevant discipline. Organisations engaged in a restricted range of repetitive work may have that work controlled by a Key Technical Personnel with appropriate practical experience and specific training in that work but without formal qualifications.

Requirements for Key Technical Personnel

(a) Appointment of Key Technical Personnel will be the responsibility of a designated senior laboratory officer who is a member of the laboratory's senior management team. Laboratories are required to have a documented person/position specification for Key Technical Persons and a documented and formal process for their qualification and appointment.

(b) The laboratory will maintain a list of current Key Technical Personnel, including the technical scope of their areas of responsibility. This list may be included in the laboratory's quality manual or as a separate document, but must be maintained up-to-date at all times. The technical scope for each individual will be described in a manner to suit the laboratory's circumstance and organisational structure, but there must be at least one Key Technical Person appointed for each calibration or group of calibration activities in the laboratory's scope of accreditation. The laboratory may choose to use the Classes of Calibration detailed in Appendix 1, with additional qualifiers as appropriate, but this is not mandatory.

(c) The list of Key Technical Personnel and their individual scope of responsibility must be notified to IANZ who will maintain this listing for each accreditation. IANZ will request this information in the Application for Accreditation or Reassessment documentation provided prior to the annual reassessment, and will also review it with laboratories during their assessment.

(d) Changes to Key Technical Personnel listings (including individuals who have left the laboratory, new Key Technical Person appointments, or changes in the technical scope of responsibility) made between annual on-site assessments must also be notified to IANZ. This is the responsibility of the laboratory's Authorised Representative.

(e) In addition to the laboratory's usual training records, each Key Technical Person is required to have a brief CV-type summary of qualifications and experience. This CV information will be requested to be provided to IANZ for each appointed Key Technical Person in the Application for Accreditation/Reassessment documentation. This information is also expected to be provided to IANZ when new Key Technical Personnel are appointed and notified to IANZ outside of annual assessments.

(f) Where a laboratory loses the sole Key Technical Person for all or part of their scope of accreditation, and no new appointment is made by the laboratory management then the laboratory's accreditation (or part thereof) will be suspended until such time as a new appointment is notified to IANZ. Where new Key Technical Personnel appointments are made outside of routine reassessments, and particularly when a new appointment is the sole Key Technical Person for all or part of the accreditation, IANZ

reserves the right to conduct an on-site assessment of the laboratory to be assured the laboratory's systems and integrity of the laboratory's calibration results will continue to be maintained.

(g) All IANZ-endorsed calibration certificates issued by an accredited laboratory must be signed or authorised by a Key Technical Person holding approval in the relevant class(es) of test, who will take full responsibility for the validity of the work. Authorisation can be by signing or by electronic signature with appropriate software safeguards covering release of the report information.

A Key Technical Personnel may be appointed to a person engaged by an accredited organisation as a consultant, with respect to work done within the scope of accreditation of that organisation, provided that there is a written agreement between the parties setting out the extent of the authority and responsibility of the consultant in relation to the services provided. The consultant's position in the organisation must be such that they can perform their role as a technical decision maker, as effectively as if they were an employee.

Staff members of the accredited organisation who are not engaged full time are also eligible as a Key Technical Person, provided that the circumstances in which they are called upon to exercise their function and their access to, and knowledge of, the technical operations are such that they are able to take full responsibility for the results they authorise.

The position and function of a Key Technical Person are quite distinct from that of an Authorised Representative. An organisation will normally have only one Authorised Representative who is appointed by the organisation and is only the contact point for IANZ and need not have any particular professional or technical expertise. However, the organisation may have several Key Technical Personnel approved by IANZ and with their own individual areas of expertise.

An Authorised Representative who is not also a Key Technical Person may not authorise the release of IANZ endorsed reports.

Appendix 4: Evaluation of Uncertainty of Measurement (with examples)

General

The uncertainty of a measurement defines its quality and is an aid to calculating risk in commercial decisions. It enables the determination of compliance with manufacturing tolerances, minimum production weights, and, therefore, the likelihood of distributing product out of specification. In the calibration environment an uncertainty analysis also demonstrates an understanding of important effects. The most helpful uncertainty statement is realistic, not conservative or optimistic.

Obtaining a model is an essential step in an uncertainty analysis. While this may appear difficult, in most cases the model is simple with the various terms simply added together (for example, corrections to thermometer or pressure gauge readings).

Uncertainty calculations improve with experience. In addition, there is usually more than one way of evaluating a contribution. Therefore, record your calculations and assumptions so that you and other staff can follow what you've done, and perhaps later add improvements.

When you are calculating measurement uncertainty, keep in mind:

(a) It is best practice, where known and if significant, to correct errors (see reference 2) and not incorporate them into the uncertainty;

(b) The total uncertainty will usually be dominated by just one or two large contributions. Once they have been identified, make the best use of your time by focusing your efforts on them;

(c) However well known a calibration process is, there may still be unrecognised contributions that become evident in a measurement audit, inter-laboratory trial, or in repeat calibrations. Wherever possible, the source of these should be identified, the contribution evaluated, and the uncertainty analysis updated;

(d) The meanings of technical terms such as coverage factor (k value), effective degrees of freedom, standard uncertainty, and correlation, are as defined in references 1, 2 and 4;

(e) To prevent 'round-off' errors, carry as many digits as practical in values of the various terms while you are doing the calculation (usually 3 significant digits is adequate);

(f) For many calibrations done in IANZ accredited calibration laboratories, type B determinations will dominate the uncertainty calculation. These usually have high degrees of freedom associated with their standard uncertainties so we can use k = 2 in most cases.

Example uncertainty evaluations are given here for the calibrations of a glass thermometer and an external micrometer. For further examples, see the Technical Guides on the MSL website.

Example 1: Calibration of a glass thermometer against a reference platinum resistance thermometer in a stirred water bath

1 Identify the sources of uncertainty in the thermometer calibration

The largest sources of uncertainty in liquid-in-glass thermometers are: irregularities in the scale markings and bore diameter; small random effects as the mercury sticks in the bore (stiction); and the slow expansion and contraction of the glass with temperature, giving rise to hysteresis (the reading depending on previous exposure to different temperatures). The mercury stiction is minimised by tapping the thermometer lightly, e.g. with a pencil, before reading. The hysteresis is minimised by only measuring rising or falling temperatures.

The simplest calibration assesses the errors over a narrow range of temperatures – say, six readings distributed over a few scale divisions above and below the temperature of interest. We apply a single correction, calculated from the average error, to account for most of the errors, and use the standard deviation to account for the remaining unpredictable variations. We will assume the reference thermometer is an electronic platinum resistance thermometer and the thermometer under calibration is a mercury-in-glass thermometer divided to 0.05 °C.

Type A Uncertainties

1. The standard deviation calculated from the six comparison measurements with the reference thermometer samples most of the important effects: the irregularities in the bore and scale markings, mercury stiction, and fluctuations in the temperature of the calibration bath. Because the six comparison temperatures are chosen randomly and do not fall exactly on scale markings of the thermometer, the standard deviation also includes effects due to the finite resolution of the thermometer and the 'readability' effects arising from the operator having to interpolate between scale markings.

Type B Uncertainties

2. The reference platinum resistance thermometer (PRT) is calibrated by an accredited laboratory. The calibration certificate gives the uncertainty, the level of confidence, and coverage factor. (We assume the electronic reference thermometer is direct-reading in temperature.)
3. Spatial non-uniformity of calibration bath temperature. This must be assessed beforehand (and at regular intervals thereafter) to ensure it does not have a significant effect on the calibration and to define the controlled ("useable") volume of the bath.
4. As described in point 1 above, there is no need to add a term for the resolution of the instrument in this case. However, if the six comparison readings are chosen to fall near the scale markings then a contribution due to the resolution and the uncertainty in reading the scale of the thermometer should be included.
5. Uncertainty due to hysteresis of the thermometer. The hysteresis is minimised by calibrating (and using) the thermometer only to measure rising temperatures (for $T > 20°C$) or falling temperatures (for $T < 20°C$).

2 Corrections applied to readings

An ice-point check of the reference platinum resistance thermometer is regularly conducted, and a correction determined for any shift in the ice-point reading, so the uncertainty due to drift is negligible.

Corrections to the reference thermometer, as reported in its calibration certificate, are applied.

In principle, large spatial errors in the calibration bath could be corrected, but it is better to ensure that they are negligible by ensuring that the bath has low non-uniformity and the sensors of the two thermometers are placed within the controlled volume of the bath.

3 Determination of standard uncertainties

3.1 Repeatability of the thermometer under calibration

The standard deviation of the differences between the readings of the device under calibration (DUC) and those of the PRT, for the six comparison temperatures, includes most of the important effects. The standard deviation was found to be:

$$u_{\text{duc}} = 0.009\ ^\circ\text{C}$$

Since six readings are taken and a mean is calculated, the number of degrees of freedom associated with the standard deviation is five. The distribution of the thermometer errors is assumed to be normal.

3.2 Uncertainty in the reference thermometer

The reference thermometer's calibration certificate tells us that it has an uncertainty of 0.008 °C, given at a level of confidence of 95 %, and the coverage factor is 2.13, corresponding to 15 degrees of freedom. The standard uncertainty is found by dividing the expanded uncertainty by the coverage factor. If only the effective degrees of freedom are quoted, we can find the k factor from the Student's t tables. If neither the coverage factor nor the degrees of freedom are given, we assume a coverage factor of k = 2 (or ask the calibration laboratory what k was) and divide the expanded uncertainty by 2. In this case:

$$u_{\text{ref}} = \frac{0.008}{2.13} = 0.0038\ ^\circ\text{C}$$

3.3 Variation with position in the calibration bath

Measurements of time and position variation in the bath temperature were made previously at several radial positions about a central position, at several immersion depths, and at several temperatures e.g. the minimum, maximum and a mid-range temperature. A number of measurements (ten or so) were taken at each point. These measurements should be repeated every few years (no more than five), or if the bath is modified.

The time variation of the bath temperature is assessed as the standard deviation of the ten or so measurements made at each point. In a well-stirred bath, the standard deviations will be similar at different positions at a given temperature. The worst-case variation normally occurs when the difference between the bath and the room temperature is greatest. The standard deviation is not used directly in the uncertainty analysis because the time variation will already contribute to the standard deviation in 3.1. However, this term must be included in the calculation of the Calibration and Measurement Capability as it limits the possible uncertainty in a calibration.

The spatial variations in the bath temperature can be assessed using the average of the measurements at each point. They will affect a calibration but not contribute to the standard deviation in 3.1. Therefore, we must add a term to account for the possible temperature gradients in the bath. Providing the thermometers involved in the calibration are always kept within the assessed diameter and immersion depths, we can use the maximum variation we have measured as the contribution to the uncertainty of calibration by considering it to be a rectangular distribution.

In this case we find that so long as the thermometers are in the centre of the bath and within 100 mm of each other, the maximum measured observed spatial difference is 0.01 °C. The standard uncertainty for this contribution is determined by treating this difference as the range of a rectangular distribution (where, if $2a = 0.01$, the standard uncertainty is $\frac{a}{\sqrt{3}}$):

$$u_{\text{bath}} = \frac{0.005}{\sqrt{3}} = 0.0029\ ^\circ\text{C}$$

3.4 Resolution of the thermometer under calibration

The readability or resolution of liquid-in-glass thermometers varies according to the quality of the scale markings on a thermometer. The scale is an analogue scale, so the quality of the markings affects how the operator interpolates between the markings. The standard uncertainty due to reading errors ranges from about 0.1 of a scale division for a high quality thermometer to 0.25 of a scale division for a very ordinary thermometer. If the comparison points in the calibration are chosen randomly then the effects are included in the standard deviation calculated in 3.1 and do not need to be included separately.

3.5 Hysteresis of the thermometer under calibration

The slow expansion and contraction of the glass introduces a small hysteresis effect (typically no more than 0.1 % of the temperature change) into the readings of the liquid-in-glass thermometer. The change can be detected by doing an ice-point check at the beginning and the end of the calibration process. The difference is taken as the range of a rectangular distribution and hence the standard uncertainty is estimated ($2a = 0.02$ °C) as:

$$u_{\text{hys}} = \frac{0.01}{\sqrt{3}} = 0.0058\ ^\circ\text{C}$$

4 Combination of uncertainties

The uncertainties are combined using the root sum square method (in quadrature). The combined standard uncertainty is, thus:

$$u_c^2 = u_{\text{duc}}^2 + u_{\text{ref}}^2 + u_{\text{bath}}^2 + u_{\text{hys}}^2$$

$$\begin{aligned} u_c &= \sqrt{(0.009)^2 + (0.0038)^2 + (0.0029)^2 + (0.0058)^2} \\ &= 0.0117\ ^\circ C \end{aligned}$$

5 Expanded uncertainty

To calculate the expanded uncertainty, U, we need the coverage factor, k, for a level of confidence of 95 %.

$$U = k\,u_c$$

If all the contributions have a large number of degrees of freedom, the value of k is 2. More typically in glass thermometer calibrations, the value is between 2.1 and 2.5. Because the uncertainties are based on a few measurements dominated by random effects, the uncertainty itself is only known to about 30 %, so using a value of 2 and rounding up is often OK. In this case, we can expect to be close.

A more accurate value of the coverage factor can be determined by calculating the effective number of degrees of freedom, ν_{eff}, for the total uncertainty:

$$\nu_{\text{eff}} = \frac{u_c^4}{\sum_{i=1}^{N} \frac{u_i^4}{\nu_i}}$$

Using the values from the uncertainty table (below), we get:

$$\begin{aligned} \nu_{eff} &= \frac{(0.0117)^4}{\left(\frac{(0.009)^4}{5} + \frac{(0.0038)^4}{15} + \frac{(0.0029)^4}{\infty} + \frac{(0.0058)^4}{\infty}\right)} \\ &= \frac{(0.0117)^4}{\left(\frac{(0.009)^4}{5} + \frac{(0.0038)^4}{15}\right)} \\ &= 14.1 \end{aligned}$$

Note that the terms with infinite degrees of freedom drop out of the calculation (in the spreadsheet calculation we have used 1000 to approximate infinite degrees of freedom). This gives an effective number of degrees of freedom of 14, so from the Student's t tables we use k ≈ 2.14. The expanded uncertainty is, therefore:

$$\begin{aligned} U &= 2.14 \times 0.0117\ ^\circ C \\ &= 0.025\ ^\circ C \end{aligned}$$

which gives a slightly different answer from before. Often, as in this case, such differences will be small when compared with the 'uncertainty' in the estimate itself. However, that is not always the case.

6 A model and the uncertainty budget

The process described above is a way of assessing uncertainty based on experience and common sense. The GUM (reference 2) has a much more structured way to do this and describes how to prepare the uncertainty evaluation based on a 'model' of the measurement.

The model is the mathematical relationship between the inputs to the calibration and the output(s). The factors we have included as inputs—bath variation, repeatability, reference uncertainty and hysteresis - are all directly related to the output (the correction at a given temperature). For many calibrations, the mathematical model is a simple sum of readings and corrections. This greatly simplifies the propagation of uncertainty equations as the sensitivity coefficients are all equal to +1 or -1. Our model for the correction to the thermometer under calibration is:

$$\Delta T = T_{\text{ref}} - T_{\text{duc}} + \Delta T_{\text{bath}} + \Delta T_{\text{hys}}$$

where

ΔT	=	The correction to be applied to the thermometer under calibration
T_{ref}	=	The corrected reading of reference thermometer
T_{duc}	=	The reading of the thermometer under calibration
ΔT_{bath}	=	Temperature correction due to bath non-uniformity
ΔT_{hys}	=	Temperature correction due to hysteresis in thermometer under calibration.

The correction is based on the average of the observed errors:

$$\text{Correction} = \text{average}\ (\Delta T) = \text{average}\ (T_{\text{ref}} - T_{\text{duc}}).$$

Note that the errors due to hysteresis and bath non-uniformity are assumed to average to zero. The equation for the uncertainty has a form corresponding to the model except that all of the terms are summed as squares:

$$u_{\text{c}}^2 = u_{\text{ref}}^2 + u_{\text{duc}}^2 + u_{\text{bath}}^2 + u_{\text{hys}}^2$$

Note also that we can convert models that involve division, multiplication and powers to a direct (or linear) relationship between input and output by using relative uncertainties (or % values).

The easiest way to develop the structured uncertainty budget is to use a spreadsheet. We need the following:

(a) A description of the source of each contribution

(b) The type of each uncertainty estimate, Type A or Type B

(c) The estimated size of each contribution (standard uncertainty)

(d) The type of distribution assumed for each contribution e.g. normal, rectangular, triangular etc.

(e) The number of degrees of freedom for each Type A uncertainty and the number of degrees of freedom for each Type B uncertainty

(f) The sensitivity coefficient for each uncertainty

(g) The combined uncertainty

(h) The effective degrees of freedom for the combined uncertainty, so we can calculate the coverage factor, k

(i) The expanded uncertainty.

IANZ expects the uncertainty budgets in calibration laboratories to be prepared as shown in the example below. A number of spreadsheets, including those developed by MSL and available online, are already in this format.

The spreadsheet for this example is shown below.

Uncertainty in Correction of Glass Thermometer

Symbol	*Source*	*Type*	*Units*	*Value*	*Distribution*	*Divisor*	c_i	u_i /°C	v_i
u_{duc}	Repeatability	A	°C	0.009	Normal	1	1	0.0090	5
u_{ref}	Reference	B	°C	0.008	Normal	2.13	1	0.0038	15
$u_{spatial}$	Spatial variation	B	°C	0.005	Rectangular	1.73	1	0.0029	1000
u_{hyst}	Hysteresis	B	°C	0.010	Rectangular	1.73	1	0.0058	1000
							Combined Uncertainty u_c	0.0117	°C
							v_{eff}		14
							k		2.14
							Expanded Uncertainty U	0.025	°C

Example 2: Calibration of an external micrometer against gauge blocks

1 Sources of uncertainty in the calibration

The calibration of a micrometer is carried out by using the micrometer to make measurements on calibrated gauge blocks. The report will give the error of measurement, which is equal to the micrometer reading minus the calibrated gauge block size. We assume here that a set of grade 2 gauge blocks is used to calibrate a 0 mm to 25 mm micrometer with a digital indicator. A full calibration of a micrometer would also include a measurement of the flatness and parallelism of the measuring faces of the micrometer along with an assessment of the uncertainty in these measurements. Here we will only consider the uncertainty in the error of the measurement of the micrometer at 25 mm.

Type A Uncertainties

1. The repeatability of the micrometer is determined by making 10 measurements at 25 mm.

Type B Uncertainties

2. The reference gauge block set is calibrated by an accredited laboratory. These calibrations have the uncertainty reported on the certificate at a level of confidence of 95% with $k = 2$. We shall assume 50 degrees of freedom for this value.
3. Temperature will affect both the gauge block and the micrometer. We assume that the micrometer and gauge block have the same thermal expansion coefficient and are at the same temperature. We shall also assume the measurements are being carried out in a temperature-controlled laboratory and the gauge block and micrometer have come to thermal equilibrium.
4. Resolution limitations in the digital readout of the micrometer will be considered.
5. Drift in the gauge block lengths since their last calibration will be considered negligible for this calibration.

2 Determination of standard uncertainties

2.1 Repeatability of the micrometer

The standard uncertainty arising from making ten measurements of a 25 mm gauge block is calculated from the standard deviation of the measurements. We shall assume a normal distribution with 9 degrees of freedom:

$$u_{\text{duc}} = 0.48\ \mu\text{m}$$

2.2 Uncertainty in the gauge block length

The 25 mm gauge block has an uncertainty of 0.06 µm on the calibration certificate. The k factor is given as 2 so we will assume 50 degrees of freedom. Then:

$$u_{\text{ref}} = \frac{0.06}{2}\ \mu\text{m} = 0.03\ \mu\text{m}$$

2.3 Resolution of the micrometer

The micrometer resolution is 1 µm. The standard uncertainty due to the resolution is given by:

$$u_{\text{res}} = \frac{1.0}{2\sqrt{3}}\ \mu\text{m} = 0.289\ \mu\text{m}$$

with infinite degrees of freedom (approximated by 1000 in the spreadsheet).

2.4 Uncertainty due to temperature effects on the gauge block and the micrometer

We assumed in Section 1 that the gauge block and micrometer had reached thermal equilibrium, that is their temperature difference $\Delta T = 0$, however the uncertainty in the temperature difference $u(\Delta T) \neq 0$. The standard uncertainty due to the temperature difference between the gauge block and micrometer is given by:

$$u_{\text{temp}} = L \cdot \alpha \cdot u\left(\Delta T\right)$$

where

L = the gauge block length

α = the thermal expansion coefficient of the gauge block

$u(\Delta T)$ = the uncertainty in the temperature difference ΔT between the gauge block and micrometer.

We assume u(ΔT) to have a rectangular distribution with a half width of 0.2 °C.

$$u_{\text{temp}} = (25\,\text{mm}) \times (11.6 \times 10^{-6}\ ^\circ\text{C}^{-1}) \times \frac{0.2\ ^\circ\text{C}}{\sqrt{3}} = 0.033\ \mu\text{m}$$

3 Combination of uncertainties

The uncertainties are combined using the root sum square method. The combined standard uncertainty is thus:

$$u_c^2 = u_{\text{duc}}^2 + u_{\text{ref}}^2 + u_{\text{res}}^2 + u_{\text{temp}}^2$$

$$u_c = \sqrt{(0.48)^2 + (0.03)^2 + (0.289)^2 + (0.033)^2} = 0.56\ \mu\text{m}$$

4 Expanded uncertainty

To calculate the expanded uncertainty, U, we need the coverage factor k for a level of confidence of approximately 95 %. In this case the repeatability uncertainty which has 9 degrees of freedom is dominant. Hence $k \approx 2.26$ and the expanded uncertainty is thus:

$$U = 2.26 \times 0.56\ \mu\text{m} = 1.27\ \mu\text{m}$$

A more accurate calculation gives k = 2.12 and U = 1.19 µm (see the spreadsheet below). This is the uncertainty in the error of measurement of the micrometer being calibrated at 25 mm. The uncertainty will need to be evaluated at other points as well.

5 A model and the uncertainty budget

$$C_{\text{micr}} = L_{\text{micr}} - L_{\text{GB}} + C_{\text{temp}}$$

where

C_{micr} = the error of measurement of the micrometer

L_{micr} = indicated length of the gauge block

L_{GB} = certified length of the gauge block

C_{temp} = correction for temperature effects

Uncertainty in Error of Measurement of an External Micrometer at L = 25 mm

Symbol	*Source*	*Type*	*Units*	*Value*	*Distribution*	*Divisor*	c_i	u_i /µm	ν_i
u_r	Repeatability	A	µm	0.48	Normal	1	1	0.480	9
u_{ref}	Reference	B	µm	0.06	Normal	2	1	0.030	50
u_{res}	Resolution	B	µm	0.5	Rectangular	1.73	1	0.289	1000
u_{temp}	Temperature	B	°C	0.2	Rectangular	1.73	0.3 µm/°C	0.033	1000
							Combined Uncertainty u_c	0.56	µm
							ν_{eff}		17
							k		2.26
							Expanded Uncertainty U	1.27	µm